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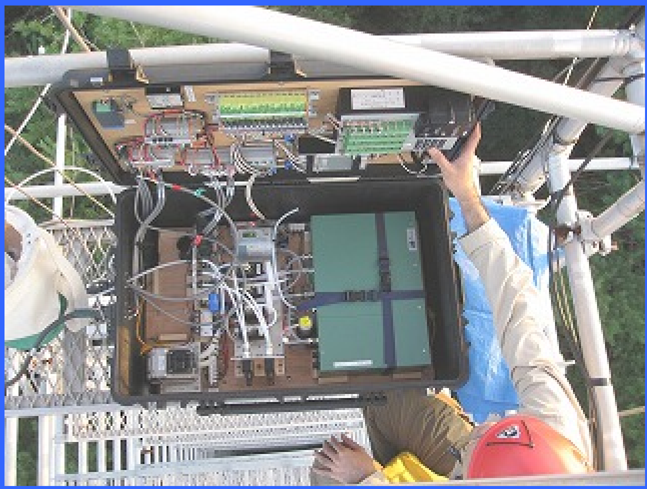


Portable Flux Observation System User Manual

Forestry and Forest Products Research Institute
Flux Observation Network Edition

森林総合研究所　第2期中期計画成果26（温暖化対策－3）

Contents

1. Overview

As a reference system for tower flux observations, a portable flux observation system which can perform sensible heat, water vapor, and CO_2 flux measurements with the eddy-covariance method was developed. The inter-site comparison of tower flux data collected by a variety of measurement systems becomes simplified with the use of this portable flux observation system as a reference device. Furthermore, because the portable flux observation system was designed on the assumption that it would be used for short-term observations, the configuration of the system is simple, and the principles of operation are easy to understand. Therefore, the portable flux observation system may serve as a barebones model of a flux observation system for researchers who intend to initiate new flux observations.

The portable flux observation system consists of a number of components including a closed-path infrared gas analyzer (LI-7000, LI-COR), an ultrasonic anemo-thermometer (CSAT3, Campbell Scientific), a humidity and temperature sensor (HMP45A, Vaisala), a data logger which allows high-speed data sampling (CR3000, Campbell Scientific), and a flow-path control system to be used for calibrations. The portable flux observation system is stored in a plastic container so that it can be easily carried and deployed. All the equipment within the portable flux observation system can be powered either by 12 V DC or 24 V DC due to the presupposition that the system will be used for inter-site comparative observations within Asia. The DC power required for the operation of the system can normally be obtained by connecting an AC power source to the 100 – 240 V AC input converter included with the system.

Fig. 1 illustrates the flow paths of sampled air and calibration gases through the portable flux observation system. This is a pressurized system in which the atmospheric air drawn in by a pump upstream of the infrared gas analyzer is transported into the analyzer. The sampled air drawn in by the pump (P-1) is introduced into the system from the gas inlet terminal. Subsequently, the sampled air passes through the dust filter (DF-1) and is sent to the mass flow controller (MFC) by way of the solenoid valves (SV-1 and SV-2). After the flow rate is adjusted by the MFC, the sampled air passes through another dust filter (DF-2) and is sent into the sample cell of the infrared gas analyzer. At other times, the zero and span gases for calibration are introduced from the gas inlet terminals into the system, then to the flow meters (FM-1 and FM-2, respectively) and to the solenoid valves (SV-1 and SV-2, respectively). The subsequent flow path is identical to the flow path for the sampled air. Regarding the infrared gas analyzer, air from which water vapor and CO_2 have been chemically removed is circulated through the reference cell of the analyzer.

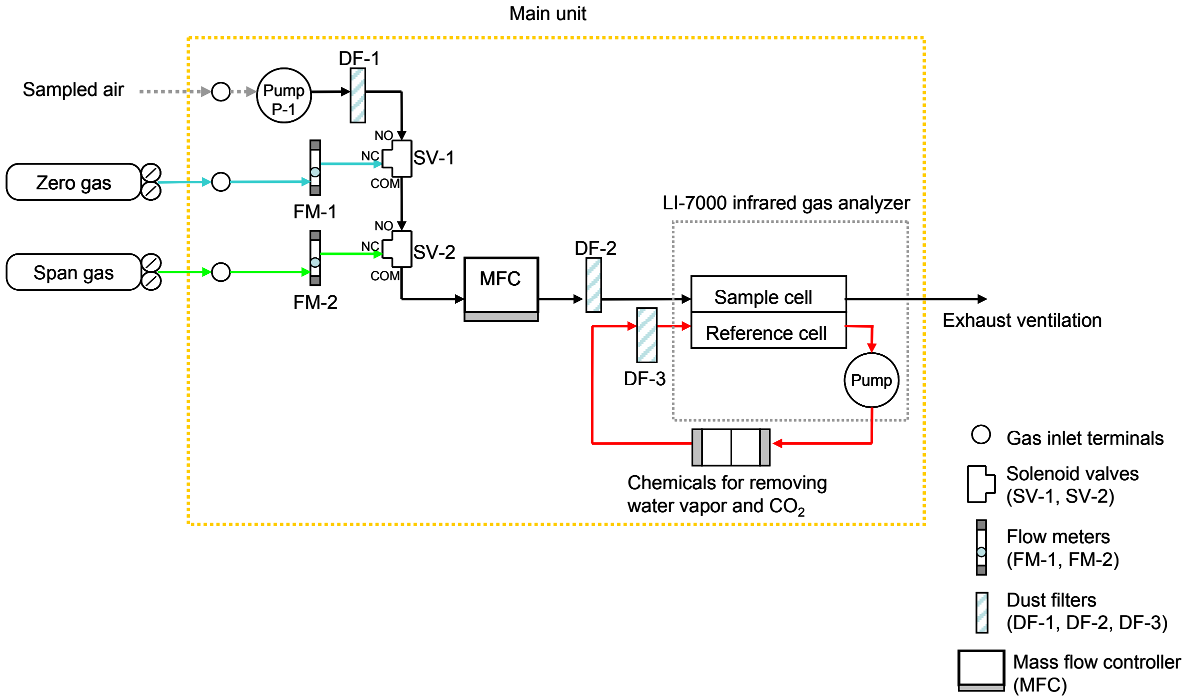


Fig. 1 Flow of sampled air and calibration gases

Fluid flow is directed by the three-way solenoid valves (SV-1 and SV-2).

NO (Normally Open): port which is open when power is off

NC (Normally Closed): port which is closed when power is off

COM (Common): common port which is always open

2. System Details

2.1 Components and Accessories

The portable flux observation system consists of a number of components including 1) the main unit which includes an infrared gas analyzer and a data logger, 2) a power supply unit, 3) an ultrasonic anemo-thermometer, and 4) a thermo-hygrometer. The major system components and accessories are summarized in Table 1. In addition to the components listed here, use of the system requires calibration gases (zero and span gases), regulators for compressed gas cylinder, a flat-bladed screwdriver (e.g., 8125 Flat-bladed screwdriver, Campbell Scientific) for connecting wires, and an adjustable wrench (or a screw wrench) for installing the regulators on the calibration gas cylinders. The numbers (①~⑪) in the table correspond to the numbers in Photo 1. For the details of other parts and components, refer to Appendix A6 “Parts and Components List” (→pg. 26).

Table 1 Major system components and accessories

①Main unit	Infrared gas analyzer (LI-7000)
	Data logger (CR3000)
	Barometer
	Mass flow controller
	Pump
	Flow-path control system
②Power supply unit	Switching power supplies (12 V, 24 V) ③Power cable
Ultrasonic anemo-thermometer (CSAT3)	④Sensor head (probe and electronics box)
	⑤Mounting hardware*
	⑥Signal/power cable
Humidity and temperature sensor	Sensor (HMP45A)
	⑦Ventilation shield
	⑧Signal extension cable
⑨Air sampling inlet	
⑩Tubes	8-6 tube: outer diameter – 8 mm; inner diameter – 6 mm
	6-4 tube: outer diameter – 6 mm; inner diameter – 4 mm
⑪Compact flash card (CF card)	

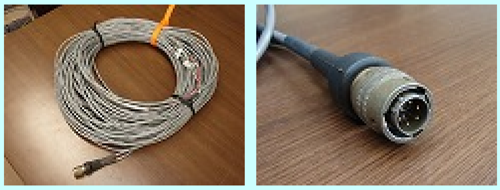
* The CSAT3 can be mounted on pipes with diameters of 48.5 ~ 50.5 mm with the included mounting hardware. If the diameter of the pipe to be used for mounting is outside this range, mounting equipment other than the one included will be required.

①Main unit

②Power supply unit

③Power cable

Upper left: CSAT3 storage case
Upper right: ④sensor head
Lower: ⑤CSAT3 mounting hardware



Left: ⑥Signal/power cable for CSAT3
Right: Connector on the CSAT3 end

⑦HMP45A installed in a ventilation shield

⑧Connectors for the signal cable for the HMP45A
(left: female connector on the extension cable,
right: male connector on the sensor cable)

⑨Air sampling inlet

⑩Tubes (8-6 tube and 6-4 tube)

⑪ Compact flash card (CF card)

Photo 1 Components and accessories for the portable flux observation system

2.2 Names of Individual Components

The names of the individual components installed in the main unit and the power supply unit are shown in Figs. 2 - 4.

Upper Part of the Main Unit

The upper part of the main unit is equipped with a data logger (CR3000), a relay unit for switching solenoid valves, a barometer, and relay terminal blocks.

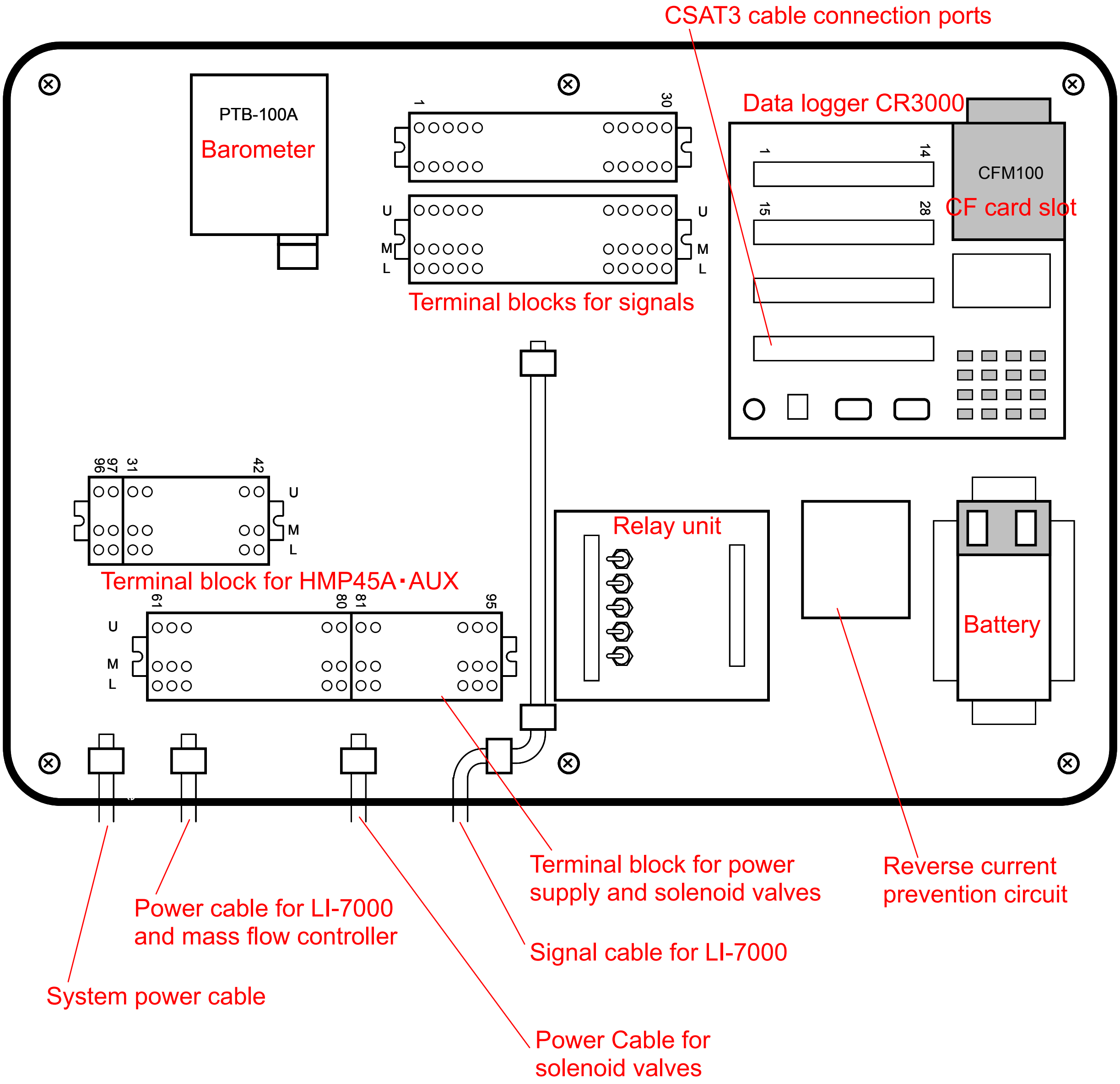


Fig. 2 Schematic layout of the components installed in the upper part of the main unit

Lower Part of the Main Unit

The lower part of the main unit is equipped with an infrared gas analyzer (LI-7000), a suction pump for air sampling, solenoid valves for flow-path control, gas inlets, and a mass flow controller.

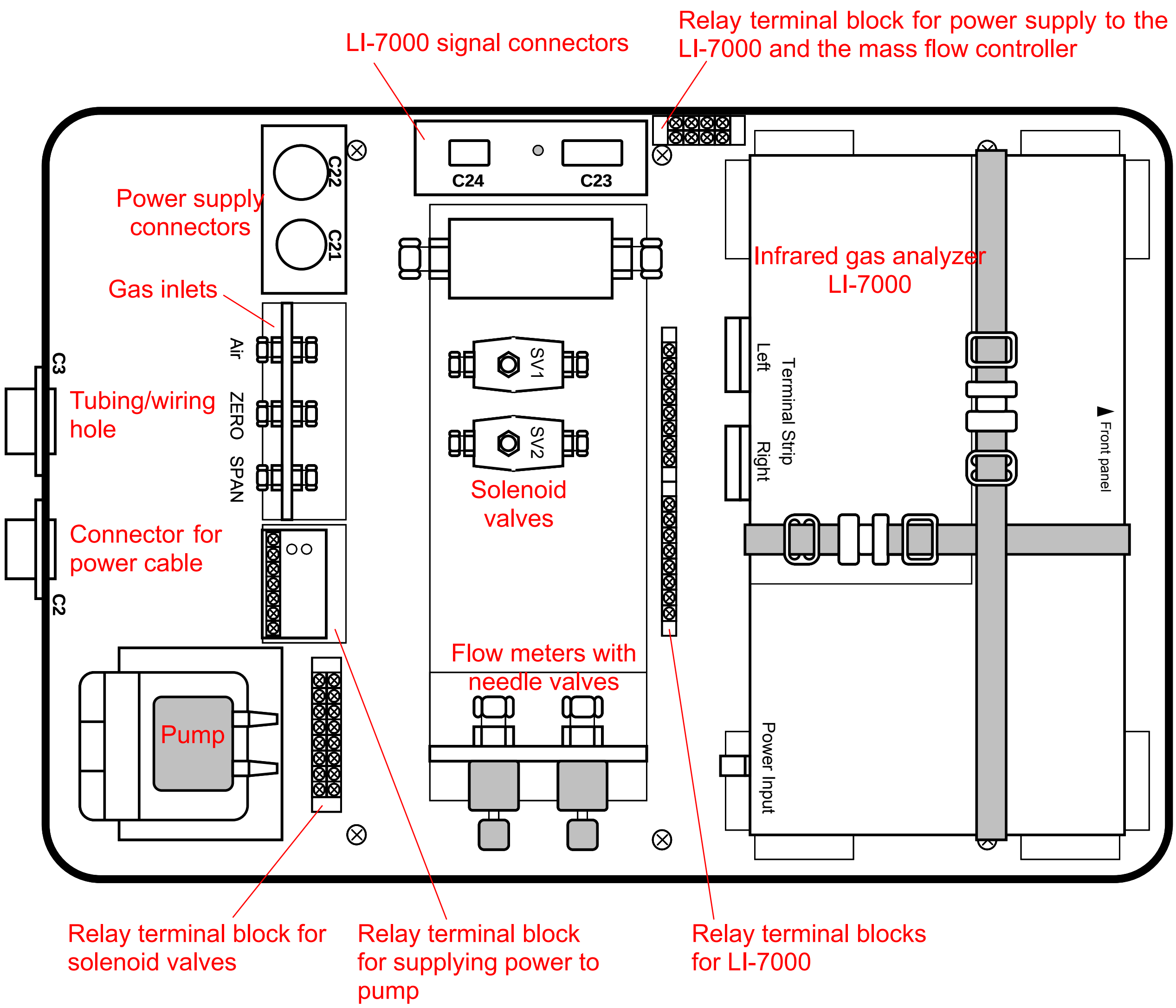


Fig. 3 Schematic layout of the components installed in the lower part of the main unit

Power Supply Unit

The power supply unit supplies power to the main unit after converting the 100 – 240 V commercial power supply into 12 V or 24 V DC.

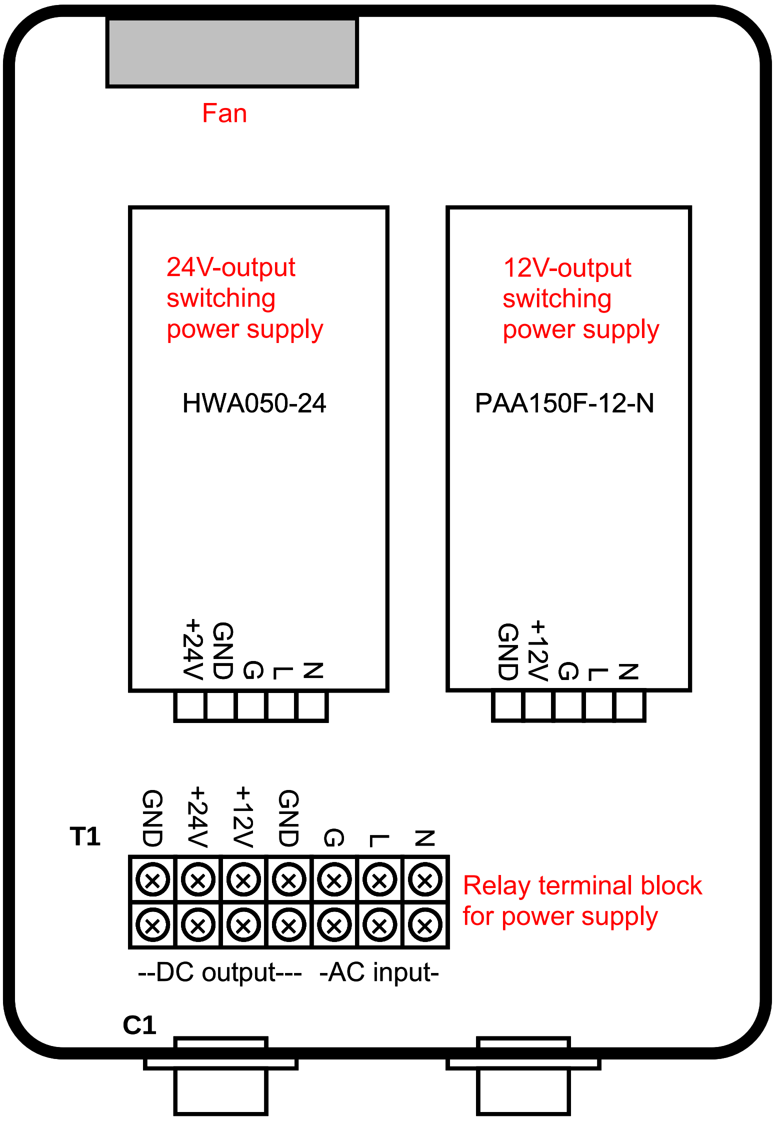


Fig. 4 Schematic layout of the components installed in the power supply unit

2.3 Settings of Individual Components

The settings for the individual components of the portable flux observation system are shown below. Note that all the components except for the flow-path control system are pre-set, thus, modifications to the settings are required only for the flow-path control system.

Flow-Path Control System

Table 2 shows the relay unit settings which are used for manually controlling the solenoid valves and the associated pump.

> **CAUTION**
> When introducing calibration gas (setting either OUT channel 1 or OUT channel 2 to "on"), make sure that OUT channel 5 is set to "off" and the pump is turned off. When controlling the flow-path via communication from the CR3000, make sure to set all the OUT channels to "off."

Table 2 Relay unit settings

OUT channel number		1	2	3	4	5
Device to be controlled		Solenoid valve 1 (SV-1)	Solenoid valve 2 (SV-2)	-	-	Pump
Channel setting for gas of interest	Sampled air	OFF	OFF	OFF	OFF	ON
	Zero gas	ON	OFF	OFF	OFF	OFF
	Span gas	OFF	ON	OFF	OFF	OFF

Mass Flow Controller

Set the mass flow controller to "control mode." Refer to Appendix A1 "Method for Checking the Mass Flow Controller Settings" (→pg. 19) for checking and modifying the controlled flow rate.

Table 3 Settings and range of analog output values for the mass flow controller

Variable to be measured	Target flow rate	Range of possible flow rate settings	Corresponding voltage
Flow rate	8.4 L min^{-1}	0 ~ 20 L min^{-1}	0-5 V

Infrared Gas Analyzer（LI-7000）

The infrared gas analyzer LI-7000 records analog output from the measuring sensors. Set the analog output ranges to the default values below.

Table 4 Ranges of analog output values from the LI-7000

Variable to be measured	Range of variable to be measured	Corresponding voltage	Output channel
Water vapor concentration	–10 ~ 40 mmol mol $^{-1}$	0-5 V	DAC1
CO_2 concentration	–100 ~ 900 ppm	0-5 V	DAC2
Temperature in the cell	0 ~ 100 °C	0-5 V	DAC3
Pressure in the cell	70 ~ 120 kPa	0-5 V	DAC4

Ultrasonic Anemo-Thermometer（CSAT3）

The ultrasonic anemo-thermometer CSAT3 outputs data in digital form for recording. Use the default setting “AutoRanging” for the output reporting range.

Barometer (PTB-100A) and Humidity and Temperature Sensor (HMP45A)

The settings for analog output value ranges from the barometer and the humidity and temperature sensor are given in Table 5.

Table 5 Settings of analog output value ranges from the barometer and the humidity and temperature sensor

Variable to be measured	Measuring sensor	Range of physical quantity	Corresponding voltage
Pressure within the main unit	Barometer (PTB-100A)	800 ~ 1060 hPa	0-5 V
Air temperature	Humidity and temperature sensor (HMP45A)	-40 ~ 60 °C	0-1 V
Relative humidity	Humidity and temperature sensor (HMP45A)	0 ~ 100 %	0-1 V

Data Logger（CR3000）

Channel settings for the data logger are given in Table 6.

Table 6 Data logger channel settings

Channel	Input signal（A: analog, D: digital）or channel use	Recording range
1	Unused	-
2	Unused	-
3	Unused	-
4	Unused	-
5	LI-7000 Water vapor concentration (A)	-5~+5 V
6	LI-7000 CO_2 concentration (A)	-5~+5 V
7	LI-7000 Temperature in the cell (A)	-5~+5 V
8	LI-7000 Pressure in the cell (A)	-5~+5 V
9	PTB-100A Air pressure in the main unit (A)	-5~+5 V
10	HMP45A Air temperature(A)	-5~+5 V
11	HMP45A Relative humidity (A)	-5~+5 V
12	Flow rate (A)	-5~+5 V
13	Unused	-
14	Unused	-
C1	Solenoid valve port 1 setting (D)	-
C2	Solenoid valve port 2 setting (D)	-
C3	Solenoid valve port 3 setting (D)	-
C4	Solenoid valve port 4 setting (D)	-
C5	Solenoid valve port 5 setting (D)	-
C6	Unused	-
C7	Unused	-
C8	Unused	-
12V	Voltage supply for sensors	-
G	Shield, power source ground, signal ground	-
SDM-C1	CSAT3 SDM data (D)	-
SDM-C2	CSAT3 SDM clock (D)	-
SDM-C3	CSAT3 SDM enable (D)	-

3. Observation Procedure

3.1 Advance Preparation

Advance preparation needs to be performed at least 24 hours before the initiation of the observation.

Changing Chemicals in the LI-7000

In order to change the chemicals in the chemical bottles on the back panel of the LI-7000 within the main unit, remove the bottles from the back panel. Replace the magnesium perchlorate and CO_2 absorbent (sodium hydroxide coated non-fibrous silicate; trade name: ASCARITE II) in the bottles with fresh chemicals.

Furthermore, check the record of chemical use and replace the chemicals in the bottles approximately once a year.

Photo 2 Chemical bottle on the back panel of an LI-7000

Photo 3 Chemicals used during LI-7000 operation

Left: ASCARITE II
Center: Magnesium perchlorate
Right: A chemical bottle which has been removed from an LI-7000

Circulating Air through the LI-7000 Reference Cell

First, apply current to the main unit by connecting it to the power supply unit with a power cable. While current is being applied, the green light on the switching power supply in the power supply unit and the indicator on the mass flow controller in the main unit will be on.

Subsequently, power up the LI-7000 and circulate air through the reference cell for 24 hours or longer to remove CO_2 and water vapor from the cell.

Calibrating the LI-7000

If calibration gas cylinders such as zero-gas and span-gas cylinders cannot be provided at the observation site, the LI-7000 needs to be calibrated before the portable flux observation system is transported to the site. Refer to the following section, Section 3.2 “Calibration Procedure” for details.

Charging the Battery of the CR3000

Charge the battery of the CR3000 as necessary.

3.2 Calibration Procedure

For the calibration of the LI-7000, use the LI-7000 software which is distributed on the LI-COR website:
http://www.licor.com/env/products/gas_analyzers/LI-7000/LI-7000_software.jsp

Preparing the Calibration Gas Cylinders

① Attach a regulator to each of the calibration gas cylinders, i.e., the zero- and span-gas (air balance) cylinders.

Connecting the LI-7000 to a PC and Starting the LI-7000 Software

② Connect the LI-7000 to a PC with a USB cable.

③ Power up the LI-7000.

④ Start the LI-7000 software on the PC.

Performing Zero Calibration

⑤ Connect the regulator for the zero-gas cylinder to the gas inlet, ZERO GAS terminal, located in the lower part of the main unit, using a 6-4 tube (outer diameter: 6mm, inner diameter: 4mm).

> **CAUTION**
> Open the cylinder valve a little and use the regulator to adjust the secondary pressure of the zero gas to a sufficiently low value (approx. 0.05 MPa) so that excess loading on the tubing system can be avoided.

Photo 4 Settings for relay unit. (Only OUT channel 1 is on.)

⑥ Set only OUT Channel 1 on the relay unit to "on" (refer to Photo 4).

⑦ Use the needle valve on the flow meter to adjust the flow rate to approximately 1.0 L min^{-1} while checking the display on the mass flow controller (refer to Photos 5 and 6).

⑧ Perform zero calibration after the concentration reading from the LI-7000 software stabilizes, which usually takes approximately 5 minutes after the initiation of the gas flow. For the software operating procedure relevant for this step, refer to Appendix A2 "LI-7000 Software Operating Procedure: Performing Zero Calibration" (→pg. 20).


Photo 5 Mass flow controller

Photo 6 Flow meters with needle valves (○ needle valves)

Performing Span Calibration

⑨ Connect the regulator for the span-gas cylinder to the gas inlet, SPAN GAS terminal, located in the lower part of the main unit, using a 6-4 tube.

> **CAUTION**
> Open the cylinder valve a little and use the regulator to adjust the secondary pressure of the zero gas to a sufficiently low value (approx. 0.05 MPa) so that excess loading on the tubing system can be avoided.

⑩ Set only OUT Channel 2 on the relay unit to "on".

⑪ Use the needle valve on the flow meter to adjust the flow rate to approximately 1.0 L min^{-1} while checking the display on the mass flow controller (refer to Photos 5 and 6).

⑫ Perform span calibration after the concentration reading from the LI-7000 software stabilizes, which usually takes approximately 5 minutes after the initiation of gas flow. For the software operating procedure relevant for this step, refer to Appendix A2 "LI-7000 Software Operating Procedure: Performing Span Calibration" (→pg. 20).

Ending Calibration

⑬ Exit the LI-7000 software. For the software operating procedure relevant for this step, refer to Appendix A2 "LI-7000 Software Operating Procedure: Shutting Down the Software" (→pg. 20).

⑭ Set all the OUT channels on the relay unit back to "off."

⑮ Close all regulator valves before removing the tubes.

3.3 Instrument Deployment and Connection Procedure

Tubes and cables are to be arranged as described in the following procedure. Tubing and cabling layouts are shown in Fig. 5 (→ pg. 15).

Photo 7 Example of air sampling inlet deployment

Deploying the Instruments

① Deploy the ultrasonic anemo-thermometer (CSAT3). For the probe coordinate system, refer to Appendix A3 "CSAT3 Probe Coordinate System" (→pg. 21).

② Install the air sampling inlet near a CSAT3 arm (refer to Photo 7) and connect an 8-6 tube (outer diameter: 8 mm, inner diameter: 6 mm) to the air sampling inlet.

③ Deploy the humidity and temperature sensor (HMP45A) at the same height as the CSAT3 probe.

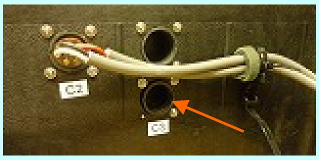


Photo 8 Tubing/wiring hole viewed from inside the main unit (←tubing/wiring hole)

Wiring Signal Cables and Installing the Air Sampling Inlet Tube

④ Insert the CSAT3 cable through the tubing/wiring hole in the main unit and connect the cable to the lowest row of terminals on the data logger (CR3000) (refer to Photo 8 and Table 7 on the next page).

⑤ Insert the tube (8-6 tube) connected to the air sampling inlet through the tubing/wiring hole in the main unit and connect the tube to the tube diameter conversion adapter attached to the Air terminal at the gas inlets (refer to Photo 9).

⑥ Insert the HPM45A signal cable through the tubing/wiring hole in the main unit. Connect the humidity and temperature sensor to the HMP45·AUX terminal block using the signal cable (refer to Table 8 on the next page).

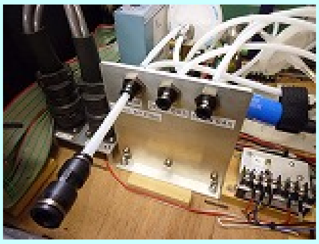


Photo 9 Gas inlets

A tube diameter conversion adaptor is attached to the Air terminal on the left.

Connecting Calibration Gas Tubes (for the Case of Automated Calibration)

⑦ If automated calibration is performed during the observation, insert the tubes for the calibration gases (zero and span gases) through the tubing/wiring hole in the main unit and connect the tubes to the ZERO GAS and SPAN GAS terminals at the gas inlets.

Starting Up the System

⑧ Connect the main and power supply units with a power cable.

⑨ Start the portable flux observation system after connecting the power supply unit cable to the power source.

Table 7 CSAT3 cable connection points
(The lowest row of CR3000 terminals)

	Cable color	Terminal label
Power cable	red	12V
	black	G
	transparent	G
Signal cable	green	SDM1
	white	SDM2
	brown	SDM3
	black	G
	transparent	G

Table 8 HMP45A signal cable connection points
(HMP45A･AUX terminal block)

Cable color	Terminal label
red	Ta+
-	(Ta- and Rh- are combined)
brown	Rh+
yellow	Rh-
blue	Pw +V
orange	Pw GND
white	FAN +V
black	FAN GND

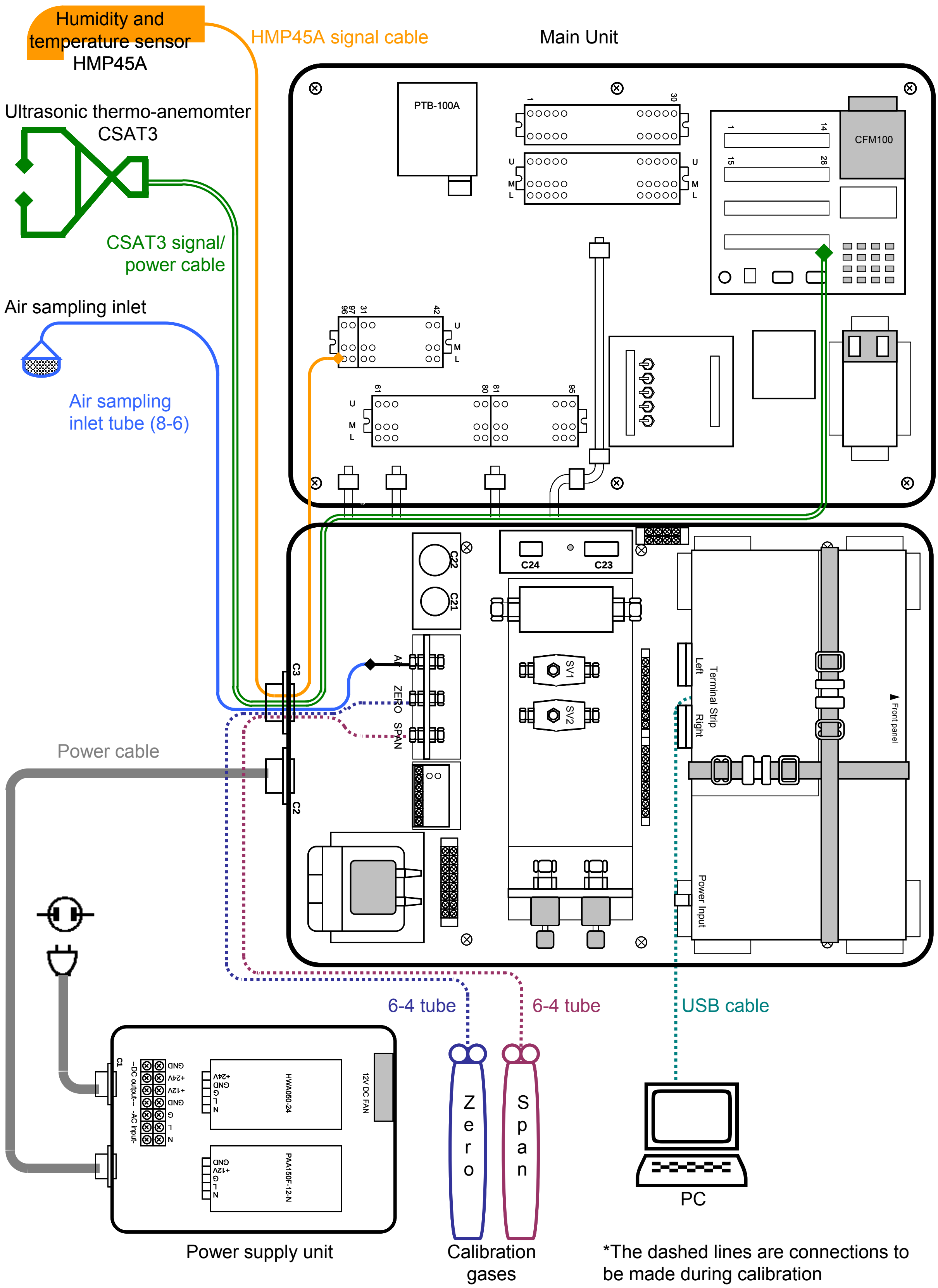


Fig. 5 Schematic of tubing and cabling layouts

3.4 Data Recording Procedure

① Perform calibration prior to the initiation of the measurements. For details, refer to Section 3.2 "Calibration Procedure" (→ pg. 11).

② Make sure that all the OUT channels on the relay unit are set to "off."

③ Connect the CR3000 power connector to the CR3000 data logger to turn on the data logger (refer to Photo 10).

④ Insert the CF card into the card slot (CF card module) on the CR3000 data logger.

⑤ When comparative flux observations are performed, check the clock on the CR3000 and set it so that it matches the time on the observation system to be compared against.

Photo 10 CR3000 power connector

⑥ Using the control panel, check to make sure that "Run on Power Up" (for automated recovery after a power outage) and "Run Now" on the CR3000 are activated. Subsequently, execute the control program to start data recording. For the operating procedure relevant for this step, refer to Appendix A4 "CR3000 Operating Procedure: Program Execution Procedure" (→pg. 22). The source code for the control program is shown in Appendix A5 "CR3000 Control Program" (→pg. 23).

⑦ During continuous observations, deploy the main unit in the shade and keep the cover closed to avoid increased temperatures in the interior of the system. (If the main unit is deployed indoors, the cover of the main unit can be left open for heat release.)

3.5 Ending Procedure

① Press the white removal button on the CF card module and wait for the status LED to turn from red to green. Within the subsequent 20 seconds, open up the cover of the CF card module and remove the CF card (refer to Photo 11).

Photo 11 Removal button (→) and status LED (→)

CAUTION

If the user continues on to the next step in the ending procedure without removing the CF card, the recorded data will not be saved, thus, caution is necessary.

② After confirming the removal of the CF card, shut down the CR3000 using the control panel. For this procedure, refer to Appendix A4 "CR3000 Operating Procedure: Program Termination Procedure" (→pg. 22).

③ Power down the portable flux observation system by unplugging the CR3000 power connector and the power supply unit.

4. System Specifications

4.1 Dimensions and Weights

Table 7 Dimensions and weights of system components

	Dimensions	Weight
Main unit	W826 × H521 × D287 mm	37.66 kg
Power supply unit	W371 × H258 × D152 mm	6.70 kg
Power cable	L5.4 m	1.56 kg
CSAT3 carrying case (including the sensor head)	W700 × H680 × D320 mm	16.47 kg
CSAT3 signal/power cable	L50 m × 2 cables	3.67 kg
Ventilated shield (HMP45A, including mounting hardware)	W760 × H220 × D220 mm	3.77 kg
HMP45A signal cable	L50 m	5.49 kg
6-4 tube (outer diameter: 6 mm, inner diameter: 4 mm)	L15 m × 2 tubes	0.67 kg
8-6 tube (outer diameter: 8 mm, inner diameter: 6mm)	L40 m	1.99 kg
Total weight		Approx. 78 kg

4.2 Current Consumption

Table 8 Current consumption of the system components

		Current consumption	Supply voltage
Main unit	Infrared gas analyzer LI-7000 (LI-COR)	4A max.	DC10.5-16 V
	Pump MVP03V12BA2 (Panasonic)	2.5A	DC8-15 V
	Mass flow controller CMQ0020 (Yamatake)	300mA max.	DC15-24 V
	Solenoid valve AG31-02-2 (CKD) *main unit is equipped with two solenoid valves	920mA (per valve)	DC12 V
	Data logger CR3000 (Campbell Scientific)	10mA	DC10-16 V
	Barometer PTB-100A (Vaisala)	4mA max.	DC10-30 V
	Ultrasonic anemo-thermometer CSAT3 (Campbell Scientific)	200mA	DC10-16 V
Ventilation shield	Humidity and temperature sensor HMP45A (Vaisala)	4mA max.	DC7-35 V
	Fan RD804A (Prince Fan)	170mA	DC12 V
	Total current consumption	9A max.	

References Cited

LI-COR, "LI-7000 CO_2/H_2O Analyzer Instruction Manual",
ftp://ftp.licor.com/perm/env/LI-7000/Manual/LI-7000Manual.pdf

Campbell Scientific, Inc., "CR3000 Micrologger Operator's Manual", Revision 5/10,
http://www.campbellsci.com/documents/manuals/cr3000.pdf

Campbell Scientific, Inc., "CSAT3 Three Dimensional Sonic Anemometer Instruction Manual", Revision: 6/10,
http://www.campbellsci.com/documents/manuals/csat3.pdf

Further Reading

Editorial Board of Practical Handbook of Tower Flux Observation: "Practical Handbook of Tower Flux Observation"
http://www2.ffpri.affrc.go.jp/labs/flux/manual/manual_index_e.html

OHTANI Yoshikazu, MIZOGUCHI Yasuko, TAKANASHI Satoru, YASUDA Yukio, IWATA Hiroki, NAKAI Yuichiro, YUTA Satoko, YAMANOI Katsumi (2010): Development of a portable CO_2 flux observation system using a closed-path gas analyzer for intercomparison. Bulletin of the Forestry and Forest Products Research Institute, 9(1):31-36, http://www.ffpri.affrc.go.jp/pubs/bulletin/414/documents/414-3.pdf

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Appendices

A1 Method for Checking the Mass Flow Controller Settings

Checking the Operating Mode

If the operating mode of the mass flow controller is properly set to “control mode”, the OK light on the upper surface of the mass flow controller will be on. If the OK light is off, the flow rate is not yet stable. In this case, wait for a while and confirm that the light has turned on. (If the OK light is blinking or the seven-segment display shows “off,” refer to the instruction manual for the mass flow controller and reset the operating mode.)

Checking the Controlled Flow Rate

When the [DISP] button on the upper surface of the mass flow controller is pressed, the SP light will turn on and the current setting of the controlled flow rate will be displayed. To modify the controlled flow rate, press either the [▵] or [▿] button to change the numerical value and then press the [ENT] button. This procedure needs to be performed while the SP light is on.

For the details of operating the mass flow controller, refer to the instruction manuals for the digital mass flow controller CMQ series manufactured by Yamatake Corporation. The manuals which can currently be viewed online are those for the succeeding models in the “digital mass flow controller CMQ-V series,” however, the procedures for checking the operating mode and for checking and modifying the controlled flow rate are the same as those for the CMQ series.

http://www.compoclub.com/products/recommend/mf/mf_mqv1.html

(the instruction manuals are available in Japanese only).

A2 LI-7000 Software Operating Procedure

Performing Zero Calibration

① [LI-7000] main window: from the [Remote] menu, select [Connect].

② [Connect to LI-7000] dialogue: click on the USB tab (confirm that SN:IRG4-0517 is displayed). Select [Use Instrument Configuration] and click the [Connect] button.

③ [LI-7000] main window: the measured values are displayed.

④ [LI-7000] main window: from the [Remote] menu, select [User Calibration].

⑤ [User Calibration] dialogue: first, perform H_2O calibration. From the [H2O Action] drop-down menu, select [Make cell B match cell A] and click the [Do H2O Cal] button.

⑥ [User Calibration] dialogue: next, perform CO_2 calibration. From the [CO2 Action] drop-down menu, select [Make cell B match cell A] and click the [Do CO2 Cal] button.

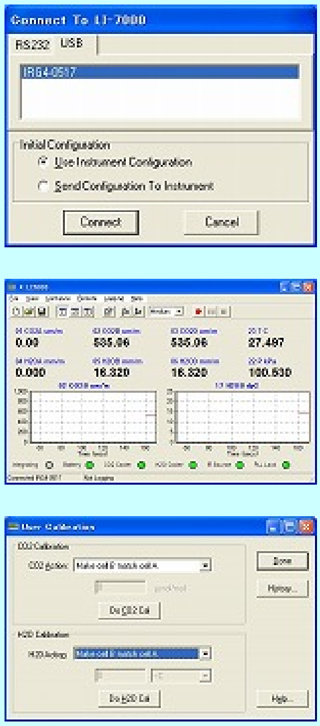

Fig. A1 LI-7000 software windows (zero calibration)

Performing Span Calibration

①~④ Same as for zero calibration

⑤ [User Calibration] dialogue: perform CO_2 calibration. From the [CO2 Action] drop-down menu, select [Make cell B read…], enter the reference concentration, and click the [Do CO2 Cal] button.

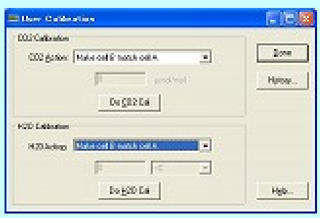

Fig. A2 LI-7000 software window (span calibration)

Shutting Down the Software

① [LI-7000] main window: from the [Remote] menu, select [Disconnect].

② [LI-7000] main window: from the [File] menu, select [Exit].

For details, refer to the LI-7000 Instruction Manual.

(ftp://ftp.licor.com/perm/env/LI-7000/Manual/LI-7000Manual.pdf)

A3 CSAT3 Probe Coordinate System

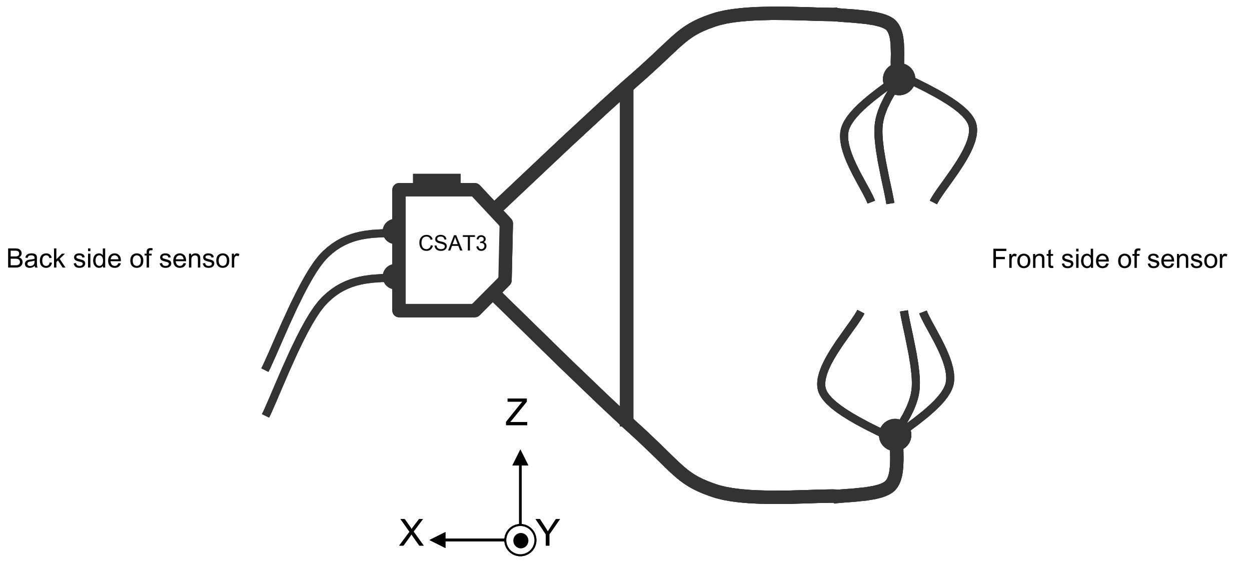

Fig. A3 CSAT3 probe coordinate system

The arrows in the figure show the directions of wind vectors. For the X-axis, a positive value is output for wind which flows from the front side of the sensor (the right side in the figure above) toward the sensor. For the Y-axis, a positive value is output for wind which flows from left to right when the front side of the sensor is viewed from the back side of the sensor, i.e. from the back of the page to the front of the page in the figure above. For the Z-axis, a positive value is output for wind which flows upward in the vertical direction.

A4 CR3000 Operating Procedure

Program Execution Procedure

① Make sure that no programs are being executed on the CR3000. Display the main menu by pressing any button other than [◃], [▹], [▵], or [ESC].

② Move the cursor to [Run/Stop Program] by pressing either the [▵] or [▿] button, and display the program list by pressing the [Enter] button.

③ Select the name of the program to be executed (the name of the program loaded on the present flux observation system is “PORTABLE_CSAT3SDM.CR”) by pressing either the [▵] or [▿] button. Press the [Enter] button. The option menu will now be displayed.

④ Select the [Run on Power Up] option by pressing either the [▵] or [▿] button, and press the [Enter] button to display a * to the left of this option name (with this operation, the selected option becomes activated). Repeat the procedure to activate the [Run Now] option.

Fig. A4 Control panel on the CR3000

⑤ Move the cursor to [Execute] which is located at the bottom of the list, and press the [Enter] button.

⑥ When the message confirming the intention to execute the program is displayed, execute the program by selecting [Yes] and pressing the [Enter] button.

Program Termination Procedure

① While a program is being executed on the CR3000, display the main menu by pressing any button on the control panel other than [◃], [▹], [▵], or [ESC].

② Move the cursor to [Run/Stop Program] by pressing either the [▵] or [▿] button. Press the [Enter] button. The option menu will now be displayed.

③ Select the [Stop, Retain Data] option by pressing either the [▵] or [▿] button, and press the [Enter] button to display a * to the left of this option name (with this operation, the selected option becomes activated).

④ Move the cursor to [Execute] which is located at the bottom of the list, and press the [Enter] button.

⑤ When the message confirming the intention to terminate the program is displayed, terminate the program by selecting [Yes] and pressing the [Enter] button.

For details of operating the CR3000, refer to the CR3000 Operator’s Manual.
(http://www.campbellsci.com/documents/manuals/cr3000.pdf)

A5 CR3000 Control Program

The program loaded on the present flux observation system, PORTABLE_CSAT3SDM.CR, controls the following three processes.

1. Sampling and recording data at 10 Hz.
2. Performing switchover of the solenoid valves and the pump for introducing calibration gases at the following times each day.
   23:39 Stop the measurements (turn off the pump)
   23:40 Introduce the zero gas
   23:45 Turn off the zero gas and introduce the span gas
   23:50 Turn off the span gas and turn on the pump
3. Outputting data to the memory card and writing reference data (physical quantities) to the internal memory (for checking the real-time data)

Output to Memory Card

Table A1 Data output to memory card

Column	Output data	Unit	Form of output
1	X-direction wind speed, X	m s $^{-1}$	Physical quantities
2	Y-direction wind speed, Y	m s $^{-1}$	
3	Z-direction wind speed, Z	m s $^{-1}$	
4	Air temperature, T (CSAT3 measurement value)	°C	
5	Water vapor concentration, H2O	mV	Analog voltage values (0~5 V max.)
6	CO_2 concentration, CO2	mV	
7	Temperature in the cell, Ti	mV	
8	Pressure in the cell, Pi	mV	
9	Air pressure in the main unit, Pa	mV	
10	Air temperature, Ta	mV	
11	Relative humidity, RH	mV	
12	Flow rate, Flow	mV	
13-14	Unused		

Source Code of the Program

```
'CR3000 Series Datalogger with CSAT3-SDM
'date: 2010-04-02
'program author: Takanashi, S. (For. Met. Lab., FFPRI)
'Declare Constants
Const StopMeasureMinutes  = 1419                 '23:39
Const StartZeroMinutes    = 1420                 '23:40
Const StartSpanMinutes    = StartZeroMinutes+5    '23:45
Const StartMeasureMinutes = StartSpanMinutes+5    '23:50
Const FileMarkMinutes     = StartMeasureMinutes+5 '23:55
```

```
Const Interval = 100 ' msec
Const DataLapse = 0  ' 0:every blank data will be timestamped
Const DataIntegration = 250 '250, _60Hz, _50Hz
Const VoltRange = mV5000
Const DataMax = 14
Const SDM_PER = 50
'Declare Public Variables
Public Diffch(DataMax)
Public IRGAData(4)
Public SATData(6)
Public TARHData(2)
Public OIRGAData(4)
Public Ptemp
Public Flow
'Define Data Tables
DataTable(FluxData,1,-1)
   DataInterval(0,Interval,msec,DataLapse)
   CardOut(1,-1)'CardOut(0:Ring 1:FillandStop, -1:Auto-allocate n:Size)
   Sample(DataMax,Diffch(1),IEEE4)
   FieldNames("X:m/s,Y:m/s,Z:m/s,T:degC,H2O:mv,CO2:mv,Ti:mv,Pi:mv,Pa:mv,Ta:mv,RH:mv,Flow:mv,AUX2:mv,AUX3:mv")
EndTable
DataTable(IRGA,1,600)
   Sample(4,IRGAData(1),IEEE4)
   FieldNames("H2O:mmol/mol,CO2:ppm,Ti:degC,Pi:kPa")
EndTable
DataTable(SAT,1,600)
   Sample(4,SATData(1),IEEE4)
   FieldNames("X:m/s,Y:m/s,Z:m/s,T:degC")
EndTable
DataTable(VAISALA,1,600)
   Sample(1,Diffch(4),IEEE4)
   FieldNames("SATa_T:degC")
   Sample(1,SATData(4),IEEE4)
   FieldNames("SATd_T:degC")
   Sample(2,TARHData(1),IEEE4)
   FieldNames("HMP45A_T:degC,HMP45A_RH:%")
   Sample(1,Ptemp,IEEE4)
   FieldNames("PTemp:degC")
EndTable
DataTable(Flow,1,600)
   Sample(1,Flow,IEEE4)
   FieldNames("Flow:l/s")
EndTable
'Define Subroutines
Sub ZeroCalibration
   PortSet(1,1)
   PortSet(2,0)
   PortSet(3,1)
   PortSet(4,1)
   PortSet(5,0)
EndSub
Sub SpanCalibration
   PortSet(1,0)
```

```
      PortSet(2,1)
      PortSet(3,1)
      PortSet(4,1)
      PortSet(5,0)
   EndSub
   Sub StartMeasure
      PortSet(1,0)
      PortSet(2,0)
      PortSet(3,0)
      PortSet(4,0)
      PortSet(5,1)
   EndSub
   'Main Program
      BeginProg
      Call StartMeasure
      SDMSpeed (SDM_PER)  'The resolution of the bit period is 1 uSec.
      Scan(Interval,msec,600,0)
        'VoltDiff(Dest,Reps,Range,Diffchan,RevDiff,Settlingtime,Integ,Mult,Offset)
        VoltDiff(Diffch(5),10,VoltRange,5,0,0,DataIntegration,1,0)
        'Set SDM bit period and get data from the CSAT3.
        CSAT3 (SATData(1),1,3,91,60)  'SDM address 3.
        Diffch(1)=SATData(1)
        Diffch(2)=SATData(2)
        Diffch(3)=SATData(3)
        Diffch(4)=SATData(4)
        IRGAData(1)=0.01*Diffch(5)-10
        IRGAData(2)=0.2*Diffch(6)-100
        IRGAData(3)=0.02*Diffch(7)
        IRGAData(4)=0.01*Diffch(8)+70
        TARHData(1)=Diffch(10)*0.1-40
        TARHData(2)=Diffch(11)*0.1
        Flow=Diffch(12)*0.004
        PanelTemp (Ptemp,250)
        If TimeIntoInterval(1320,1440,min) Then Call StartMeasure
        If TimeIntoInterval(StopMeasureMinutes,1440,min) Then Call EndMeasure
        If TimeIntoInterval(StartZeroMinutes,1440,min) Then Call ZeroCalibration
        If TimeIntoInterval(StartSpanMinutes,1440,min) Then Call SpanCalibration
        If TimeIntoInterval(StartMeasureMinutes,1440,min) Then Call StartMeasure
        CallTable IRGA
        CallTable SAT
        CallTable FluxData
        CallTable VAISALA
        CallTable Flow
      NextScan
   EndProg
```

A6 Parts and Components List

Main Unit

1. MASS FLOW CONTROLLER (MFC)	
MFC	CMQ series (YAMATAKE, Japan) CMQ0020BSSN000000. 20 L min^{-1} full scale (FS) (control range :1 to 100% FS) Working voltage: 24 V DC
2. SOLENOID VALVE	
SV-1, SV-2	AG31-02-2-03A-DC12V (CKD, Japan) Working voltage: 12 V DC
3. FLOW METER	
FM-1, FM-2	RK1650 (KOFLOC, Japan) 5 L min^{-1} FS
4. DUST FILTERS	
DF-1	Balston Disposable Air Filter #300-01961 (available from LI-COR, U.S.A)
DF-2, DF-3	Gelman Acro 50, #9967-008 (available from LI-COR, U.S.A) 1.0μm, PTFE
5. ELECTRIC TERMINALS	
	280-681 (terminal) (WAGO, Japan) 280-326 (end plate for 280-681) (WAGO, Japan) 280-907 (common earth terminal) (WAGO, Japan) 280-309 (end plate for 280-907) (WAGO, Japan) 249-116 (end stop) (WAGO, Japan) 209-666 (number plate) (WAGO, Japan) 209-607 (number plate) (WAGO, Japan) DIN Rail (50 cm length, Aluminum) Gap arrester Y08U-75B (Sankosha, Japan)
6. ELECTRIC CONNECTORS	
	8-pin panel mount: female MMS3102A-22-23-S (MISUMI, Japan)
	8-pin straight: male MMS3106B-22-23-P (MISUMI, Japan)
	7-pin panel mount: female MMS3102A-20-15-S (MISUMI, Japan)
	7-pin straight: male MMS3106B-20-15-P (MISUMI, Japan)
	Dust cap NMS25042-20D (MISUMI, Japan)
	Dust cap NMS25043-20D (MISUMI, Japan)
	Cable clamp NMS3057-12A (MISUMI, Japan)

7. TUBE	
	For the pump-filter segment: NRK Unitube (Nippon Rikagaku Kikai) #7SW 7×13
	6-4 tube: polyethylene
	8-6 tube: PTFE
8. TUBE FITTINGS	
	PU6 (straight) (PISCO)
	PG8-6 (straight, different diameters on ends) (PISCO)
	PM6 (bulkhead) (PISCO)
	SS-6M0-1-4RT (straight) (Swagelok)
	SS-6M0-7-4RT (straight) (Swagelok)
	SS-6M0-2-4RT (90deg elbow) (Swagelok)
9. CARRY CASE	
Pelican Box	#1650 (PELICAN, USA)
10. PUMP	
	MVP03V12BA1 (Panasonic, Japan) 30 L min^{-1} Working voltage: 12 V DC

Power Supply Unit

1. SWITCHING POWER SUPPLY	
	PAA150F-12-N (COSEL, Japan) Input: 85 to 264 V AC, Output: 12 V DC 13A Working voltage: 100-240 AC
	HWA050-24 (SANKEN, Japan) Input: 85 to 264 V AC, Output: 24 V DC 2.1A Working voltage: 100-240 AC
2. FAN	
	CF-50SS（ADDA, China） 50 mm, 3700 rpm ± 10 % Working voltage: 12 V DC
3. CARRY CASE	
Pelican Box	#1450 (PELICAN, USA)

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Editors and Authors:

TAKANASHI Satoru, OHTANI Yoshikazu, YUTA Satoko
(Department of Meteorological Environment)

MIZOGUCHI Yasuko, YAMANOI Katsumi
(Hokkaido Research Center)

Forestry and Forest Products Research Institute

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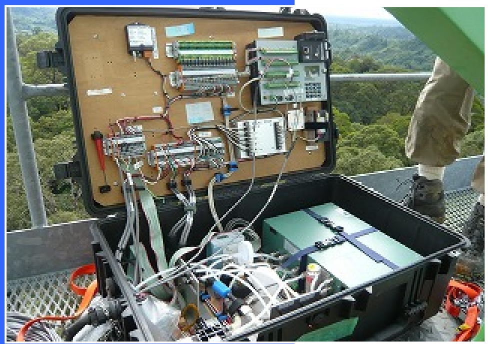
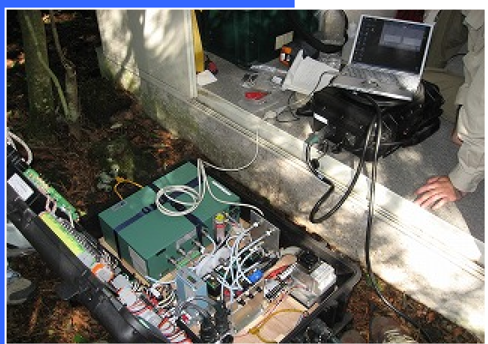
Editing / Publication Hokkaido Research Center
Forestry and Forest Products Research Institute
7 Hitsujigaoka Toyohira-ku, Sapporo 062-8516 Japan
Ph: +81-11-851-4131 Fax: +81-11-851-4167

Reproduction / Printing Digital Print Co. Ltd.
1322-1 Hasunuma, Tsukuba 300-3262 Japan
Ph: +81-29-877-1331 Fax: +81-29-864-6602





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