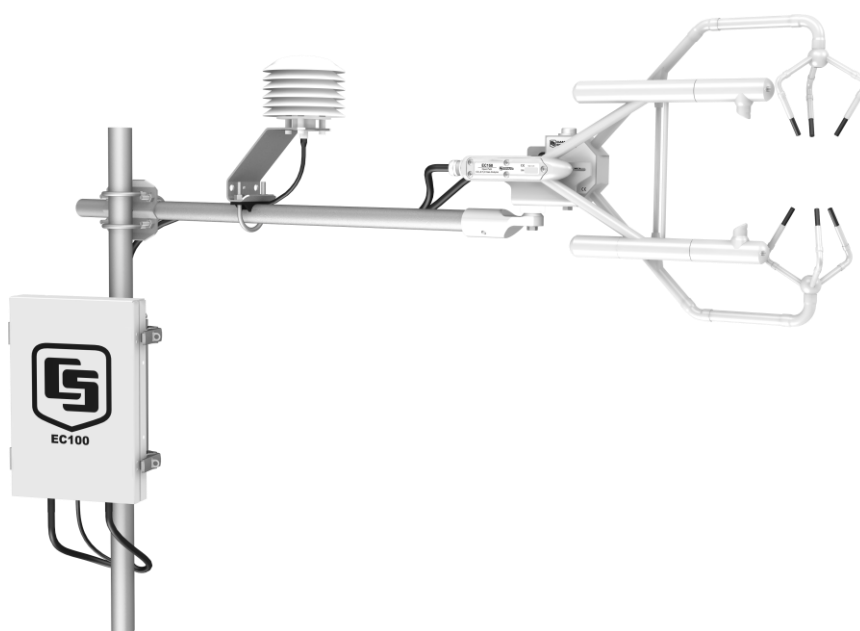


***EC150  
CO<sub>2</sub> and H<sub>2</sub>O  
Open-Path Gas Analyser  
and  
EC100 Electronics with  
Optional CSAT3A 3D Sonic Anemometer***



*Issued: 23.7.13*

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# Guarantee

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This equipment is guaranteed against defects in materials and workmanship. This guarantee applies for twelve months from date of delivery. We will repair or replace products which prove to be defective during the guarantee period provided they are returned to us prepaid. The guarantee will not apply to:

- Equipment which has been modified or altered in any way without the written permission of Campbell Scientific
- Batteries
- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific will return guaranteed equipment by surface carrier prepaid. Campbell Scientific will not reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This guarantee and the Company's obligation thereunder is in lieu of all other guarantees, expressed or implied, including those of suitability and fitness for a particular purpose. Campbell Scientific is not liable for consequential damage.

Please inform us before returning equipment and obtain a Repair Reference Number whether the repair is under guarantee or not. Please state the faults as clearly as possible, and if the product is out of the guarantee period it should be accompanied by a purchase order. Quotations for repairs can be given on request. It is the policy of Campbell Scientific to protect the health of its employees and provide a safe working environment, in support of this policy a "Declaration of Hazardous Material and Decontamination" form will be issued for completion.

When returning equipment, the Repair Reference Number must be clearly marked on the outside of the package. Complete the "Declaration of Hazardous Material and Decontamination" form and ensure a completed copy is returned with your goods. Please note your Repair may not be processed if you do not include a copy of this form and Campbell Scientific Ltd reserves the right to return goods at the customers' expense.

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# PLEASE READ FIRST

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## About this manual

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

Some useful conversion factors:

<b>Area:</b>	1 in <sup>2</sup> (square inch) = 645 mm <sup>2</sup>	<b>Mass:</b>	1 oz. (ounce) = 28.35 g 1 lb (pound weight) = 0.454 kg
<b>Length:</b>	1 in. (inch) = 25.4 mm 1 ft (foot) = 304.8 mm 1 yard = 0.914 m 1 mile = 1.609 km	<b>Pressure:</b>	1 psi (lb/in <sup>2</sup> ) = 68.95 mb
		<b>Volume:</b>	1 UK pint = 568.3 ml 1 UK gallon = 4.546 litres 1 US gallon = 3.785 litres

In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users.

Differences include the U.S standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. *Please note, however, that when a power supply adapter is ordered it will be suitable for use in your country.*

Reference to some radio transmitters, digital cell phones and aerials may also not be applicable according to your locality.

Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered. Details of the alternatives will be covered in separate manuals.

Part numbers prefixed with a “#” symbol are special order parts for use with non-EU variants or for special installations. Please quote the full part number with the # when ordering.

## Recycling information



At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility.

Campbell Scientific Ltd can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories.

For further advice or support, please contact Campbell Scientific Ltd, or your local agent.



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# EC150 CO<sub>2</sub> and H<sub>2</sub>O Open-Path Gas Analyser

---

## 1. Introduction

The EC150 is an in-situ, open-path, mid-infrared absorption gas analyser that provides measurements of absolute densities of carbon dioxide and water vapour. The EC150 may be used in conjunction with the CSAT3A sonic anemometer, which measures orthogonal wind components.

Before using the EC150, please study

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*
- Section 6, *Installation*

More details are available in the remaining sections.

## 2. Cautionary Statements

- DANGER:
  - The scrubber bottles (see Section 9.5, *Replacing Desiccant and Scrubber Bottles*) contain the strong oxidizing agents sodium hydroxide (caustic soda, NaOH) and anhydrous magnesium perchlorate (Mg(ClO<sub>4</sub>)<sub>2</sub>).
    - Avoid direct contact with the chemicals.
    - Ensure your work area is well ventilated and free of reactive compounds, including liquid water.
    - Store used chemical bottles in a sealed container until disposal.
    - Dispose of chemicals and bottles properly.
    - Materials Safety Data Sheets (MSDS) are provided in Appendix C. MSDS are updated periodically by chemical manufacturers. Obtain current MSDS at [www.campbellsci.com](http://www.campbellsci.com).
- WARNING:
  - Do not carry the EC150 or CSAT3A by the arms or carry the EC150 by the strut between the arms. Always hold them by the block, where the upper and lower arms connect.
  - Handle the EC150 carefully. The optical source may be damaged by rough handling, especially while the analyser is powered.
  - Over-tightening bolts will damage or deform the mounting hardware.
- CAUTION:
  - Grounding the EC100 measurement electronics is critical. Proper grounding to earth (chassis) will ensure maximum ESD (electrostatic discharge) protection and improve measurement accuracy.
  - Do not connect or disconnect the gas analyser or sonic connectors while the EC100 is powered.
  - The SDM, USB, and RS-485 output options include EC150 diagnostic data. Be aware that the absence of diagnostic data in the analogue output option could make troubleshooting difficult and may lead to the user not being aware of potential problems with the instrumentation (see Section 8, *EC100 Outputs*).
  - Resting the analyser on its side during the zero-and-span procedure may result in measurement inaccuracy.

- When cleaning the gas-analyser window, make sure the alcohol and any residual water completely evaporate before proceeding with the zero-and-span procedure (see Section 9.3, *Analyser Window Cleaning*).

## 3. Initial Inspection

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

## 4. Overview

The EC150 is an in-situ open path mid-infrared absorption analyser that measures absolute densities of carbon dioxide and water vapour. It has been designed specifically for eddy covariance flux measurements and may be used in conjunction with the CSAT3A 3D sonic anemometer sensor head. The analyser has a rugged, aerodynamic design with low power requirements, making it suitable for field applications.

The EC150 gas analyser head, along with a temperature probe and optional external barometer, connect directly to the EC100 electronics. After receiving inputs from these sensors, the EC100 computes CO<sub>2</sub> and H<sub>2</sub>O absolute densities. A CSAT3A sonic anemometer head may also be connected to the EC100. The EC100 synchronizes data from the EC150 and the CSAT3A, essential for valid flux measurements using the eddy covariance method.

The EC150 has been designed specifically to address issues of aerodynamics, power consumption, spatial displacement, and temporal synchronicity. Its unique design contains no obstructions surrounding the sample volume; it operates with 5 W of power at room temperature; it has minimal spatial displacement from the sample volume of a CSAT3A sonic anemometer head; and the EC100 synchronously samples data from the EC150 and CSAT3A.

## 5. Specifications

### 5.1 Measurements

#### Features

- To compute carbon dioxide and water vapour fluxes using the eddy-covariance method, the EC150 measures:
  - absolute carbon dioxide
  - water vapour densities
  - three-dimensional wind speed (requires the CSAT3A)
  - sonic air temperature (requires the CSAT3A)
  - air temperature
  - barometric pressure

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

- Standard outputs:
  - CO<sub>2</sub> density, H<sub>2</sub>O density
  - gas analyser diagnostic flags
  - air temperature, air pressure

- CO<sub>2</sub> signal strength, H<sub>2</sub>O signal strength
- Air temperature and air pressure are auxiliary sensor inputs
- Additional outputs:
  - $u_x$ ,  $u_y$ , and  $u_z$  orthogonal wind components
  - sonic temperature (based on the measurement of  $c$ , the speed of sound)
  - sonic diagnostic flags

**Datalogger compatibility:** CR1000  
CR3000  
CR5000

**Measurement**

**Rate:** 100 Hz  
**Output bandwidth<sup>2</sup>:** 5, 10, 12.5, 20, or 25 Hz  
**Output rate<sup>2</sup>:** 10, 25 or 50 Hz

**Operating temperature:** -30° to +50°C

**Gas analyser**

**Measurement precision<sup>1</sup>**

**CO<sub>2</sub> density:** 0.2 mg·m<sup>-3</sup> (0.15 μmol·mol<sup>-1</sup>)  
**H<sub>2</sub>O density:** 0.00350 g·m<sup>-3</sup> (0.006 mmol·mol<sup>-1</sup>)

**Factory calibrated range**

**CO<sub>2</sub>:** 0 to 1000 μmol·mol<sup>-1</sup>  
**H<sub>2</sub>O:** 0 mmol·mol<sup>-1</sup> to 37°C dew point  
**Analyser temp:** -30° to +50°C  
**Baro pressure:** 70 to 106 kPa

**CO<sub>2</sub> performance**

**Zero max drift<sup>3</sup>:** ±0.55 mg·m<sup>-3</sup>·°C<sup>-1</sup> (±0.3 μmol·mol<sup>-1</sup>·°C<sup>-1</sup>)  
**Gain drift:** ±0.1% of reading·°C<sup>-1</sup> (maximum)  
**Sensitivity to H<sub>2</sub>O:** ±1.1 × 10<sup>-4</sup> μmol CO<sub>2</sub>·mol<sup>-1</sup> H<sub>2</sub>O (max)

**H<sub>2</sub>O performance**

**Zero max drift<sup>3</sup>:** ±0.037 g·m<sup>-3</sup>·°C<sup>-1</sup> (±0.05 mmol·mol<sup>-1</sup>·°C<sup>-1</sup>)  
**Gain drift:** ±0.3% of reading·°C<sup>-1</sup> (maximum)  
**Sensitivity to CO<sub>2</sub>:** ±0.1 mol H<sub>2</sub>O·mol<sup>-1</sup> CO<sub>2</sub> (maximum)

#### CSAT3A sonic measurement precision<sup>4</sup>

<b>u<sub>x</sub>:</b>	1 mm·s <sup>-1</sup>
<b>u<sub>y</sub>:</b>	1 mm·s <sup>-1</sup>
<b>u<sub>z</sub>:</b>	0.5 mm·s <sup>-1</sup>
<b>Sonic temperature:</b>	0.025°C

#### CSAT3A sonic accuracy<sup>5</sup>

##### Offset error

<b>u<sub>x</sub>, u<sub>y</sub>:</b>	< ±8 cm·s <sup>-1</sup>
<b>u<sub>z</sub>:</b>	< 4 cm·s <sup>-1</sup>

##### Gain error

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

#### CSAT3 sonic reporting range

<b>Full scale wind:</b>	±65.553 m/s
<b>Sonic temperature:</b>	-50° to +60°C

#### Auxiliary sensors<sup>6</sup>

##### Barometer

##### 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 Hz

##### Optional enhanced barometer

<b>Manufacturer:</b>	Vaisala
<b>Model:</b>	PTB110/CS106

##### Accuracy

-40 to +60°C:	±0.15 kPa
---------------	-----------

**Measurement rate:** 1 Hz

##### EC150 temperature sensor:

<b>Manufacturer:</b>	BetaTherm
<b>Model:</b>	100K6A1A Thermistor
<b>Accuracy:</b>	±0.15°C (-30° to +50°C)

<sup>1</sup> noise rms, assumes:

- 25°C
- 85 kPa
- 14 g·m<sup>-3</sup> H<sub>2</sub>O
- 597 mg·m<sup>-3</sup> CO<sub>2</sub>
- 25 Hz bandwidth.

<sup>2</sup> user selectable

<sup>3</sup> -30° to 50°C

<sup>4</sup> noise rms

<sup>5</sup> assumes:

- -30° to +50°C
- wind speed <30 m·s<sup>-1</sup>
- azimuth angles between ±170°

<sup>6</sup> refer to manufacturer's product brochure or manual for details

## 5.2 Output Signals

### Features

- EC100 electronics outputs data using:
  - CS SDM
  - RS-485
  - USB
  - Analogue out

### Digital

#### SDM (Synchronous Device for Measurement)<sup>1</sup>

**Data type:** FLOAT

#### RS-485

**Data type:** ASCII

**Output Rate<sup>2</sup>:** 5 to 50 Hz

**Baud rate<sup>2</sup>:** 1200 to 230400 bps

### USB

**Data type:** ASCII

**Output rate<sup>2</sup>:** 10, 25 or 50 Hz

### Analogue (two outputs for CO<sub>2</sub> and H<sub>2</sub>O densities)

**Voltage range:** 0 mV to 5000 mV

**Resolution:** 76 µV (16 bit)

**Update rate:** 100 Hz

**Accuracy (at 25°C):** ±3 mV

**CO<sub>2</sub> density equation:**  $\text{mg} \cdot \text{m}^{-3} = 0.38632 \cdot (\text{mV}_{\text{out}}) - 102.59$

**Full scale range:** -103 to 1829  $\text{mg} \cdot \text{m}^{-3}$

**H<sub>2</sub>O density equation:**  $\text{g} \cdot \text{m}^{-3} = 0.00865 \cdot (\text{mV}_{\text{out}}) - 2.26$

**Full scale range:** -2 to 41  $\text{g} \cdot \text{m}^{-3}$

<sup>1</sup> Synchronous Device for Measurement. A Campbell Scientific, Inc. proprietary serial interface for datalogger to peripheral and sensor communication. See Section 8.1, *SDM Output* for details.

<sup>2</sup> user selectable

## 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)

### Dimensions

**Head housing diameter:** 3.2 cm (1.25 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 in x 5.5 in)

### Weight

**Analyser and cable:** 2 kg (4.4 lbs)

**EC100 electronics and EC100 enclosure:** 3.2 kg (7 lbs)

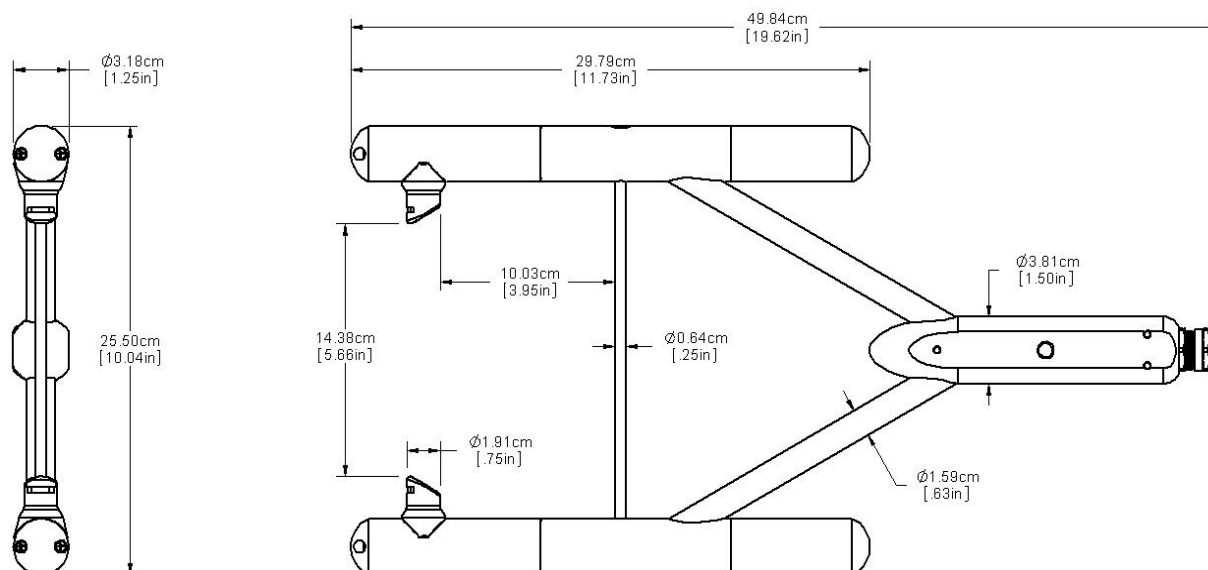


Figure 5-1. Dimensions of EC150 analyser head

## 5.4 Power Requirements During Power-up and Operation

**Voltage supply:** 10 to 16 Vdc

**Power at 25°C including CSAT3A:** 5.0 W

**Power at 25°C excluding CSAT3A:** 4.1 W

**Power at 25°C in power-down mode (CSAT3A fully powered and EC150 in stand-by):** 3.0 W

# 6. Installation

## 6.1 Orientation

During operation the EC150 should be positioned vertically ( $\pm 15$  degrees) 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, it should be levelled and pointed into the prevailing wind to minimize flow distortion from the analyser's arms and other supporting structures.

## 6.2 Mounting

The EC150 is supplied with mounting hardware to attach it to the end of a horizontal pipe of 1.31 inch outer diameter, such as the CM202, CM204, or CM206 crossarm (pn #1790x). The EC150 mounting hardware also accommodates an optional CSAT3A sonic anemometer. The following steps describe the normal mounting procedure. Refer to Figure 6-1 or Figure 6-2 throughout this section.

- a. Secure a CM20X crossarm (pn #1790X) to a tripod or other vertical structure using a CM210 crossarm-to-pole bracket (pn #17767).



- b. Point the horizontal arm into the direction of the prevailing wind. Tighten all the fitting set screws.

**WARNING**

**Do not carry the EC150 or the CSAT3A by the arms or the strut between the arms. Always hold them by the block, where the upper and lower arms connect.**

- c. If a CSAT3A is being used, bolt the EC150/CSAT3A mounting bracket (pn #26786) to the CM250 levelling mount (pn #26559) (see Figure 6-1). Next install the CSAT3A sonic head to the EC150/CSAT3A mounting bracket by aligning the threaded hole on the CSAT3A sonic head with the hole on the bracket. Insert and finger-tighten the bolt, making sure there is no cross-threading. Finish tightening with a wrench. Install the assembly to the end of the crossarm by fitting the levelling mount over the end of the crossarm. Tighten the set screws on the levelling mount. The EC150 gas analyser head may now be installed to the EC150/CSAT3A mounting bracket. To do this, tighten the mounting screw and loosely thread the mounting bolt into the analyser head. Next align the analyser parallel with the vertical plate of the mounting bracket and insert the mounting screw and bolt into the mounting bracket slot. Carefully slide the analyser forward. Avoid crashing the arms of the sensors together. The arms of the analyser should slide in between the claws of the CSAT3A; the sonic head may need to be loosened and repositioned to do this. Tighten the bolts. Make sure that the analyser is vertically oriented so that the label is right-side-up and the upper arm (source) is directly above the lower arm (detector).

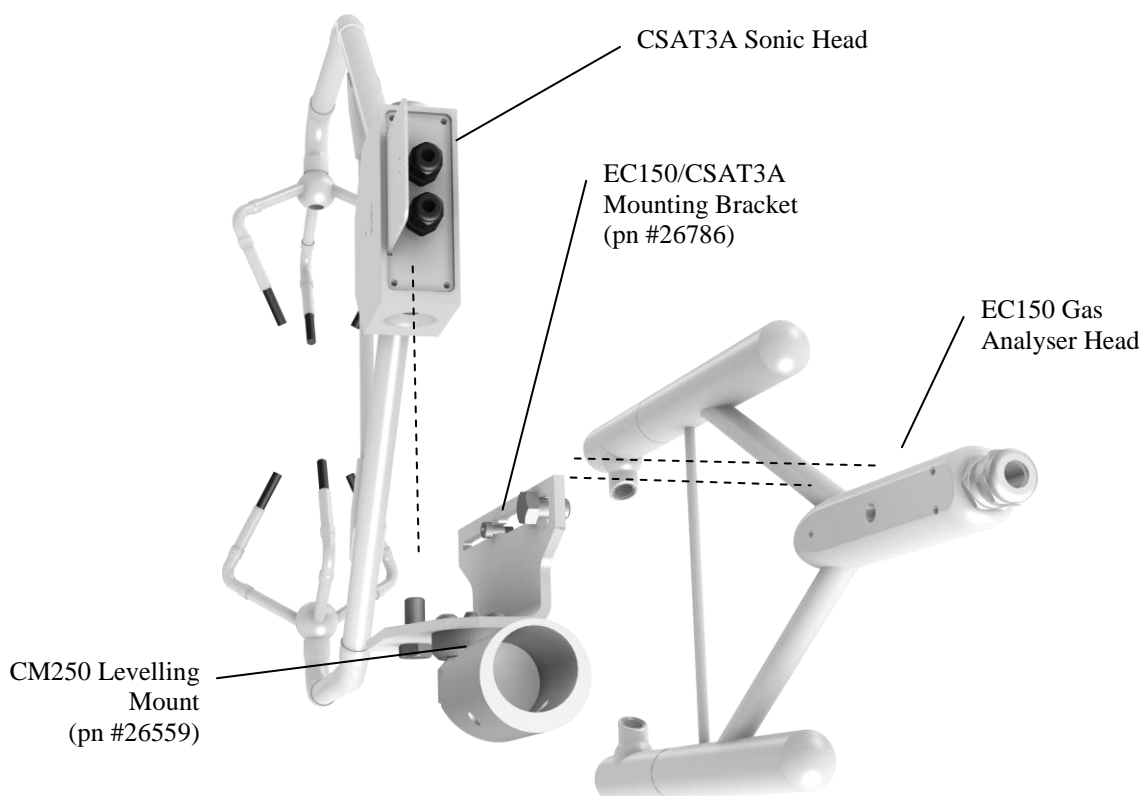


Figure 6-1. Exploded view of mounting the CSAT3A sonic head and EC150 gas analyser head

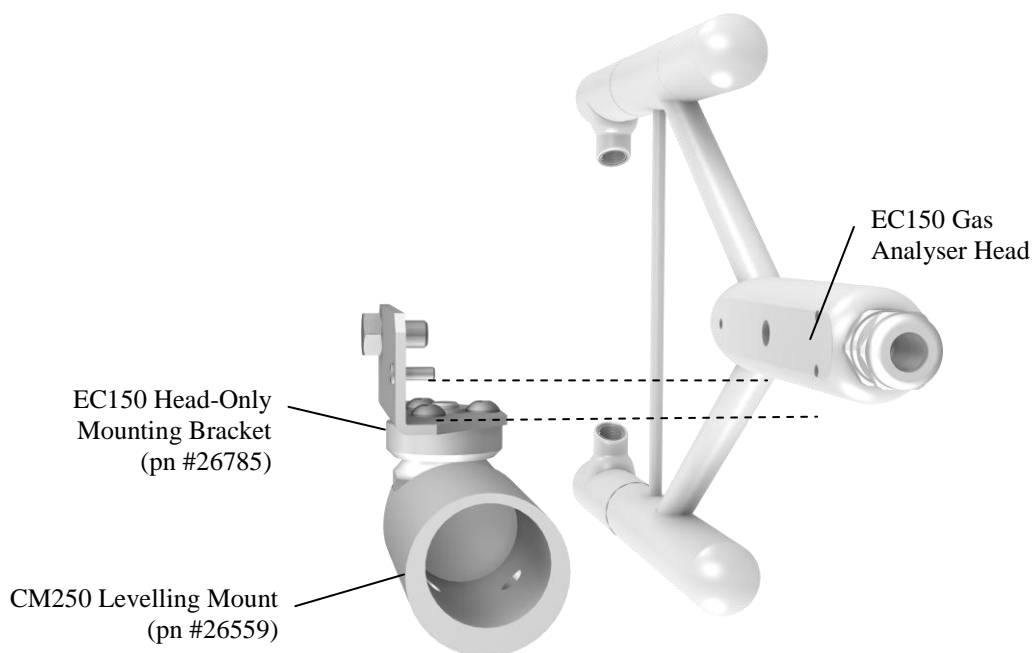


Figure 6-2. Exploded view of mounting the EC150 gas analyser head without the CSAT3A

#### WARNING

**Over-tightening bolts will damage or deform the mounting hardware.**

- d. If a CSAT3A is not being used, bolt the EC150 head-only mounting bracket (pn #26785) to the CM250 levelling mount (pn #26559) (see Figure 6-2). Mount the EC150 gas analyser head to the EC150 head-only mounting bracket. To do this, tighten the mounting screw into the back, lower hole of the analyser head, and place the mounting bracket on the analyser head so that mounting screw fits into the bracket's small hole. The other hole in the bracket should line up with the threaded hole on the analyser. Insert the mounting bolt through the holes and tighten. Now mount this assembly to the end of the crossarm by fitting the levelling mount over the end of the crossarm. Tighten the set screws on the levelling mount.

#### CAUTION

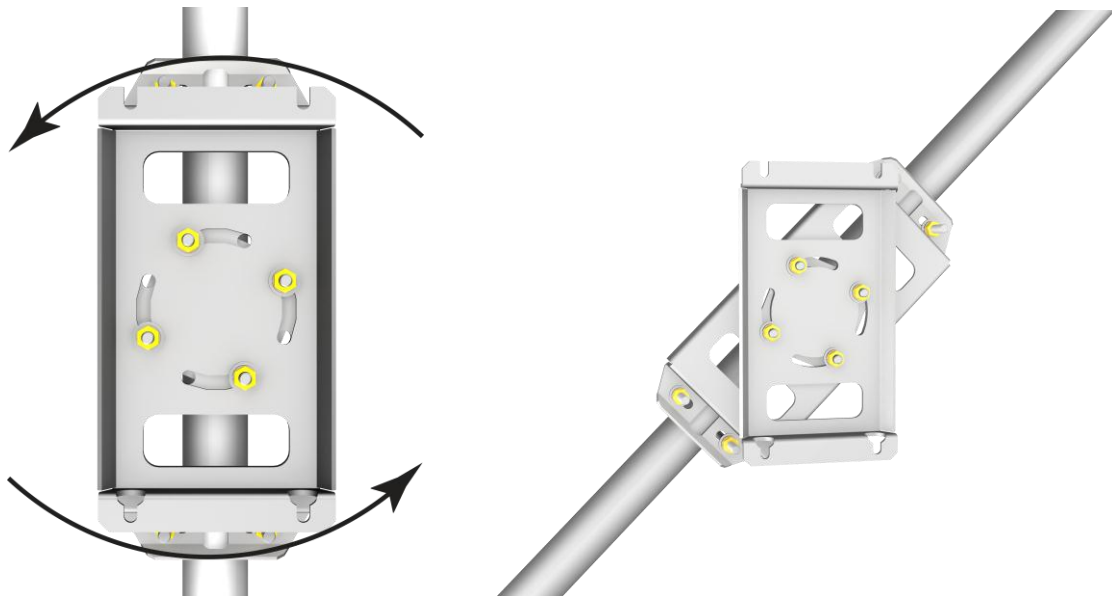
Use caution when handling the EC150 gas analyser head. The optical source may be damaged by rough handling, especially while the EC150 is powered.

#### 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 Campbell Scientific for details.

- e. If the assembly is not level, slightly loosen the bolt that holds the mounting bracket on the levelling mount and adjust the assembly. If the CSAT3A is being used, adjust the assembly until the levelling bubble on the top of the CSAT3A head is within the bulls eye. Retighten the bolt.
- f. Attach the EC100 electronic enclosure to the mast, tripod leg, or other part of the mounting structure. To do this, attach the EC100 enclosure mounting bracket (pn #26604) to the pipe by loosely tightening the u-bolts around the

pipe. The u-bolts are found in the mesh pocket inside the EC100 enclosure. If the pipe does not run vertically up-and-down (e.g., if you are attaching the enclosure to a leg of a tripod), rotate the bracket to the side of the pipe. As the enclosure must hang up-right, angle adjustments may need to be made 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, the four nuts may be removed and the top plate indexed by 90 degrees to allow the bracket to travel in the other direction (see Figure 6-3). Once adjusted, tighten all the nuts. Finally 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 tightening the bolts (see Figure 6-4).



*Figure 6-3. EC100 enclosure mounting bracket mounted on a vertical mast (left) and a tripod leg (right)*

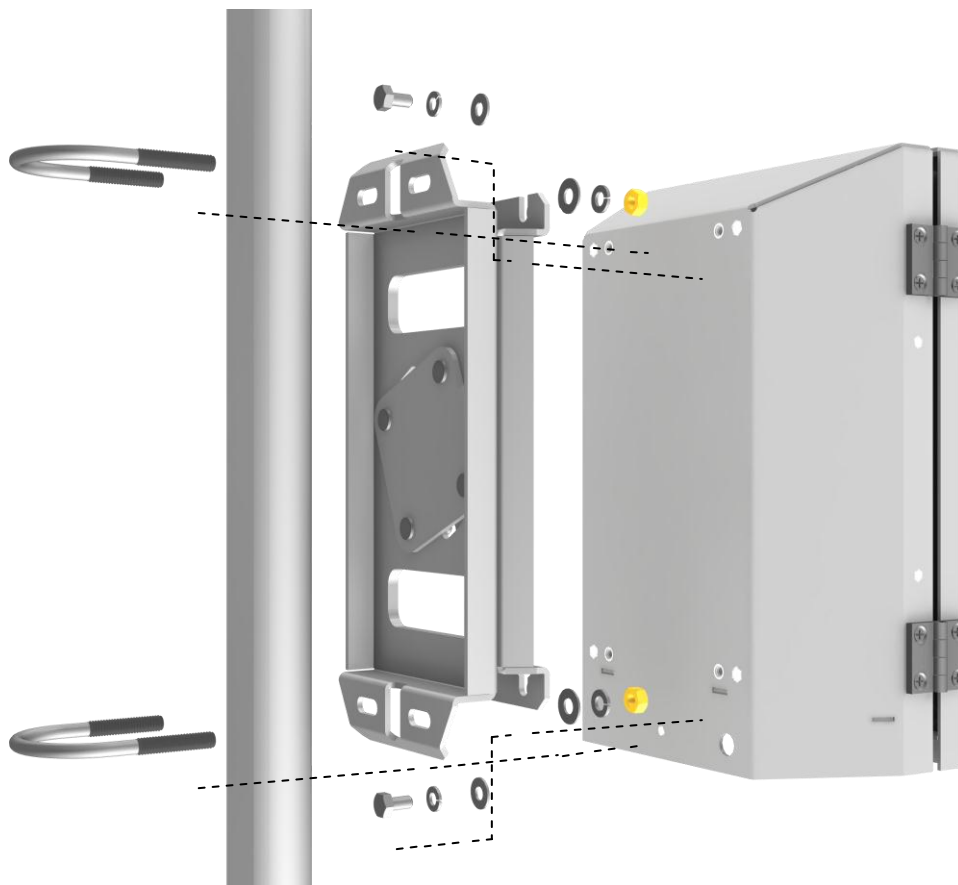


Figure 6-4. Exploded view of mounting the EC100 enclosure

- g. Mount the EC150 temperature probe so that it measures temperature at the same height as the sample volume of the EC150 and CSAT3A. To do this, first attach the R.M. Young 41303-5A 6-plate solar radiation shield (pn #4020) to the mast with the included u-bolt. Next insert the end of the temperature probe into the hole on the bottom of the shield. Tighten the screws to hold the probe in place. For more detailed information about the temperature probe installation and specifications, refer to the Model 107 Temperature Probe instruction manual.
- h. Remove the EC100 enclosure desiccant from the plastic bag and put it back in the mesh pocket of the enclosure. Adhere the humidity indicator card to the inside of the enclosure.

### 6.3 Wiring and Connections

Figure 6-5 and Figure 6-6 below show EC100 electronics panel and the bottom of the EC100 enclosure, respectively. Refer to these figures during wiring and connecting.

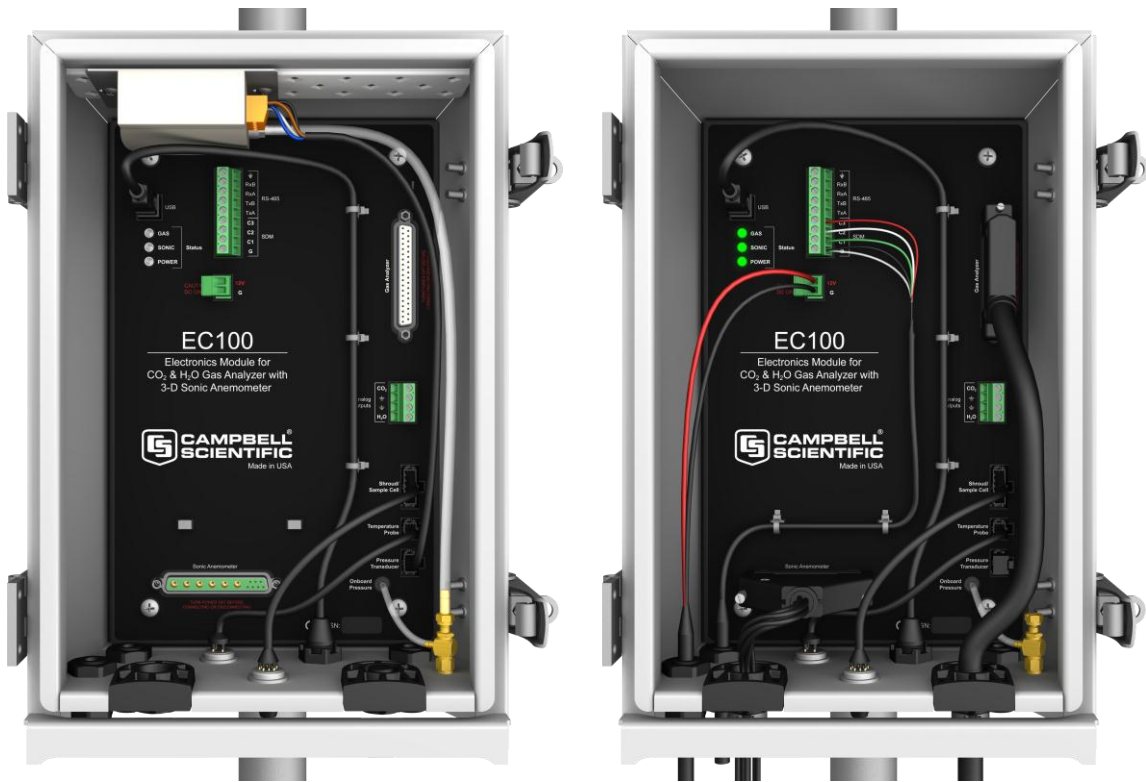


Figure 6-5. EC100 electronics front panel. The one on the left shows how the EC100 will look shipped from the factory (enhanced barometer shown). The one on the right shows the panel after the user has done all the wiring and made all connections (basic barometer shown).

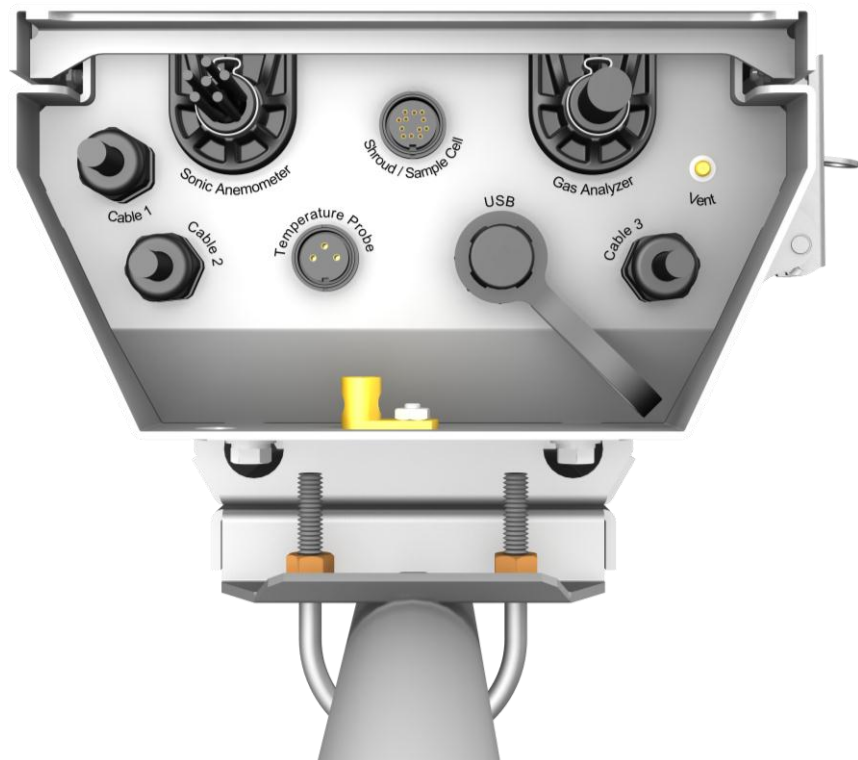


Figure 6-6. Bottom of EC100 enclosure

- a. Connect the EC150 gas analyser head. Begin by removing the black rubber cable entry plug (pn #26224) on the bottom right of the EC100 enclosure. (This plug can be stored in the mesh pocket of the enclosure). Now insert the cable entry plug that is attached to the large cable of the EC150 gas analyser head into the vacant slot. Push the connector at the end of the cable onto its mating connector (labelled *Gas Analyser*) and tighten the thumbscrews (see Figure 6-6). The EC150 gas analyser cable is approximately 3 meters in length.
- b. Connect the CSAT3A sonic head (skip this step if not using the CSAT3A). Similar to (a), begin by removing the black rubber cable entry plug found on the bottom left of the EC100 enclosure. Insert the cable entry plug on the CSAT3A cable into the slot and connect the male end to the female connector labelled *Sonic Anemometer* on the EC100 electronics (see Figure 6-6). The CSAT3A cable is approximately 3 meters in length.

**NOTE**

---

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

---

- c. Connect the EC150 temperature probe. Unscrew the temperature connector cover, which is found on the bottom of the EC100 enclosure (see Figure 6-6). Insert the 3-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 meters in length.
- d. Ground the EC100 by attaching a thick wire (e.g., 12 AWG) to the grounding lug found on the bottom of the EC100 enclosure. The other end of the wire should be connected to earth (chassis) ground using a grounding rod. For more details on grounding, see the CR3000 datalogger manual, grounding section.

**CAUTION**

---

Grounding electronics such as the EC100 is critical in a measurement system. Proper grounding to earth (chassis) will ensure maximum ESD (electrostatic discharge) protection and improve measurement accuracy.

---

**CAUTION**

---

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

---

- e. Connect a communications signal cable to the EC100. Loosen the nut on one of the cable entry seals (Cable 1 or Cable 2) on the bottom of the EC100 enclosure, remove the plastic plug (plug may be stored in mesh pocket of enclosure), insert the cable, and retighten the nut by hand. Refer to the sections below on SDM, USB, RS-485, and analogue communications for information on required signal cable types and connections to the EC100 panel.

1. SDM Communications: Use cable CABLE4CBL-L (pn #21972). “L” denotes the length of the cable, which is customer-specified at time of order. Table 6-1 below details which colour of wire in the cable should be connected to each terminal found on the SDM connector of the EC100 panel.

<b>Table 6-1. EC100 SDM output to a Campbell Scientific CR1000, CR3000, or CR5000 Datalogger</b>		
<b>EC100 Channel</b>	<b>Description</b>	<b>Colour</b>
SDM-C1	SDM Data	Green
SDM-C2	SDM Clock	White
SDM-C3	SDM Enable	Red (or brown)
G	Digital Ground	Black
G	Shield	Clear

2. USB Communications: Use the EC100 USB cable (pn #26561) to connect a PC to the bottom of the EC100 enclosure.
3. RS-485 Communications: Use cable CABLE3TP-L (pn #26987) for lengths less than 500 ft. The connector on the EC100 panel labelled *RS-485* displays which terminals are for receiving and transmitting.
4. Analogue Output: Use cable CABLE4CBL-L (pn #21972) or CABLE2TP-L (pn #26986-L). Once again, the customer specifies the length of this cable at time of order. The connector labelled *Analogue Outputs* on the EC100 panel indicates where each wire should be connected (CO<sub>2</sub> voltage signal, H<sub>2</sub>O voltage signal, and two ground connections).
- f. Wire power and ground (i.e., power reference) cable CABLEPCBL-L (pn #21969-L) to the EC100. Feed the cable through one of the cable port openings in the bottom of the EC100 enclosure and attach the ends into the green EC100 power connector (pn #3768). 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 labelled 12V and ground, respectively.
- g. 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.
- h. Once power is applied to the EC100, three LED status lights on the EC100 panel will illuminate. The power LED will be green and the sonic and gas LEDs will be red until the unit has warmed up and is ready to make measurements at which time the LEDs will be green. If after several minutes the LED lights do not turn green, 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, the user interface software included with the EC150 (see Section 7, *Settings*), or with a datalogger (see Section 10, *Datalogger Programming with CRBasic*). The diagnostics may reveal that the unit needs to be serviced (e.g., clean the optical windows on the EC150, clear the CSAT3A transducers of ice or debris, etc. See Section 9, *Maintenance*).

## 7. 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 Section 7.3, *ECMon*) or the Device Configuration Utility (see Section 7.4, *Device Configuration Utility*), or with a datalogger using the **EC100Configure()** instruction (see Section 10.2, *EC100Configure() Instruction*).

### 7.1 Factory Defaults

Table 7-1 shows the default value for each of the settings.

Table 7-1. Factory Default Settings	
<b>SDM Address</b>	1
<b>Bandwidth</b>	20 Hz
<b>Unprompted Output</b>	disabled
<b>RS-485 Baud Rate</b>	115200 bps
<b>Unprompted Output Rate</b>	10 Hz
<b>Analogue Output</b>	disabled
<b>ECMon Update Rate</b>	10 Hz
<b>Temperature Sensor</b>	Auto-Select (EC150 Temperature Probe)
<b>Pressure Sensor</b>	EC100 Basic or EC100 Enhanced (depending on order)
<b>Pressure Differential Enable</b>	Auto-Select (Disabled for EC150)
<b>Heater Control</b>	Disabled

### 7.2 Details

This section gives an explanation for each setting.

#### 7.2.1 SDM Address

This parameter must be set to use SDM output from the EC100. See Section 8.1, *SDM Output* 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.

#### 7.2.2 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<sub>2</sub> and H<sub>2</sub>O, or else the high frequency contributions to the flux will be lost. The factory default bandwidth of the EC100 is 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 A, *Filter Bandwidth and Time Delay* for more information on the digital filter options.

If a spectral analysis is being done 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 that if too small a bandwidth is selected, high frequency fluxes may be under-measured.

### 7.2.3 Unprompted Output

If the EC100 is to output data in one of the unprompted modes (USB or RS-485, see Section 8.2, *USB or RS-485 Output*), this setting must be set accordingly. The factory default is to disable the unprompted output, assuming data will be logged via SDM (see Section 8.1, *SDM Output*).

Only one unprompted output type (i.e., USB, 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.

### 7.2.4 Unprompted Output Rate

This setting determines the output rate for unprompted output (USB or RS-485, see Section 8.2, *USB or RS-485 Output*). 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.

### 7.2.5 RS-485 Baud Rate

If the unprompted output mode is set to RS-485, this 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.

### 7.2.6 Analogue Output

The EC100 has two analogue outputs for CO<sub>2</sub> and H<sub>2</sub>O densities (see Section 8.3, *Analogue Outputs* for more information). These outputs may be enabled/disabled with this setting. The default is for analogue output to be disabled.

### 7.2.7 ECMon Update Rate

This 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.

### 7.2.8 Temperature Sensor

This setting configures the EC100 electronics to work with either an EC150 open-path gas analyser or an EC155 closed-path gas analyser. The EC150 measures ambient air temperature using a thermistor probe, while the EC155 measures the temperature of the air sample as it passes through the sample cell with a thermocouple mounted in the sample cell. 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.

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

### 7.2.9 Fixed Temperature Value

If the **Temperature Sensor** setting is **None**, the EC150 will use the value of this 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.

### 7.2.10 Pressure Sensor

This setting determines which pressure sensor will be used to measure the barometric pressure. The EC100 always includes the EC100 basic barometer, but it may be ordered with the optional EC100 enhanced barometer. This setting is factory defaulted to the Enhanced barometer if it is ordered and to the Basic barometer otherwise.

There are two other possible settings for the **Pressure Sensor**. First, the user may provide his or her own pressure sensor. In this case the setting should be changed to **User Supplied**, with the appropriate values for gain and offset entered (see below).

The final option is to select **None** for the **Pressure Sensor** setting. The EC100 will use a fixed (see below) value for pressure. This mode is intended for troubleshooting only.

#### 7.2.10.1 Pressure Gain

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

#### 7.2.10.2 Pressure Offset

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

#### 7.2.10.3 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.

### 7.2.11 Pressure Differential Enable

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

### 7.2.12 Heater Control

When enabled, this setting applies a voltage between 0 and 4500 mV to heaters near the optical windows of the analyser. Heated windows inhibit the formation of condensation, such as dew and frost, and help the analyser recover more quickly when precipitation has blocked the optical path. Use this setting with caution. Excessive heating may lead to density fluctuations and subsequent flux measurement errors. More information about heater control, and specifically using a datalogger for control, may be found at the end of Section 10.2, *EC100Configure() Instruction*.

## 7.3 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 on the company website in the Support Downloads section ([www.campbellsci.com/downloads](http://www.campbellsci.com/downloads)).

Before installing ECMon, read the file titled *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 #26561). (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 #26561). The USB connection for the EC100 electronics is found on the bottom of the enclosure (see Figure 6-6). Once connected, select the appropriate communications port in the ECMon Main Page and click **Connect** (see Figure 7-1). Next click on the **Setup** button. All of the above settings are now available for the user to change (see Figure 7-2).

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 9.4, *Zero and Span*)
- Troubleshooting and monitoring diagnostics using the Status window.

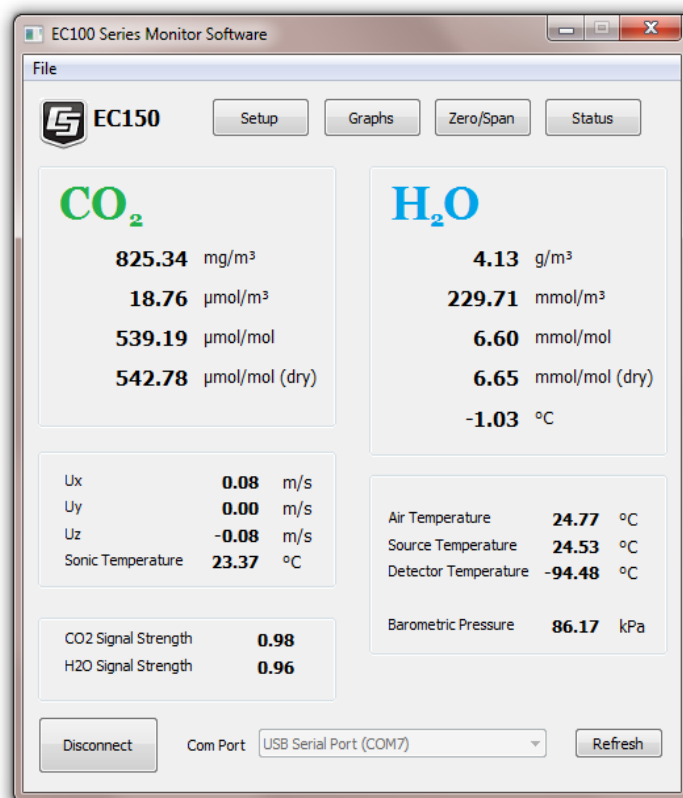


Figure 7-1. The Main screen in ECMon

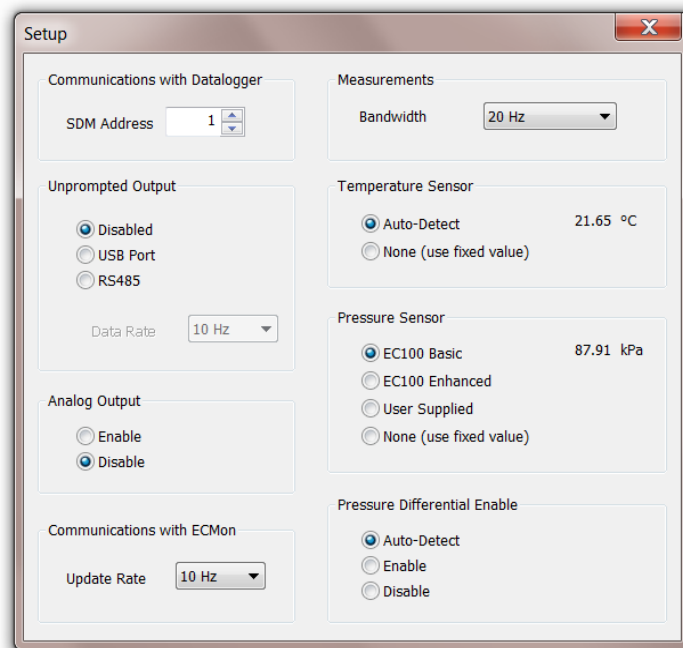


Figure 7-2. The Setup screen in ECMon

## 7.4 Device Configuration Utility

The Device Configuration Utility software may also be used to change settings, although ECMon is generally preferred because of its more user-friendly interface. Device Configuration may be downloaded from the *EC150 & EC155 Support CD* (pn #27007), or may be downloaded free of charge from the Campbell Scientific website in the Support/Downloads section ([www.campbellsci.com/downloads](http://www.campbellsci.com/downloads)). Device Configuration requires a USB driver to communicate with the EC100, similar to ECMon. See Section 7.3, *ECMon* 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 #26561) 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.

## 8. EC100 Outputs

The EC100 outputs data in one of four types: SDM, USB, RS-485, or analogue. In general Campbell Scientific recommends that SDM be used if a Campbell Scientific datalogger is responsible for data collection. However, RS-485 output is recommended over SDM if cable lengths exceed 100 meters. If a PC is being used as the collection vehicle, USB and RS-485 are suitable outputs. Analogue output may also be used, however only CO<sub>2</sub> density and H<sub>2</sub>O density will be output. More information regarding each output type is provided in sections below.

## 8.1 SDM Output

SDM (Synchronous Device for Measurement) 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 of the Campbell Scientific dataloggers support SDM, only the CR1000, CR3000, and CR5000 dataloggers support the EC150.

To use SDM data output, connect an SDM communications cable from the EC100 (see Section 6.3, *Wiring and Connections*) 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's 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 Section 7.2.1, *SDM Address*).

The sample rate for SDM output is determined by the inverse of the datalogger scan interval, as set by the user in the datalogger program. Data are output from the EC100 when a request is received from the logger (i.e., 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 detail under Section 7, *Settings* of this manual.

## 8.2 USB or RS-485 Output

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 (i.e., USB, RS-485) may be selected at a given time. RS-485 output is recommended over SDM if cable lengths exceed 100 meters. If a Campbell Scientific datalogger is not being used to collect the data from the EC150, either unprompted mode is recommended.

To use USB or RS-485 output, connect a USB or RS-485 cable from the EC100 to the receiving device (see Section 6.3, *Wiring and Connections*), and configure the settings (see Section 7, *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 8-1 below lists the elements in each output array, and Figure 8-1 shows an example USB data feed in terminal mode.

Table 8-1. USB and RS-485 Output Elements		
Data Element	Description	Units/comments
1	U <sub>x</sub>	m/s
2	U <sub>y</sub>	m/s
3	U <sub>z</sub>	m/s
4	Sonic Temperature	°C
5	Sonic Diagnostic Flag	
6	CO <sub>2</sub> Density	mg/m <sup>3</sup>
7	H <sub>2</sub> O Density	g/m <sup>3</sup>
8	Gas Diagnostic Flag	
9	Air Temperature	°C
10	Air Pressure	kPa
11	CO <sub>2</sub> Signal Strength	Nominally 0.0 to 1.0
12	H <sub>2</sub> O Signal Strength	Nominally 0.0 to 1.0
13	Pressure Differential (used for EC155 only, disregard for EC150)	kPa
14	Counter	Arbitrary
15	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 8-1. An example of USB data output in terminal mode

The final data element in each row or output array is the signature, a four character hexadecimal value that is a function of the specific sequence and number of bytes in the output array. The recording device (i.e., 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. This is very similar to a Cyclic-Redundancy-Check (CRC).

In most situations, a PC begins by reading in the ASCII data and extracting the last four ASCII characters, casting them as Long data type. The signature is then calculated on the science data sent from the EC150, starting with CO<sub>2</sub> and ending on the counter. All the characters after the counter are not part of the signature. Once the signature is computed using the algorithm below, it is compared to the transmitted signature. If signatures do not match, the data should be disregarded.

The following block of code 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);
}

```

### 8.3 Analogue Outputs

If analogue output is enabled, the EC100 will output two analogue signals that correspond to CO<sub>2</sub> density and H<sub>2</sub>O density. These signals range from 0 to +5 Volts. Table 8-2 below gives the multipliers and offsets for the analogue outputs.

#### CAUTION

Be aware that the absence of diagnostic data in analogue output could make troubleshooting difficult and may lead to the user not being aware of potential problems with the instrumentation.

**Table 8-2. Multipliers and Offsets for Analogue Outputs**

Density (mg m <sup>-3</sup> )	Voltage Output Multiplier (mg m <sup>-3</sup> V <sup>-1</sup> )	Offset (mg m <sup>-3</sup> )
CO <sub>2</sub>	386.32	-102.59
H <sub>2</sub> O	8.65	-2.26

## 9. Maintenance

EC150 operation requires six maintenance tasks:

- routine maintenance
- wick maintenance
- analyser window cleaning
- zero and span
- replacing the analyser desiccant / scrubber bottles
- factory recalibration

### 9.1 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 or recharge the desiccant bags. Replacement desiccant bags may be purchased (pn #6714), or old ones may be recharged by heating in an oven. See the manual *ENC10/12*, *ENC12/14*, *ENC14/16*, available at [www.campbellsci.com](http://www.campbellsci.com), for more details on recharging desiccant bags.

Make sure the *Power* and *Gas* LED status lights on the EC100 panel are green. If not, verify that all sensors are connected securely and that the instruments are powered. Also check the individual diagnostic bits for the specific fault. See Table 10-2 and Table 10-3.

### 9.2 Gas Analyser Wicks

EC150 gas analyser windows 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 wicks. The weave of the wick 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<sub>2</sub>O and CO<sub>2</sub>. Following installation, these values should be unchanged.

Wicks are available as listed in Table 9-1.

Table 9-1. Rain Wick Replacement Parts		
Wick	Campbell Scientific, Inc Part Number	Campbell Scientific 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 has to 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 9-1, *Proper location of the sonic top wick and bottom 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 snugly over the cylindrical part of the snout without any creases or wrinkles.

The wicks are constructed with a UV-resistant fabric and should function over long time periods. Nevertheless, they should be inspected periodically. Check for contamination from dust, pollen, pitch or other debris. If needed, wash them in warm water with mild detergent or replace them. When performing the zero-and-span procedure, the wicks should be removed before installing the zero-and-span shroud.

Remove the wicks during the winter. The wicks will accumulate snow or freezing rain, resulting in blockage of the optical path. Besides the wicks, controlling the heaters in the snouts is another method the user may consider in preventing data loss during precipitation and condensation events. The heaters can be controlled statically using the **Setup** window in ECMon or dynamically using a datalogger (see Section 10.2, *EC100Configure() Instruction* for more details).

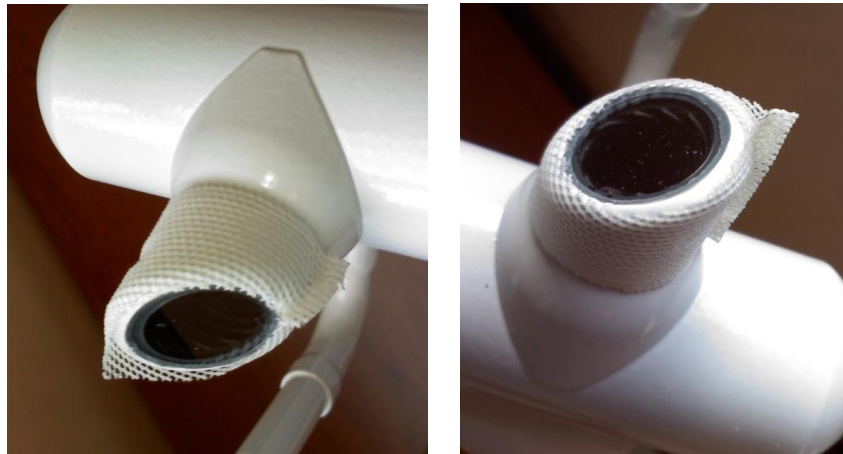


Figure 9-1. Proper location of the gas analyser top wick (left) and bottom wick (right)

### 9.3 Analyser Window Cleaning

The windows of the analyser should be cleaned if the signal strength for CO<sub>2</sub> or H<sub>2</sub>O drops below 0.7 (i.e., 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 non-scratching tissue or cloth. Verify that following cleaning the signal strengths are restored to values close to 1.0.

### 9.4 Zero and Span

As is the case with all optical instruments, EC150 measurements may drift slightly with exposure to natural elements. Therefore, routine maintenance requires a periodic zero-and-span procedure. The frequency with which this should be done is heavily dependent on the environmental conditions in which the instrument is making measurements. Campbell Scientific recommends that a new instrument, or an instrument that has been moved to a new location, should have a monthly zero and span procedure performed. Additionally, it is recommended to always zero and span the analyser after cleaning the windows (see Section 9.3, *Analyser Window Cleaning*). After the first several zero-and-span procedures, the

rate of drift in gain and offset (explained later in this section) will be better understood for the existing environmental conditions. A regimented protocol for zero and span of the instrument initially, will allow the user to assess the appropriate time interval between zero and span procedures. However, if the EC150 is being used at a site with large seasonal changes in ambient conditions, the zero-and-span procedure should be done at least seasonally.

In situations in which spanning the instrument is extremely difficult (for example, in below freezing temperature conditions or in very remote sites), performing a monthly zero will help mitigate the drift in the analyser's measurements.

The first part of the procedure listed below, simply measures the CO<sub>2</sub> and H<sub>2</sub>O span and zero, without making any adjustments. This allows the CO<sub>2</sub> and H<sub>2</sub>O gain factors to be calculated. These gain factors quantify the state of the analyser 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 (e.g., in a lab), be sure to mount the EC150 on the zero-and-span stand. This will ensure the analyser is in the correct upright orientation and has the correct optical alignment.

It is imperative that the zero-and-span procedure be done correctly and not rushed; allocate plenty of time for the procedure (at least an hour).

---

**CAUTION**

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

---

To check and then set the EC150 zero and span, follow the steps below:

- a. Remove power from the EC100/EC150.
- b. If not already done, clean the windows and snouts with alcohol and a non-scratching tissue or cloth.

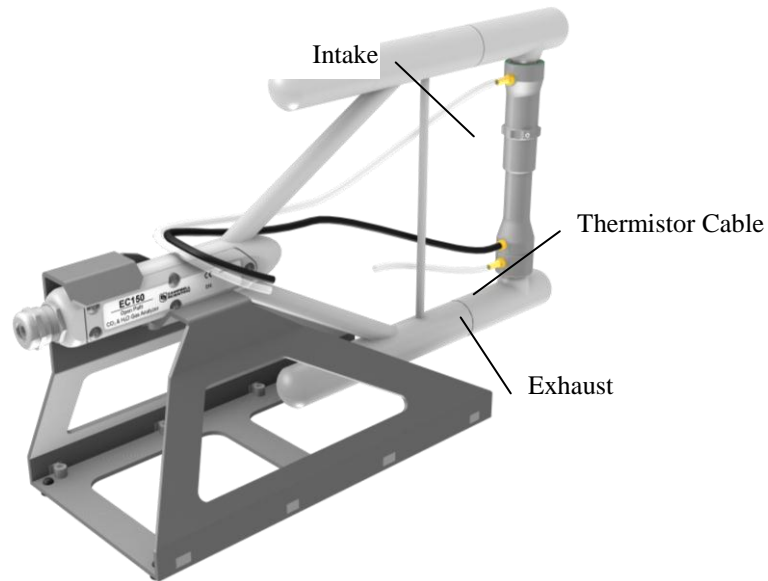
---

**CAUTION**

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

---

- c. Position the EC150 zero-and-span shroud (pn #26390) over the upper and lower snouts. To do this, 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. 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. Continue twisting the shroud until it is fully extended and covering both snouts. Twist the shroud so that the gas lines and temperature thermistor cable are directed towards the back of the sensor. Hang the lines and cable over the trunk of the sensor to alleviate any strain on the optical arms. See Figure 9-2.



*Figure 9-2. The zero-and-span shroud mounted on the zero-and-span stand. The top tube is the gas intake, the black cable is the temperature thermistor, and the short bottom tube is the gas exhaust.*

- d. Disconnect the EC150 temperature probe from the EC100, and connect the shroud temperature probe in its place.
- e. Connect the EC100 to a PC with the EC100 USB cable (pn #26561).
- f. Resume power to the EC100/EC150. Wait for all the *Gas* and *Power* LED status lights on the EC100 panel to turn green.
- g. Launch ECMon, select the appropriate USB port, and click **Connect**. The main screen should now be reporting real-time CO<sub>2</sub> and H<sub>2</sub>O concentrations. Click **Zero/Span**. A graph will appear in the lower half of the zero-and-span window showing measured CO<sub>2</sub> and H<sub>2</sub>O concentrations (see Figure 9-3).
- h. Connect a gas tank of known CO<sub>2</sub> concentration to a pressure regulator, then to a flow controller, and finally to the intake of the shroud. Optimally, the concentration of span CO<sub>2</sub> should be near the concentration of CO<sub>2</sub> being measured in the field. Begin with both the pressure regulator and flow controller turned off. Then use the pressure regulator to slowly increase pressure to the recommended setting for the flow controller. Next set the flow between 0.4 and 0.6 l/min. Watch the ECMon zero-and-span graph for the CO<sub>2</sub> measurement readings to stabilize (5 to 10 minutes). Once stable, write down the reported CO<sub>2</sub> concentration.

#### NOTE

Use mixtures of CO<sub>2</sub> and ambient air for the CO<sub>2</sub> span gas. The use of reference CO<sub>2</sub> gas mixtures in pure nitrogen will lead to errors due to a carrier gas effect on pressure-broadening of the CO<sub>2</sub> absorption lines since oxygen gas has a smaller line-broadening coefficient than nitrogen.

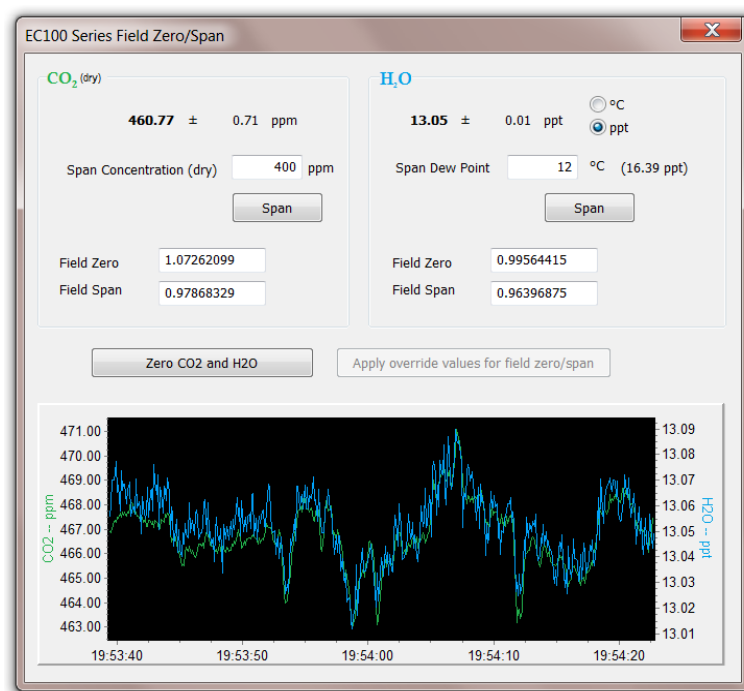


Figure 9-3. ECMon zero-and-span window

- i. Remove the CO<sub>2</sub> span gas from the inlet of the shroud, and replace it with H<sub>2</sub>O span gas from a dew-point generator or another standard reference. Because water molecules can adsorb to inside of the tubing and the shroud, it may take many minutes for the H<sub>2</sub>O concentration to stabilize. If desired, increase the flow rate for the first several minutes to more quickly stabilize the system before returning it to between 0.4 and 0.6 l/min to make the H<sub>2</sub>O measurement. Write down the reported H<sub>2</sub>O concentration.
- j. Remove the H<sub>2</sub>O span gas, and connect a zero air source (no CO<sub>2</sub> or H<sub>2</sub>O) to the inlet tube of the shroud. As described in step h, use a pressure regulator and flow controller so that zero air flows through the shroud between 0.4 and 0.6 l/min. Wait for the measurement readings to stabilize (this may require several minutes) and write down the reported values for CO<sub>2</sub> and H<sub>2</sub>O concentrations. If the readings remain erratic, ensure that flow of the zero air is sufficient and the shroud is correctly seated on the snouts.
- k. Examine the measurements that were written down for span CO<sub>2</sub>, span H<sub>2</sub>O, and zero air. 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 dew-point temperature. The software calculates  $span_{actual}$  by taking into account the dew-point temperature and current ambient temperature and pressure. The equations used for this

calculation may be found in Appendix B. If drift (offset or gain) for CO<sub>2</sub> or H<sub>2</sub>O is excessive, it may be time to replace the desiccant and CO<sub>2</sub> scrubber bottles (see Section 9.5, *Replacing Desiccant and Scrubber Bottles*).

- l. With zero air still flowing and measurements stabilized, click on the **Zero CO<sub>2</sub> and H<sub>2</sub>O** 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 analyser will not be zeroed and spanned properly.

- m. Remove the zero air source and replace it with the CO<sub>2</sub> span gas. Allow the gas to flow through the shroud, maintaining a flow between 0.4 and 0.6 l/min. Wait for readings to stabilize.
- n. In the zero-and-span window, enter the known concentration of CO<sub>2</sub> (in ppm) in the box labelled **Span Concentration (dry)** and press **Span**.
- o. Replace the CO<sub>2</sub> span gas with an H<sub>2</sub>O span gas of known dew point. 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 0.4 and 0.6 l/min. Wait for the readings to stabilize.
- p. Enter the known dew point (in C°) in the box labelled **Span Dew Point** and press **Span**.
- q. The zero-and-span procedure is now complete. Remove the shroud, reconnect the EC150 temperature probe, and prepare the site for normal operation.

## 9.5 Replacing the EC150 Desiccant/CO<sub>2</sub> 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 6.3 above), the desiccant/scrubber bottles within the EC150 analyser head need to be replaced. To do this, twist the scrubber bottle covers of the upper and lower arms counter clockwise until they detach (they should loosen by hand). Remove the EC150 chemical bottles (pn #26510) from inside the covers, and replace them with new bottles lid-first (see Figure 9-4). Once this is done, firmly screw the covers back on the arms. Allow the sensor to equilibrate for at least 24 hours (longer if in high humidity), and then perform a zero-and-span procedure. If readings continue to be suspect, the sensor may need to be recalibrated at the factory (see Section 9.6, *Factory Recalibration* below).

#### 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.**

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

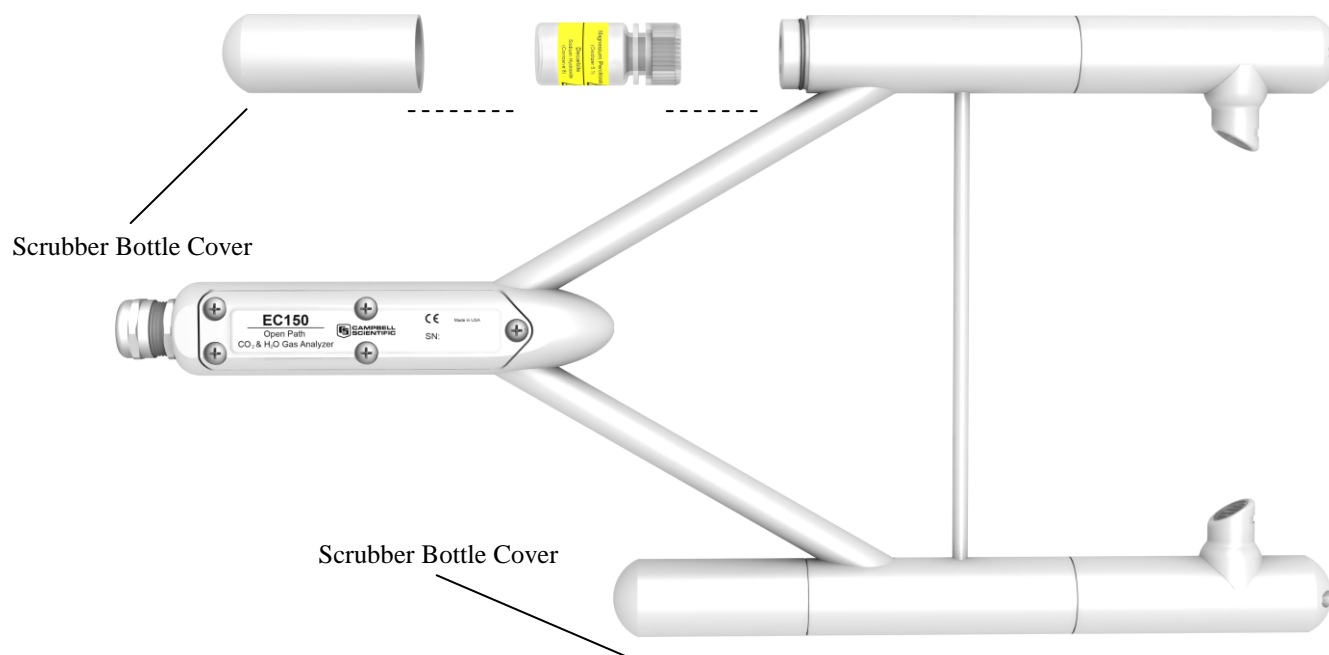


Figure 9-4. Replacing the desiccant/CO<sub>2</sub> scrubber bottles

## 9.6 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<sub>2</sub> calibration gases used in this process are mixtures of CO<sub>2</sub> in ambient air 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.

After an extended period of time in the field, the EC150 may need to undergo this factory calibration again in order to ensure valid measurements. When recalibration is deemed necessary, contact Campbell Scientific.

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

## 10. Datalogger Programming with CRBasic

CRBasic supports two instructions to communicate with the EC100 via SDM. The first is the **EC100()** instruction, which reads measurement data from the EC100. The second is the **EC100Configure()** instruction, which receives and sends configuration settings.

### 10.1 EC100() Instruction

The **EC100()** instruction is used to retrieve data from the EC150 via SDM. The instruction syntax is:

**EC100**(*Dest*,*SDMAddress*,*EC100Cmd*)

*Dest* is the input variable name in which to store the data from the EC150. The length (i.e., number of data elements) of the input variable array will depend on the selected value for *EC100Cmd*. A value of -99999 will be loaded into *Dest*(1) if a signature error on SDM data occurs.

EC100Cmd	Dest Variable Length
0	8
1	12
2	13

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

**EC100Cmd** is a parameter that requests the data to be retrieved from the analyser. The results for the command will be returned in the array specified by the *Dest* parameter. A numeric code is entered to request the data, as shown in Table 10-1.

Table 10-1. Output Modes for EC100 Instruction			
Output Mode	Data Field	Description	Units
0, 1, 2,	1	U <sub>x</sub>	m/s
	2	U <sub>y</sub>	m/s
	3	U <sub>z</sub>	m/s
	4	Sonic Temperature	°C
	5	Sonic Diagnostic Flag	
	6	CO <sub>2</sub> Density	mg/m <sup>3</sup>
	7	H <sub>2</sub> O Density	g/m <sup>3</sup>
	8	Gas Diagnostic Flag	
1, 2	9	Air Temperature	°C
	10	Air Pressure	kPa
	11	CO <sub>2</sub> Signal Strength	nominally 0.0 ≤ strength ≤ 1.0
	12	H <sub>2</sub> O Signal Strength	nominally 0.0 ≤ strength ≤ 1.0
2	13	Sample Cell Pressure Differential	kPa

As shown, all output modes give two diagnostic values, the **Sonic Diagnostic Flag** and the **Gas Diagnostic Flag**. The values contain a bit field, with each bit representing a monitored condition. When a certain condition is detected, the corresponding bit is set. The value remains set until the event that caused the condition is no longer present. Table 10-2 and Table 10-3 below describe the bits in the sonic diagnostic flag and the gas diagnostic flag, respectively.

**Table 10-2. Bits in the Sonic Diagnostic Flag**

bit	hex value	decimal	Name	Function
0	0x1	1	Low Amp	Amplitude is too low
1	0x2	2	High Amp	Amplitude is too high
2	0x4	4	Tracking	Poor signal lock
3	0x8	8	Hi 3 Axis DC	Delta temperature exceeds limits
4	0x10	16	Acquiring	Acquiring ultrasonic signals
5	0x20	32	Cal Mem Err	Sonic head calibration signature error

**Table 10-3. Bits in the Gas Diagnostic Flag**

bit	hex value	decimal	Name	Function
0	0x1	1	Bad Data	Data are suspect (there is an active diagnostic flag)
1	0x2	2	Sys Fault	General system fault
2	0x4	4	Sys Startup	Gas analyser is starting up
3	0x8	8	Motor Speed	Motor speed outside of limits
4	0x10	16	TEC Temp	TEC temperature exceeds limits
5	0x20	32	Light Power	Source power exceeds limits
6	0x40	64	Light Temp	Invalid source temperature
7	0x80	128	Light I	Source current exceeds limits
8	0x100	256	Power Off	Gas head not powered
9	0x200	512	Chan Err	Gas input data out of sync with home pulse
10	0x400	1024	Amb Temp	Invalid ambient temperature
11	0x800	2048	Amb Press	Invalid ambient pressure
12	0x1000	4096	CO <sub>2</sub> I	CO <sub>2</sub> I exceeds limits
13	0x2000	8192	CO <sub>2</sub> I <sub>o</sub>	CO <sub>2</sub> I <sub>o</sub> exceeds limits
14	0x4000	16384	H <sub>2</sub> O I	H <sub>2</sub> O I exceeds limits
15	0x8000	32768	H <sub>2</sub> O I <sub>o</sub>	H <sub>2</sub> O I <sub>o</sub> exceeds limits
16	0x10000	65536	CO <sub>2</sub> I <sub>o</sub> Var	Moving variation in CO <sub>2</sub> I <sub>o</sub> exceeds limits



**Table 10-3. Bits in the Gas Diagnostic Flag**

bit	hex value	decimal	Name	Function
17	0x20000	131072	H <sub>2</sub> O I <sub>0</sub> Var	Moving variation in H <sub>2</sub> O I <sub>0</sub> exceeds limits
18	0x40000	262144	CO <sub>2</sub> I <sub>0</sub> Ratio	CO <sub>2</sub> signal level too low
19	0x80000	524288	H <sub>2</sub> O I <sub>0</sub> Ratio	H <sub>2</sub> O signal level too low
20	0x100000	1048576	Cal Mem Err	Gas head calibration signature error
21	0x200000	2097152	Heater Control	Heater control error
22	0x400000	4194304	Diff Pressure	Differential pressure exceeds limits

## 10.2 EC100Configure() Instruction

This instruction is another way, besides ECMon and Device Configuration, to retrieve and modify settings. ECmon and Device Configuration are user-interactive, while the **EC100Configure()** instruction allows automated control under CRBasic datalogger programming.

**EC100Configure()** is a processing instruction. Whether running in pipeline mode or sequential mode the datalogger will execute the instruction from processing. This functionality allows the instruction to be placed in conditional statements. Running 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.

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 result 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* (i.e., 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 10-4.

**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 10-4. 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
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 <sub>2</sub> , 3 = Span H <sub>2</sub> O (See Section 10.2.1, <i>Config Command Span/Zero Control</i> .)
12	112	CO <sub>2</sub> Span Concentration
13	113	H <sub>2</sub> O Span Dew Point Temperature
14	114	CO <sub>2</sub> Zero
15	115	CO <sub>2</sub> Span
16	116	H <sub>2</sub> O Zero
17	117	H <sub>2</sub> O Span
18 or 218	118	Heater Voltage (0 to 4.5375V, -1 = Off) (See Section 10.2.2, <i>Config Command Heater Voltage</i> .)
19	119	Reserved
20	120	Analogue 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

### 10.2.1 ConfigCmd 11 Zero-and-Span Control

To perform zeroing of CO<sub>2</sub> and H<sub>2</sub>O, *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<sub>2</sub> span, the *CO<sub>2</sub> Span Concentration* setting (*ConfigCmd 12*) must be written to the proper value in ppm CO<sub>2</sub> prior to setting the Span/Zero Control setting (*ConfigCmd 11*) to 2. After the CO<sub>2</sub> span is completed, the value of the Span/Zero Control setting will change to -2. H<sub>2</sub>O span is similar to CO<sub>2</sub>. First the *H<sub>2</sub>O 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 analyser's algorithms for calculating gas concentrations.

### 10.2.2 ConfigCmd 18 Heater Voltage

Normally the **EC100Configure()** instruction is run in the datalogger's processing task. Skipped scans can occur when the **EC100Configure()** instruction executes. When changing operational parameters, these skipped scans are acceptable. However, it may not be acceptable when changing the heater voltage. *ConfigCmd 218* allows the **EC100Configure()** instruction to operate in the SDM task, thus avoiding skipped scans. When using *ConfigCmd 218*, the command must be a constant and the instruction cannot be placed in a conditional statement.

The EC150 includes heaters near the optical windows. This setting gives the voltage applied to the heater. It can be set to -1 to disable the heater, or set it to any voltage between 0 and 4.5375 V.

The heater resistance is 5 ohms, so the heater power will be given by:

$$P_H = \frac{V^2}{5} \text{ (W)}$$

The maximum power (at 4.5375 V) is 4.12 (W).

Operating the heaters following a precipitation event encourages water droplets on the windows to evaporate more quickly, thus restoring signal strength. Heater usage may also be desired in order to prevent formation of dew and frost on the windows, which leads to invalid measurements due to differences in absorption spectra of liquid water and water vapour.

The heaters, however, should be disabled when they are not needed; this is because heating near the sample volume may cause air density fluctuations which can affect flux measurements. Disabling the heaters will also conserve power. Care should be taken to avoid operating the heaters if the system voltage is too low or if the ambient temperature is high (i.e., > 45°C). Operation at high temperatures will overload the thermoelectric coolers of the detector, as indicated by the TEC Temp diagnostic flag (see Table 10-3, *Bits in Diagnostic Flag*).

### 10.3 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
```

## 11. Theory of Operation

The EC150 is a non-dispersive mid-infrared absorption analyser. Infrared radiation is generated in the upper arm of the analyser head before propagating along a 15 cm optical path. 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 analyser measures the decrease in radiation intensity due to absorption, which can then be related to analyte concentration using the Beer-Lambert Law:

$$P = P_o e^{-\epsilon cl}$$

where P is irradiance after passing through the optical path, P<sub>o</sub> is initial irradiance,  $\epsilon$  is molar absorptivity, c is analyte concentration, and l is 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<sub>2</sub>, light with a wavelength of 4.3  $\mu\text{m}$  is selected, as it corresponds to the molecule's asymmetric stretching vibrational band. For H<sub>2</sub>O, radiation at 2.7  $\mu\text{m}$ , corresponding to water's symmetric stretching vibrational band, is used.

The EC150 is a dual wavelength single beam analyser; thus, rather than using a separate reference cell and detector, the initial intensity of the radiation is calculated by measuring the intensity of nearby, non-absorbing wavelengths (4  $\mu\text{m}$  for CO<sub>2</sub> and 2.3  $\mu\text{m}$  for H<sub>2</sub>O). These measurements account for any source and detector aging and window contamination.

The chopper wheel spins at a rate of 100 revolutions per second, and the detector is measured 512 times per revolution, resulting in a detector sampling rate of 512 kHz. The detector is maintained at -40°C using a 3-stage thermoelectric cooler and is coupled to a low noise pre-amp module.

The EC100 electronics digitize and process the detector data (along with ancillary data such as sample temperature and pressure) to give the CO<sub>2</sub> and H<sub>2</sub>O densities after each chopper wheel revolution (100 Hz). These are then filtered to the user-specified bandwidth. The EC100 also synchronously measures and processes data from an optional CSAT3A 3D sonic anemometer head.



# Appendix A. Filter Bandwidth and Time Delay

---

The EC100 measures CO<sub>2</sub> and H<sub>2</sub>O from the EC150 gas analyser head (as well as wind velocity and sonic temperature from the optional CSAT3A sonic head) at 100 Hz and then applies a user-selectable low-pass filter. The available filter bandwidths are 5, 10, 12.5, 20, and 25 Hz. Figure A-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 A-2 compares the EC100 10-Hz filter to a 50-msec moving average filter with approximately the same bandwidth.

The ideal eddy-covariance filter is one that is wide enough to preserve the low-frequency signal variations that transport flux and narrow enough to attenuate high-frequency noise. In addition, to minimize aliasing (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. First, the time-averaged (typically thirty-minute) covariance calculations inherently reduce noise, and second, aliasing does not degrade the accuracy of covariance calculations. Therefore, the factory default for the EC100 bandwidth (20 Hz) is rather wide to preserve the signal variations that transport flux, and that bandwidth is suitable for most flux applications. Additional bandwidths are available for experimenters 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 (or datalogger scan rate), and experimenters should be careful to avoid attenuation of flux-carrying signals.

The EC100 electronics synchronously sample the EC150 analyser and the CSAT3A sonic head. However, experimenters wishing to synchronize their EC100 data with other measurements (e.g., energy balance sensors) in the data acquisition system must account for the time delay of the EC100 filter. Table A-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.

The following examples show how to use Table A-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 A-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 100 Hz, and the 100-Hz data are down-sampled to the datalogger's scan rate through SDM communications (see Section 8, *EC100 Outputs*). This process synchronizes the EC100 gas and wind data with other signals measured by the datalogger to within  $\pm 3.333$  ms (plus or minus one-half of the inverse of 100 Hz). Alternatively, when sending data to a non-Campbell data acquisition system, 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.

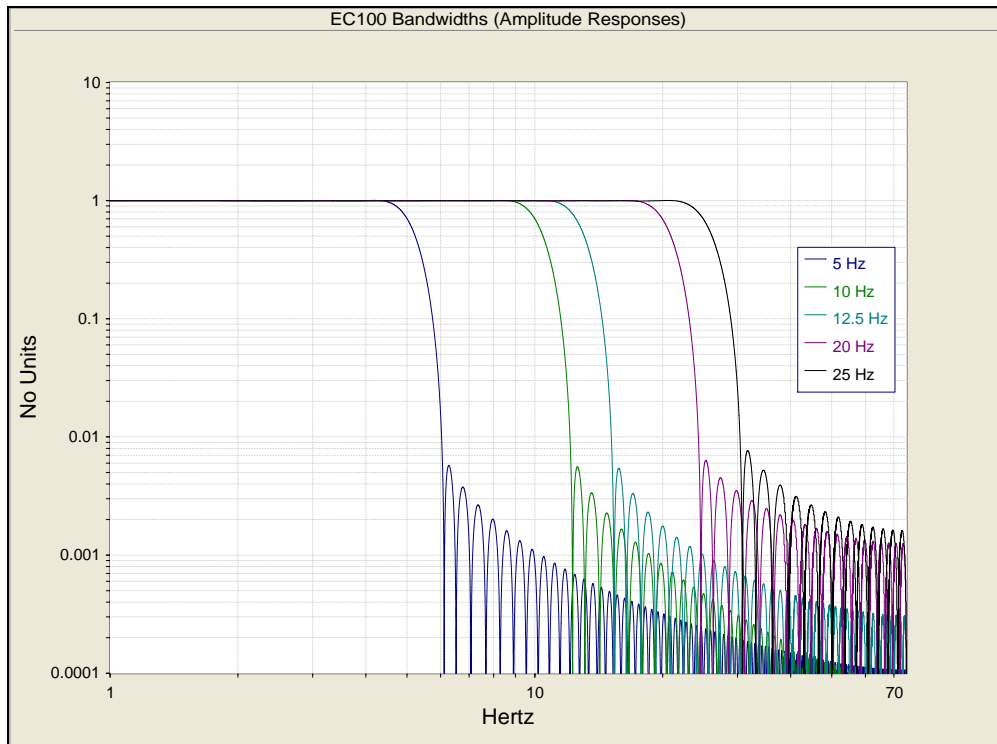


Figure A-1. Frequency and amplitude response of the EC100 filter at various bandwidths



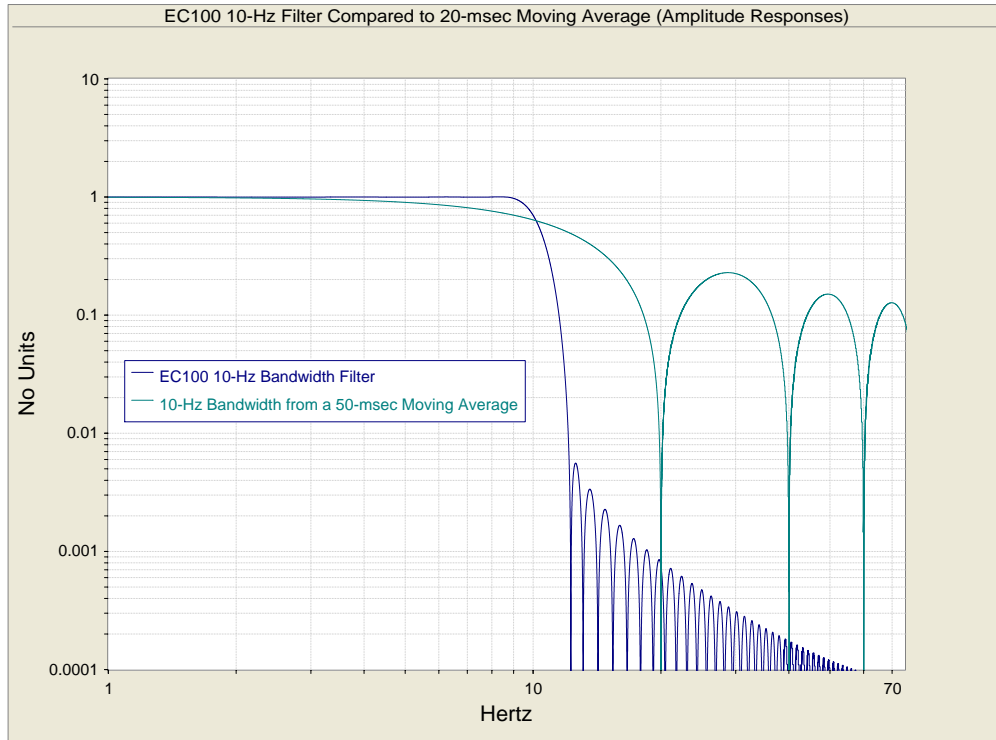


Figure A-2. Frequency response comparison of the EC100 10-Hz bandwidth and a 50-msec moving average

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



# Appendix B. Useful Equations

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

Table of Variables and Constants		
Variable or Constant	Description	Units
$\rho_c$	CO <sub>2</sub> Mass Density	mg m <sup>-3</sup>
$\rho_v$	H <sub>2</sub> O Mass Density	g m <sup>-3</sup>
$\rho_d$	Mass Density of Dry Air	g m <sup>-3</sup>
$X_c$	CO <sub>2</sub> Molar Mixing Ratio (concentration relative to dry air)	μmol mol <sup>-1</sup>
$X_v$	H <sub>2</sub> O Molar Mixing Ratio (concentration relative to dry air)	mmol mol <sup>-1</sup>
$M_c$	Molecular Weight of CO <sub>2</sub>	44 mg mmol <sup>-1</sup>
$M_d$	Molecular weight of dry air	0.029 g mmol <sup>-1</sup>
$M_v$	Molecular weight of H <sub>2</sub> O	0.018 g mmol <sup>-1</sup>
$P$	Ambient Pressure	kPa
$R$	Universal Gas Constant	8.3143×10 <sup>-6</sup> kPa m <sup>3</sup> K <sup>-1</sup> mmol <sup>-1</sup>
$T$	Ambient Temperature	°C
$e$	Vapour Pressure	kPa
$f$	Enhancement Factor	Arbitrary
$T_d$	Dew Point Temperature	°C
$T_{d\_tmp}$	Temporary variable for dew point calculation	Arbitrary

## Mass Density from Molar Mixing Ratios

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

$$\rho_v = \frac{X_v P M_v}{R(T + 273.15)(1000 + X_v)} \quad (\text{B-2})$$

$$\rho_d = \frac{(P - e)M_d}{R(T + 273.15)} \quad (\text{B-3})$$

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

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

**Dew Point from Molar Mixing Ratio**

$$T_d = \frac{240.97 T_{d\_tmp}}{17.502 - T_{d\_tmp}} \quad (B-6)$$

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

$$f = 1.00072 + (3.2 \times 10^{-5})P + (5.9 \times 10^{-9})PT^2 \quad (B-8)$$

**Water Vapour Molar Mixing Ratio from Dew Point**

$$X_v = \frac{e}{P - e} 1000 \quad (B-9)$$

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

**Water Vapour Mass Density from Dew Point**

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

**Vapour Pressure from Molar Mixing Ratio and Water Vapour Density**

$$e = \frac{X_v P}{1000 + X_v} \quad (B-12)$$

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

Equations (1) and (2) were derived from Leuning, 2004; Eq. 6.23.

Equations (6) - (8) and (10) - (11) were derived from Buck, 1981; Eq. 2a, 3a, and 6.

# Appendix C. Material Safety Data Sheets (MSDS)

## C.1 Magnesium Perchlorate MSDS

<b>GFS CHEMICALS, INC.</b> P.O. Box 245 Powell, OH 43065 740-881-5501 (Tel.) 740-881-5989 (Fax) 1-800-424-9300 (Chemtrec 24Hr. Info.)			
<b><u>MATERIAL SAFETY DATA SHEET</u></b>			
55			
<b>MAGNESIUM PERCHLORATE, ANHYDROUS</b>			
<b><u>CHEMICAL NAME &amp; SYNONYMS</u></b> Magnesium Perchlorate, Anhydrous		<b><u>DOT CLASS</u></b> 5.1/II <b><u>TSCA listed</u></b> - Yes	<b><u>SARA TITLE 313</u></b> No
<b><u>FORMULA</u></b> Mg(ClO <sub>4</sub> ) <sub>2</sub>	<b><u>REPORTABLE QUANTITY</u></b> N/A	<b><u>F.W.</u></b> 223.23	<b><u>CAS#</u></b> 10034-81-8
<b><u>PHYSICAL DATA</u></b> Melting point 250°C. Density 2.21. Deliquescent. Very soluble in water with evolution of heat.			
<b><u>APPEARANCE &amp; ODOR</u></b> White granules and powder. Odorless.			
<b><u>REACTIVITY &amp; CONDITIONS TO AVOID</u></b> Stable. Strong dehydrating agent. Potentially strong oxidant (over 150°C). Do not heat with organic matter, flammables or combustibles. Avoid contact with strong acids.			
<b><u>FIRE HAZARDS</u></b> May cause fire or explosion when heated with combustibles or organic matter. Avoid inhalation of smoke or fumes. Firefighters wear SCBA. NFPA 1-0-3			
<b><u>EXTINGUISHER</u></b> Water.	<b><u>FLASHPOINT</u></b> N/A	<b><u>LEL</u></b> N/A	<b><u>UEL</u></b> N/A
<b><u>HEALTH HAZARDS</u></b> Irritating to skin, eyes and nasal passages. Overexposure may lead to dermatitis externally or diarrhea internally. Toxicity is low and indeterminate. OSHA TLV/ACGIH PEL not established. Perchlorate has been shown to interfere with iodine uptake by the thyroid in test animals. Studies on workers in plants where perchlorate salts are manufactured have shown no thyroid abnormalities. Thyroid effects on humans continues to be studied. No evidence of carcinogenicity.			
<b><u>SPECIAL PRECAUTIONS</u></b> Wear goggles and rubber gloves while handling. Store away from organics, combustibles, strong acids. Do not use to dry organic liquids.			
<b><u>FIRST AID</u></b> Wash skin and eyes well with water. After washing eyes get medical attention. If swallowed give ice to suck, water to drink and call a physician.			
<b><u>SPILLS &amp; LEAKS</u></b> Wash up spill immediately with water. Disposal to sanitary drain, check local regulations. If spilled on wooden floor, wash up thoroughly with water and remove flooring for disposal. Rinse mops thoroughly with water. Do not use sawdust, rags or paper as absorbant.			
<b><u>CATALOG #</u></b> 55	<b><u>PREPARED BY</u></b> MDM	<b><u>DATE</u></b> April 22, 2005	

## C.2 Decarbite MSDS

Material Safety Data Sheet May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.		<b>U.S. Department of Labor</b> Occupational Safety and Health Administration (Non-Mandatory Form) Form approved OMB No. 1218-0072	
<b>IDENTITY</b> (As Used on Label and List) <div style="text-align: center; border: 1px solid black; padding: 2px;">DECARBITE</div>		Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.	
<b>Section I</b>			
Manufacturer's Name <b>P. W. PERKINS CO., INC.</b>		Emergency Telephone Number <b>1-800-424-9300</b>	
Address (Number, Street, City, State, and ZIP Code) <b>221 Commissioners Pike</b>		Telephone Number for Information <b>(856) 769-3525</b>	
<b>Woodstown NJ 08098-2032 USA</b>		Date Prepared <b>1/2/07</b>	
<b>Section II — Hazardous Ingredients/Identity Information</b>			
Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended
<b>Sodium Hydroxide, caustic soda, CAS #1310-73-2</b>			
<b>Chemical formula: NaOH</b>			
<b>D.O.T. Shipping name: Sodium Hydroxide, Solid</b>			
<b>D.O.T. Hazard Class: 8, Corrosive, Packaging Group II</b>			
<b>D.O.T. ID #UN1823</b>			
<b>PEL = 2mg/m<sup>3</sup></b>			
<b>TLV = 2mg/m<sup>3</sup></b>			
<b>Hazardous Substance RO 1000</b>			
<b>Proprietary formulation indicating CO<sub>2</sub> Adsorbent</b>			
<b>Sodium Hydroxide: CAS #1310-73-2</b>			
<b>Non Fibrous Silicate: CAS #1318-00-9</b>			
<b>Section III — Physical/Chemical Characteristics</b>			
Boiling Point	Specify Gravity (H <sub>2</sub> O = 1)		
<b>@ 760 mm Hg: 1388°C</b>	<b>2.13 @ 20°C</b>		
Vapor Pressure (mm Hg.)	Melting Point		
<b>42 mm Hg @ 1000°C</b>	<b>NA</b>		
Vapor Density (AIR = 1)	Evaporation Rate (Butyl Acetate = 1)		
<b>NA</b>	<b>NA</b>		
Solubility in Water			
<b>Completely soluble</b>			
Appearance and Odor			
<b>Light tan, no distinct odor</b>			
<b>Section IV — Fire and Explosion Hazard Data</b>			
Flash Point (Method Used)	Flammable Limits	LEL	UEL
<b>No flash to 550°F ASTM D-56</b>	<b>non flammable</b>	<b>NA</b>	<b>NA</b>
Extinguishing Media			
<b>Product not combustible, foam/CO<sub>2</sub> or dry chemical can be used.</b>			
Special Fire Fighting Procedures			
<b>Protective clothing/self contained breathing apparatus should be worn</b>			
<b>by fire fighters in area where product is stored.</b>			
Unusual Fire and Explosion Hazards			
<b>Material is stable (non explosive), non flammable. Will react with</b>			
<b>varying degrees of intensity on exposure to water and strong acids.</b>			
Form 30-510 Printed and Sold by <b>UNICO</b> 190 Baldwin Ave., Jersey City, NJ 07308 • (800) 631-3098 • (201) 795-5400			OSHA 174, Sept. 1985

<b>Section V — Reactivity Data</b>			
Stability	Unstable		Conditions to Avoid <u>Contact with water causes strong exothermic reaction. Avoid strong acids contact.</u>
	Stable	X	
Incompatibility (Materials to Avoid) <u>Water, strong acids, aluminum, tin, zinc</u>			
Hazardous Decomposition or Byproducts <u>Exposure to air results in formation of H<sub>2</sub>O and carbonate</u>			
Hazardous Polymerization	May Occur		Conditions to Avoid <u>Material not known to polymerize</u>
	Will Not Occur	X	
<b>Section VI — Health Hazard Data</b>			
Route(s) of Entry:		Inhalation? <u>4-Extreme</u>	Skin? <u>4-Extreme</u> Ingestion? <u>3-Severe</u>
Health Hazards (Acute and Chronic) <u>Corrosive to all body tissue which it comes in contact.</u>			
<u>The chronic local effect may consist of multiple areas of superficial destruction of the skin. Inhalation of dust may cause varying degrees of irritation.</u>			
Carcinogenicity:		NTP? <u>NA</u>	IARC Monographs? <u>NA</u> OSHA Regulated? <u>NA</u>
<u>Not listed as a carcinogen</u>			
Signs and Symptoms of Exposure <u>Itching, burning of skin or eyes. Temporary discomfort of breathing passages.</u>			
Medical Conditions Generally Aggravated by Exposure <u>Increased susceptibility to respiratory illness.</u>			
Emergency and First Aid Procedures <u>Flush with water. Seek medical attention. Eyes - flush with large amounts of clean water, followed by boric acid eye wash solution.</u>			
<b>Section VII — Precautions for Safe Handling and Use</b>			
Steps to Be Taken in Case Material Is Released or Spilled <u>Wash area with 1 molar Hydrochloric acid or use caustic spill kit. Wash with clean water.</u>			
Waste Disposal Method <u>Appropriate disposal should conform with local and state health regulations.</u>			
Precautions to Be Taken in Handling and Storing <u>Wear protective clothing, use adequate ventilation where dust may be generated.</u>			
Other Precautions <u>Respirator, eye protection, gloves, lab coat or other clothing to cover exposed skin area.</u>			
<b>Section VIII — Control Measures</b>			
Respiratory Protection (Specify, Type) <u>MSA Dust Foe 77 or NIOSH approved respirator</u>			
Ventilation	Local Exhaust	<u>exhaust fan</u>	Special <u>NA</u>
	Mechanical (General)	<u>NA</u>	Other <u>NA</u>
Protective Gloves <u>Impervious</u>		Eye Protection <u>Goggles/face shield</u>	
Other Protective Clothing or Equipment <u>Coveralls, chemically resistant shoes.</u>			
Work/Hygienic Practices <u>Wash contaminated clothes; showers &amp; eye wash should be accessible.</u>			
Page 2			
(FR Doc. 85-28201 Filed 11-25-85; 8:45 am) BILLING CODE 4510-26-C			





# Appendix D. Packing Information

## D.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.

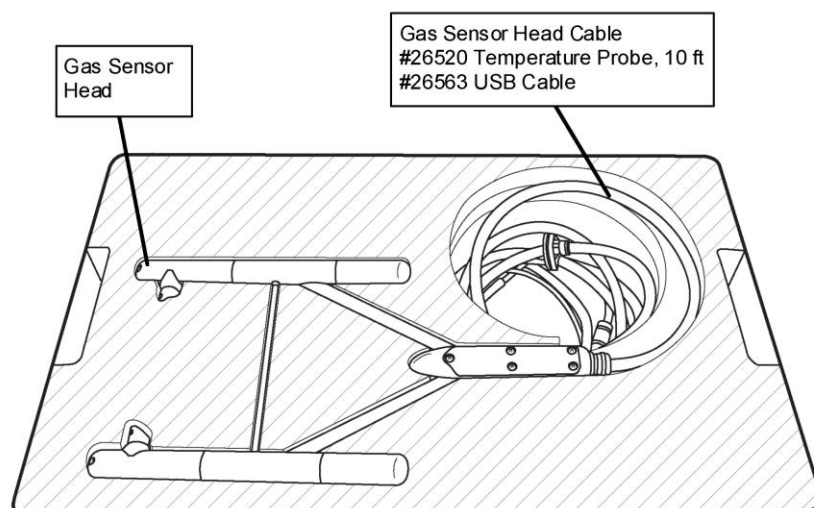


FIGURE 1. Foam Cutout and Components in Upper Level of Packaging

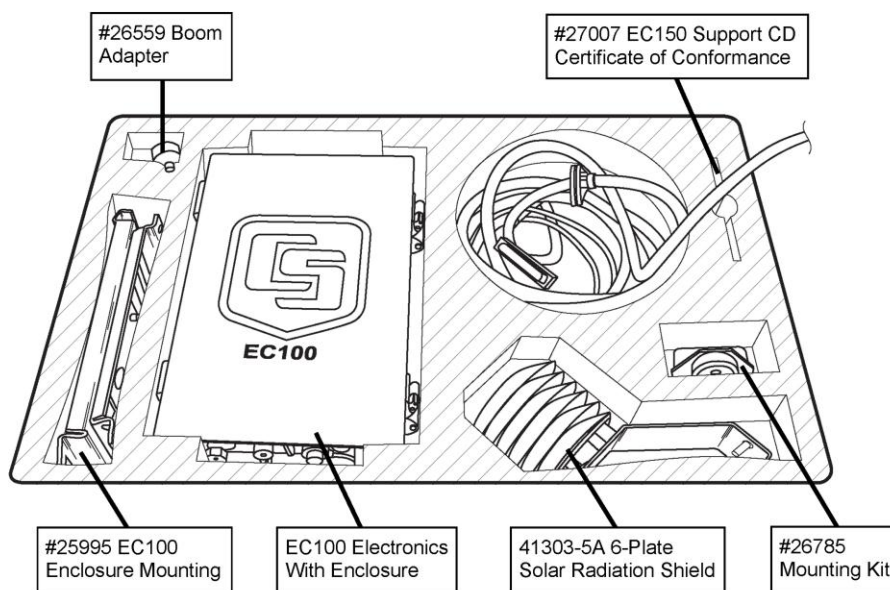


FIGURE 2. Foam Cutout and Components in Lower Level of Packaging



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## D.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.

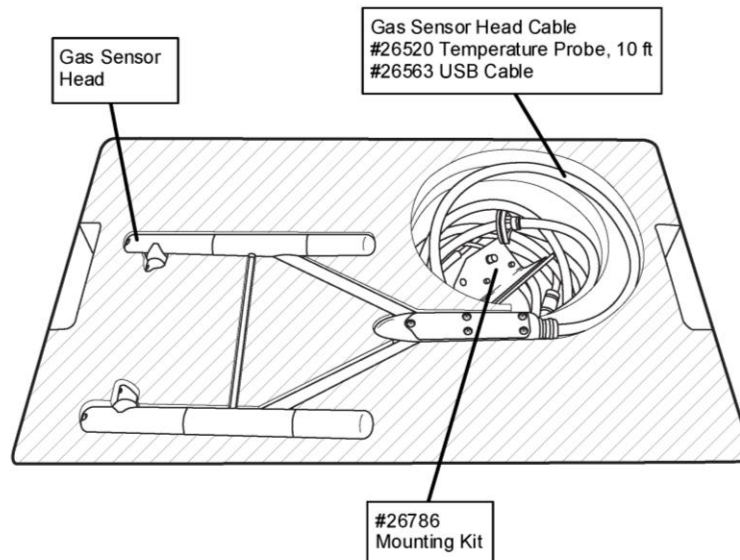


FIGURE 1. Foam Cutout and Components in Upper Level of Packaging

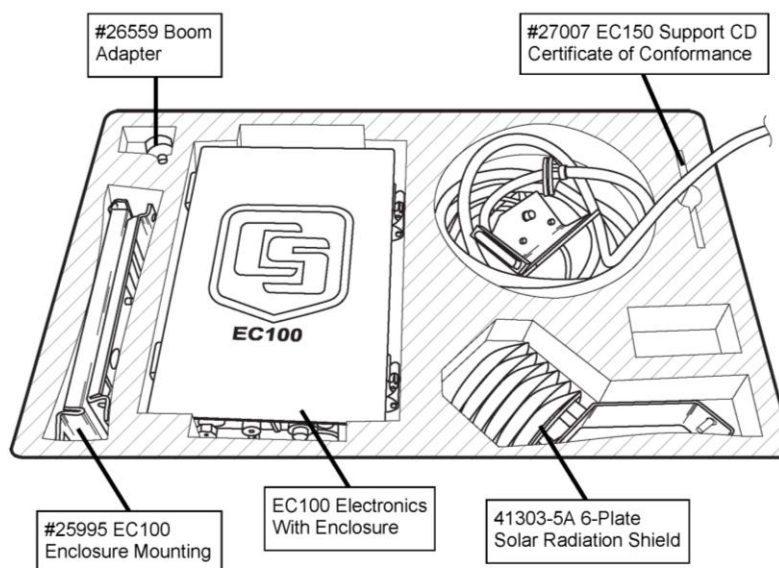


FIGURE 2. Foam Cutout and Components in Lower Level of Packaging



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