CIRAS-2
Portable Photosynthesis System
Technical Manual

Version 2.03

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Europe
PP Systems
Unit 2, Glovers Court, Bury Mead Rd.
Hitchin, Hertfordshire SG5 1RT U.K.
Tel: +44 1 462 453 411
Fax: +44 1 462 431 090

North America
PP Systems, Inc.
110 Haverhill Road, Suite 301
Amesbury, MA 01913 U.S.A.
Tel: +1 978 834-0505
Fax: +1 978 834-0545

Email: support@ppsystems.com

Web Site: http://www.ppsystems.com

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Preface

Notice

This equipment must not be used in situations where its failure could result in injury or death.

For applications where failure of this equipment to function correctly would lead to consequential damage, the equipment must be checked for correct operation and calibration at intervals appropriate to the criticality of the situation.

PP Systems' equipment warranty is limited to replacement of defective components, and does not cover injury to persons or property or other consequential damage.

This manual is provided to help you install and operate the equipment. Every effort has been made to ensure that the information contained in this manual is accurate and complete. PP Systems does not accept any liability for losses or damages resulting from the use of this information.

It is extremely important that you take the time to review this Operator's Manual prior to installation and operation of the equipment. Otherwise, damage may be caused which is not covered under our normal warranty policy.

Documentation Conventions

If viewed electronically, text marked blue act as Hyperlinks. Some links refer to links to external files, which may cause the viewer to prompt whether the action should be performed.

User Registration

It is very important that all new customers register with us, to ensure that our user list is kept up to date. If you use any of PP Systems products then please register yourself electronically on our web site at:

http://www.ppsystems.com/Register.html

Only **REGISTERED** users will be allowed access to our protected "Users" section of our web site. This section will contain important product information including hardware/software updates, application notes, newsletters, etc.

Thank you in advance for your co-operation.

Service & Warranty

PP Systems' equipment warranty is limited to replacement of defective components, and does not cover injury to persons or property or other consequential damage.

The equipment is covered under warranty for one complete year, parts and labour included. This, of course, is provided that the equipment is properly installed, operated and maintained in accordance with written instructions (i.e. Operator's Manual).

The warranty excludes all defects in equipment caused by incorrect installation, operation or maintenance, misuse, alteration, and/or accident.

If for some reason, a fault is covered under warranty, it is the responsibility of the customer to return the goods to PP Systems or an authorized agent for repair or replacement of the defective part(s).

Contact Information

Europe
PP Systems
Unit 2, Glovers Court, Bury Mead Rd.
Hitchin, Herts SG5 1RT
UK
Tel: #44-1462-453411
Fax: #44-1462-431090

USA & Canada
PP Systems, Inc.
110 Haverhill Rd, Suite 301
Amesbury, MA 019313
USA
Tel: #1-978-834-0505
Fax: #1-978-834-0545

e-mail: support@ppsystems.com

Unpacking Your Equipment

It is extremely important that you check the contents of your equipment immediately upon receipt to ensure that your order is complete and that it has arrived safely. Please refer to the checklist supplied (if applicable) for a detailed list of spares and accessories that are included with your order.

DO NOT DISCARD ANY OF THE PACKAGING MATERIAL UNTIL ALL OF THE ITEMS LISTED ARE ACCOUNTED FOR.

WE RECOMMEND THAT YOU RETAIN THE ORIGINAL PACKING FOR FUTURE USE.

If you suspect that any of the items listed on the appropriate checklist are not included or damaged, you must contact PP Systems or authorised distributor immediately.

CIRAS-2 Do's and Do Not's

Please try to read the manual, and at least read the following notes to avoid damage to CIRAS-2:

Do's:

- Charge both NiMH batteries the night prior to making measurements.
- Charge the NiMH batteries independently using ONLY the 2 chargers supplied by PP Systems.
- Use only the power supply supplied by PP Systems for powering the CIRAS-2 externally.
- Charge the integral PC battery (For those customers that are using the Pencentra PC) with it's own charger the night prior to making measurements (not applicable for the PP Systems' User Interface (U/I),
- Check that the chemicals are fresh.
- Check that all absorber columns are properly seated in the proper manifolds.
- Check that the water vapour equilibrator is properly seated in the proper manifold.
- Check for any pinched "O" rings on the absorber columns, as well as cracks in the clear tubes themselves.
- Always operate CIRAS-2 in a vertical position.

Do Not's

- **Do Not** use substitute battery chargers or power supplies with the CIRAS-2.
- CIRAS-2 and water **Do Not** mix. Do not use water bubblers or manometers with your system.
- If there is any risk of water condensing and entering CIRAS-2, water dropout traps must be fitted.
- In dirty atmospheres, external filtration may be required.
- Do not change CO2 cartridges until at least 24 hours have elapsed.
- In case of queries please quote the CIRAS-2 serial number.

!!! WARNING !!!

USE ONLY POWER SUPPLIES AND BATTERY CHARGERS SUPPLIED BY PP SYSTEMS FOR THE CIRAS-2.
ANY OTHER WILL INVALIDATE THE WARRANTY.

NiMH Batteries

Due to the self-discharge characteristics of the NiMH batteries used with CIRAS-2, it is recommended that if the batteries are to be stored for more than 2 weeks time, the batteries should be charged for a minimum of 8 hours prior to next use.

Introduction

The most commonly used method of measuring the gas exchanges of leaves is to enclose them in a cuvette, pass a known flow rate of air over the leaf, and measure the change in concentration of CO_2 and H_2O in the air.
For the last 8 years, CIRAS-1 has been the preferred equipment as it was accurate, completely self-contained and truly
portable.

CIRAS-2 is a logical development, offering a Microsoft Windows control environment, a new range of cuvettes, a far longer battery life and, a first from any manufacturer, an **INTEGRAL CO2 CALIBRATION SYSTEM**.

CIRAS-2-employs a non-dispersive infrared measurement, coupled with microprocessor-based signal processing, to achieve very good stability and specificity to make accurate of CO_2 and water vapour concentrations.

The analyser measures the absolute concentration of one gas sample referred to for the purposes of this manual as the reference air abbreviated to REF. It also measures the difference in concentration to a second sample (the analysis air or AN). With gas exchange measurements, REF and AN are the air entering and leaving the leaf cuvette respectively.

The CIRAS-2 uses 4 infrared gas analysers, two for CO_2 and two for H_2O. Each analyser consists of a source of infrared radiation (a small tungsten filament lamp) at one end of a highly polished, gold plated tube through which the air passes. At the other end of the tube is the infrared detector, fitted with a window through which only infrared radiation absorbed by the gas of interest can pass. Thus the analyser responds only to the presence of that gas. Carbon Dioxide absorbs infrared radiation strongly at a wavelength of 4.26 microns. H_2O absorbs at a shorter wavelength. Detector wavelengths are carefully chosen so that there is no overlap of the CO_2 and H_2O absorption bands. Because the analysers are all simple absorptiometers, their theoretical range is from 0-100% of the gas they are designed to measure. However, because of the absorption characteristics of gases, the absorption path lengths, infrared source intensities, detector sensitivities and the Signal/Noise ratio of the system define their effective ranges. The absorption path length for CO_2 is optimised for 2000ppm but good accuracy is still available up to 10000 ppm. The H_2O is optimised for 0-75mb (75,000ppm). Temperature corrections are not required as the opto-electronics are fitted with thermostats set to about 54^{o}C and the sample air is also equilibrated to this temperature before entering the absorption cells. Absolute pressure changes in the cells and the differential pressure between cells, are measured by built in transducers, and corrected for in the firmware.
CIRAS-2 has-internal air sampling pumps with mass flow controllers that pump the air through the cells at about 100mls/minute. This flow is user controllable.

In part, the excellent stability of CIRAS-2 is due to the regular ZERO process when CO_2/H_2O free, air is passed through the cells, (referred to in future as ZERO). ZERO minimises the effects on span (gas sensitivity), of sample cell contamination, source ageing, and changes in detector sensitivity, amplifier gains, and reference voltages. It is done on start up, and then after 5,10,20 and 30 minutes, and subsequently every 30 minutes.

Accurate determination of the differential concentrations from measurement of the absolute concentrations of the REF. and AN. samples requires that the analysers be matched to within the instrument specifications. In building CIRAS-2 great care is taken to match detectors, filters, polished cells and finally in individual linearising the analysers. Even so, small differences remain and these are taken care of by balancing the cell outputs to ensure that the differential readings are correct. At regular intervals, subsequent to ZERO or following large changes in the measurement concentrations, then the reference sample is passed through both the REF. and AN. cells to determine the offset between them. This is called Differential Balancing abbreviated to DIFF-BAL.

The user has control of how and when these will occur. (see Table 8 Zero Options)

CIRAS-2 contains the cuvette air supply system,. This evolved from the one pioneered by CIRAS-2-1, and of course has full control of both the CO_2 and H_2O concentrations. But it has been so refined that it can be used to deliver a CALIBRATION CO_2 CONCENTRATION. Experience has shown that the CIRAS-2 analyser technology is extremely stable and re-calibration is not normally required, but we do recommend a regular check that this facilitates.

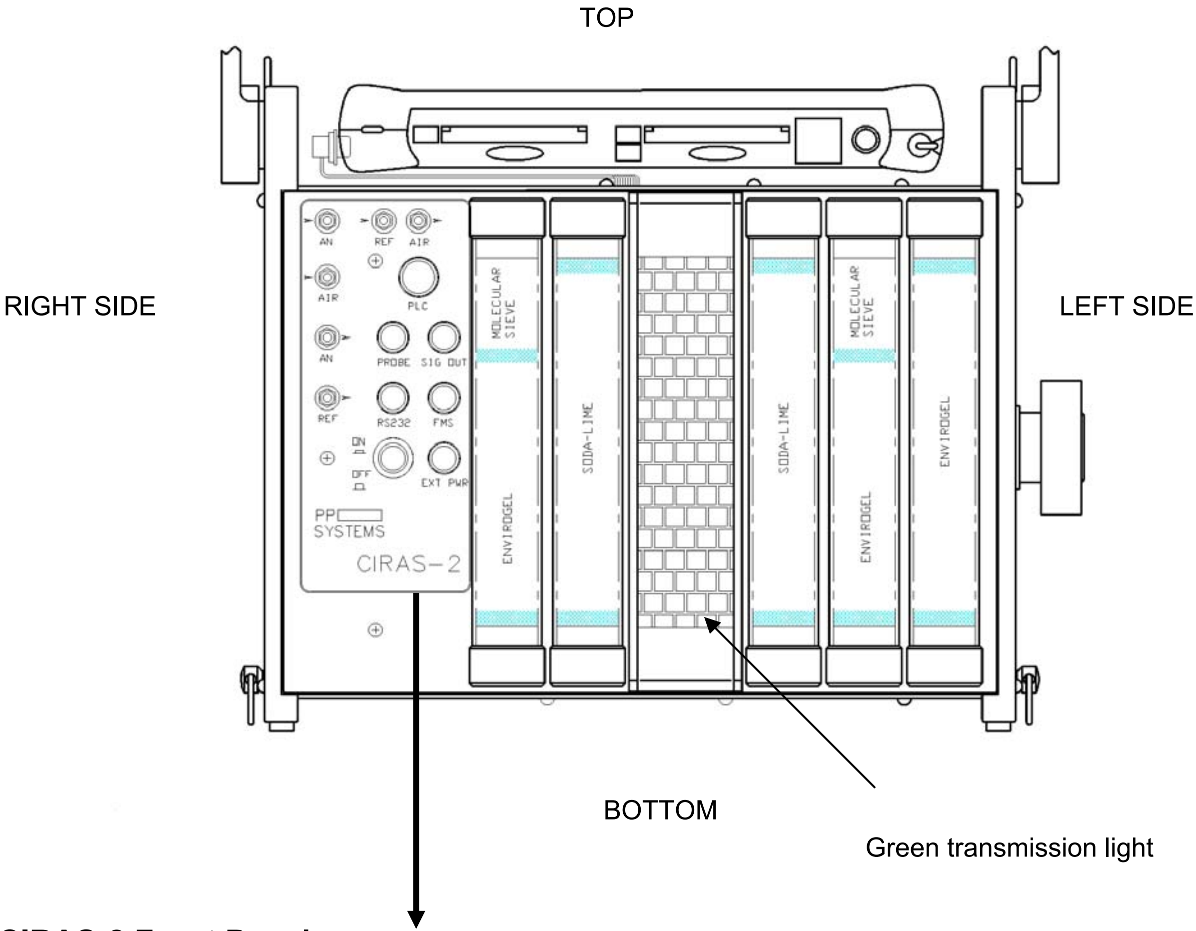
CIRAS-2 uses a microcomputer, for analyser control, A/D conversions, and interaction with the user.

CIRAS-2 is designed for use with a PC. An integral hand-held PC is normally supplied, though for field use, any portable PC is suitable. A connection is supplied for a 2nd PC or another measuring instrument (e.g. Hansatech FMS2) that can communicate with the controlling PC.

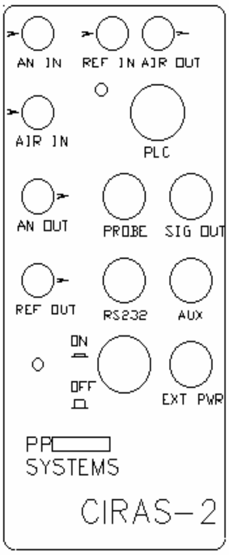
Analogue output of the data is also provided, for use with a chart recorder etc.

Analogue input sockets are provided. One accepts inputs from PP Systems standard environmental probes, and a second, from all types of PP Systems PLCs. Adapters are required for the standard probe 15 pin sockets and for CIRAS-1 PLCs.

CIRAS-2 Front Layout

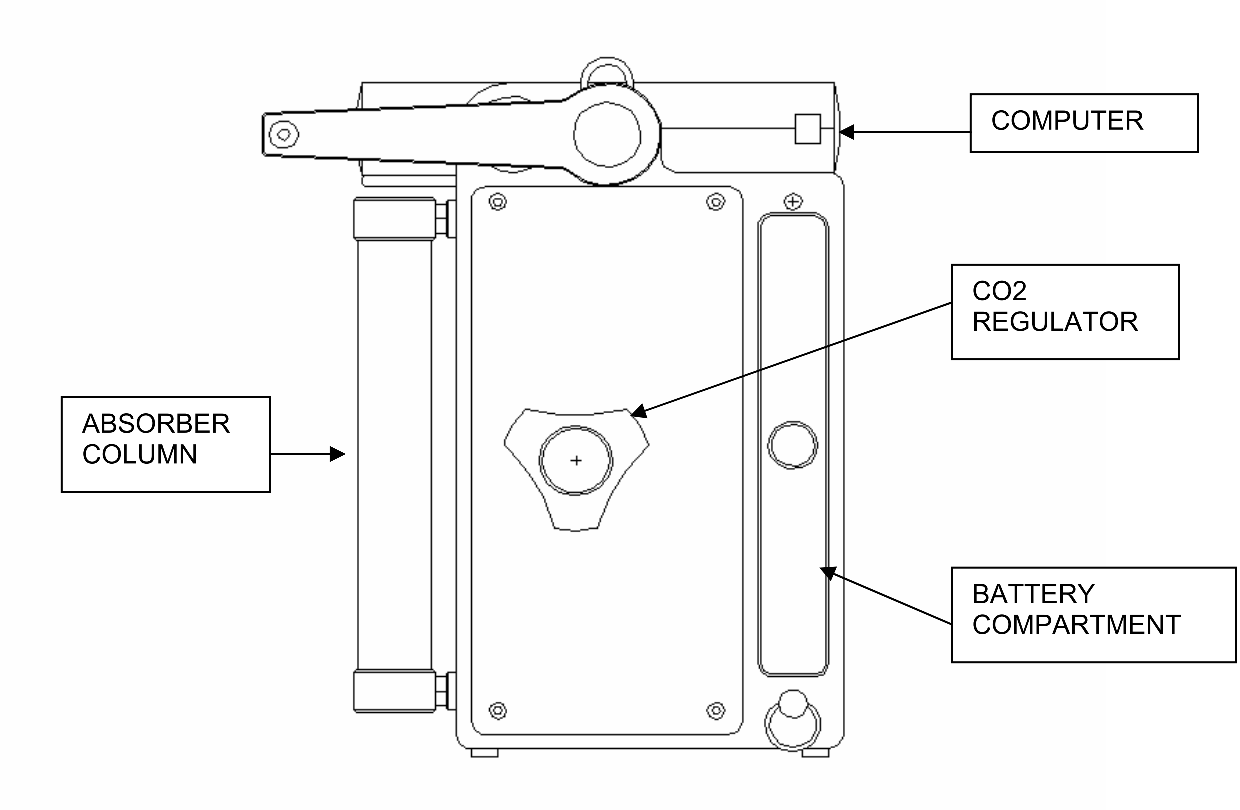


CIRAS-2 Front Panel



CIRAS-2 Electrical and Pneumatic Connections

CIRAS-2 Left Side Layout



CIRAS-2 Electrical & Air Connections

Figure 1 CIRAS-2 Electrical and Air Connections

Electrical Connections

ON/OFF

CIRAS-2 is turned On/Off using the illuminated red push button. Push the button to latch it in and power up CIRAS-2. Push it in again to unlatch it and turn CIRAS-2 off. The button will illuminate when pushed in, though it can fail to latch properly. If CIRAS-2 does not turn on, as indicated by the green flashing transmission light, then try again, making sure that the button is firmly depressed.
NB. If power is disconnected while CIRAS-2 is on then the button will be disabled, even though it is still latched in.

EXT PWR

The CIRAS-2 can be powered by an external power supply if required. Electrical connection to the CIRAS-2 is via the 4-pin socket labelled EXT PWR (= power).

PIN	FUNCTION	
1	V NEGATIVE	}LINK
2	V NEGATIVE	
3	V POSITIVE	}LINK
4	V POSITIVE	

RS232

The 5-pin socket labelled RS232 is for connection to the serial port of an external PC (now called PC(Ext)). It provides for 2-way RS232 communication with either the integral PC (now called PC(Int)) for data transfer, or with CIRAS-2 for control.

CIRAS-2 only uses TXD/RXD and ground. There is no handshake. So that PC(Ext) can detect that it is plugged into CIRAS-2, DTR is powered.

To communicate with PC(Ext), PC(Int) sends STX (ASCII Character Code 2) to CIRAS-2 which then switches the RXD of PC(Int) through to the TXD of PC(Ext), instead of to the CIRAS-2 microprocessor. Both CIRAS-2 and PC(Ext) are connected to the TXD of PC(Int).

To terminate PC(Int) to PC(Ext) communications and return to CIRAS-2, PC(Int) sends ETX (ASCII Character Code 3).

Table 1 BAUD Rate And Format Of The RS232

BAUD RATE	9600
START BITS	1
DATA BITS	8
STOP BITS	2
PARITY	NONE

PIN	FUNCTION
1	LINK TO GND
2	TX OF CIRAS-2 TO RX OF PC
3	RX OF CIRAS-2 FROM TX OF PC
4	DTR
5	NOT USED

FMS

The 5-pin socket labelled FMS is for connection to an external device, such as the FMS-2. It gives the integral PC RS232 access to these other devices, while continuing to control CIRAS-2. CIRAS-2 continually monitors the RS232 for control characters from the integral PC, and switches RS232 communication between itself and the external device accordingly (refer to the RS232 section). This feature is not implemented yet.

PIN	FUNCTION
1	NC
2	TX TO EXTERNAL DEVICE
3	RX FROM EXTERNAL DEVICE
4	NC
5	GND

PROBE

The 7pin socket labelled PROBE is for connection to external devices such as environmental probes, chambers, FMS-2, and Gas Switching Unit (GSU). Connection should only be made to this socket when the **PLC connector is not used**, except with the FMS-2 and GSU.

Environmental Probes & Chambers

CIRAS-2 PROBETYPE must be set to 1 for use with HTR-2 sensors, and to 2 for oxygen sensors. Closed systems require PROBETYPE to be set to 1 and all calculations, along with switching of the ALARM LINE that controls the fan speed, is through the PC software.

PIN		FUNCTION	RANGE (1V=)
1	+12V OUTPUT	Power for Probes and Chambers.	
2	GROUND (0V)	Analogue return.	
3	ALARM OUTPUT	Fan speed control in src-1.	
3	Ditto	FMS-2/GSU operating pulse.	
4	SENSOR INPUT 1	HTR-2 %RH Input.	100.0%
5	SENSOR INPUT 2	CPY/HTR-2 Air Temperature Input	50^oC
6	SENSOR INPUT 3	CPY/HTR-2 PAR Input/ OP-1 Input	PAR 3000 mmol.m^{-2}s^{-1} Oxygen 30.0%(PARReadingx0.1)
7	GROUND (0V)	Digital return	

Table 2 Probe Socket Connections

PAR and OXYGEN sensors use a common input pin (PAR Reading x 0.1 = % O_2).
PP Systems can supply a cable to interface the standard plugs to the CIRAS-2 connector.

FMS-2

The Alarm Output (Pin 3) is used by CIRAS-2 to synchronize recording with the FMS-2.

PIN	FUNCTION
2	GND
3	SIGNAL TO FMS

SIG OUT

The 8-pin socket labelled SIG OUT is used for the analogue outputs. The outputs have maximum voltage of 5.0V from a source impedance of about 60 ohms so if external resistors are used to drop the voltage then it is recommended that they exceed 10kohms in total.
There are currently four analogue output voltages in use corresponding to the absolute and differential CO_2 and H_2O concentrations. These have a range of 0-5V with 8 bit (0.4% of fsd) resolution. To optimise the outputs it is possible to set the corresponding concentration ranges e.g. for CO_2 REF set 0V=300ppm and 5V=450ppm. The span must be greater than 25ppm(CO_2) and 5mb(H_2O). Similarly the differential ranges can be set (CO_2 +/- 25ppm to +/-999ppm and for H_2O +/- 5mb to +/-50mb N.B. 2.5V Output = ZERO Differential). These ranges are set up from the PC (refer to the Remote Control Section).

Example:

If CO_2 Reference = 356ppm and Range is set to 0V=0ppm, 5V=2000ppm then: -
CO2 REF output = 356/2000 x 5.0 V = 0.89 V

If CO_2 Differential = +25ppm and Range is set to +/-50 ppm then: -
CO_2 DIFF output = 25/50 x 2.5 +2.5 = 3.75V

If H_2O Reference = 25.56mb and Range 0V=10mb; 5V=50mb then: -
H_2O REF output = (25.56-10.0)/40 x 5.0 VOLTS = 1.95 V

PIN	FUNCTION
1	CO_2 REFERENCE
2	CO_2 DIFFERENCE
3	H_2O REFERENCE
4	H_2O DIFFERENCE
5	NOT USED
6	NOT USED
7	NOT USED
8	GND

PLC

The 18-pin socket labelled PLC is for the connection of PP Systems leaf cuvettes (PLC5 and PLC6 series) and the various open/closed chambers.

PIN	FUNCTION
AI	GND
A2	T AMBIENT
A3	EXT BATTERY VOLTAGE
BI	GND
B2	GND
B3	T CUVETTE
C1	T RADIATION
C2	LIGHT 1 CONTROL
C3	T POLARITY
DI	T RADIATION BASE
D2	LIGHT 2 CONTROL
D3	PAR
EI	T CONTROL
E2	REC/OPEN
E3	VREF 552
FI	+12V
F2	+12V
F3	GND

Air Connections

There are six air connections as follows:

Air Connection	Function
REF >	Reference outlet air connection.
AN >	Analysis outlet air connection.
> AIR	Air inlet air connection. Normally, the AIR IN connection will not be used. However, if you wanted to use other than normal air, for example a different oxygen/nitrogen ratio, then this would be connected to the AIR IN. **Please Note**. If the source is a gas cylinder or pump, the connection should be through a T piece venting to atmosphere so that CIRAS-2 draws its own sample and is not pressurised.
> AN	Analysis inlet air connection. Analysis connection from PLC5 & PLC6 cuvettes connects pneumatically to this connector.
> REF	Reference inlet air connection. Reference connection from PLC5 & PLC6 cuvettes connects pneumatically to this connector.
AIR >	Air outlet air connection. Air connection from PLC5 & PLC6 cuvettes (second leg from “Y” type gas connector) connects pneumatically to this connector.

Please Note. Arrows pointing towards and away from the gas connectors respectively mark the inlets/outlets on CIRAS-2.

AN and REF correspond to the analyser and reference inlets/outlets of the analyser cells and the sample pumps.

The samples are filtered by passing through hydrophobic filters. Though these will not completely inhibit the passage of water, they should greatly decrease the flow of air causing CIRAS-2 to switch off the pumps.

CIRAS-2 System Air Flow Paths

Analyser Air Flow Paths

See Figure 2 Analyser Air Flow Diagram

AN/REF correspond to inlets/outlets of the analyser cells and the sample pumps. The samples are filtered by passing through hydrophobic filters. Though these will not inhibit completely the passage of water, they should greatly decrease the flow of air causing CIRAS-2 to switch off the pumps.

Measure Mode

SV1 and SV2 are solenoid valves and in this mode neither is energised. The REF air passes through SV1 to the REF cell, mass flowmeter and the sample pump. Similarly the analysis air goes through SV2 to the AN cell.

ZERO Mode

Both SV1 and SV2 are energised. All the sample air is then drawn through the Soda Lime in Absorber Column 2 to remove $CO_{2,}$ then through the 2/3rd Envirogel (removes H_2O) and 1/3rd Molecular Sieve (removes the final traces of both CO_2 and H_2O) in absorber column 1. The ZERO air then passes through SV1 to the reference cell and through SV2 to the analysis cell.

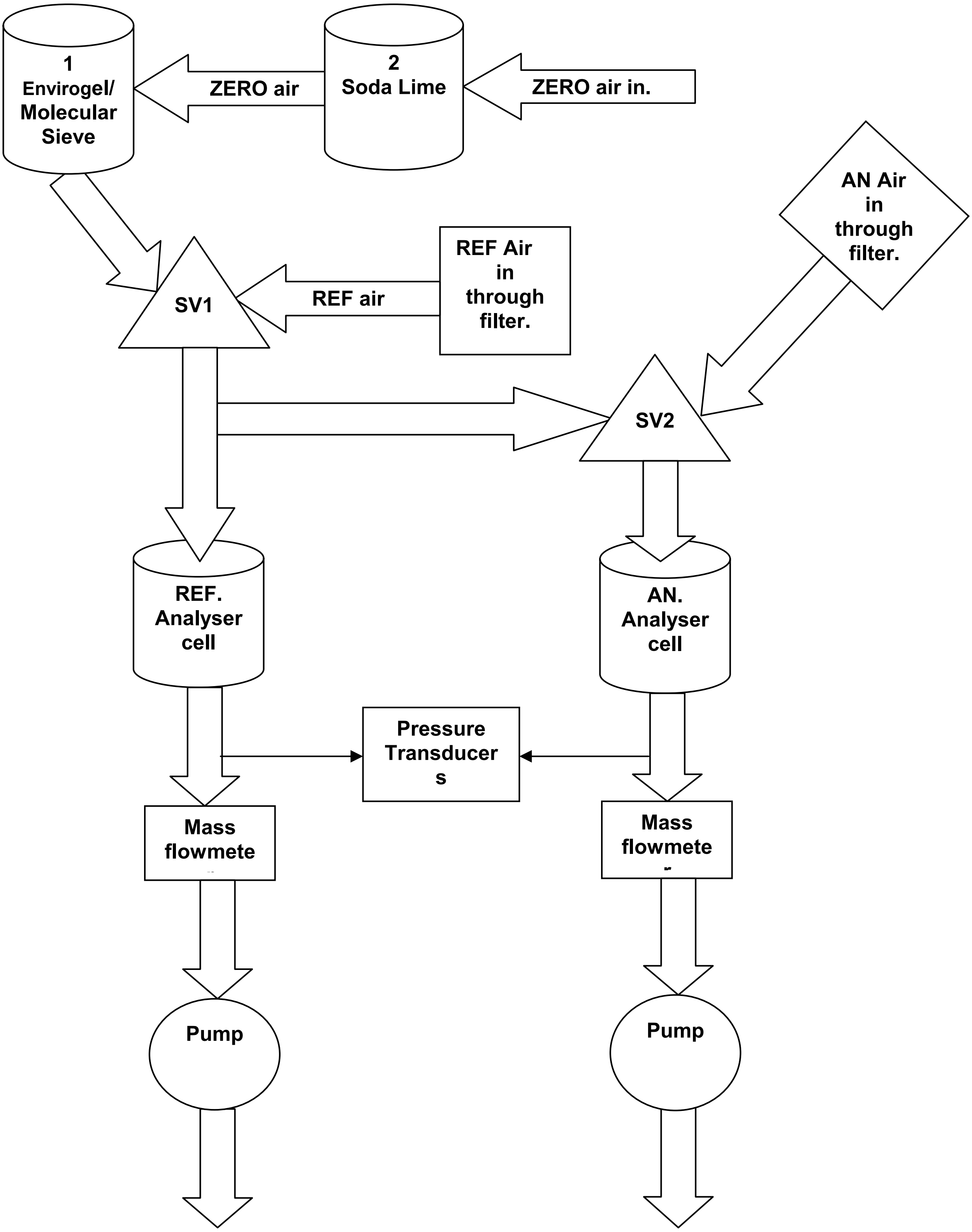
DIFF-BAL Mode

SV2 is energised. The REF air passes through SV1 to the REF cell and through SV2 to the AN cell.

Closed Systems

The analyser can be run in closed system mode but during ZERO both cell inlets are connected to CO_2 free, dry air, which will therefore emerge from the outlets. During DIFF-BAL the REF sample emerges from both cell outlets.

Figure 2 Analyser Air Flow Diagram



Cuvette Air Supply Flow Paths

See Figure 3 Air Supply Diagram

From the AIR IN the air passes through a hydrophobic filter to the -forwarding pump. This is a small diaphragm pump. This pumps the air through the Soda Lime in Column 3 to scrub out the CO_2. However, Soda Lime also raises the air humidity so the air is passed through the water vapour equilibrator to bring it back to ambient. In the equilibrator the air passes through Permapure tubing. The tubing is made from a Perfluorosulphonic acid material manufactured by DUPONT under the trade name NAFION. This material is extremely permeable H_2O but not to CO_2. Depending on the position of the H_2O control valve, the air either passes through Envirogel (Columns 4 and 5) or direct to the CO_2 control section. At the entrance to the CO_2 controller there is a vent to atmosphere and from this point the air is drawn through the CO_2 controller by the main air supply pump. It is essential therefore that the forwarding pump delivers a greater flow than the main air supply. Both pumps are managed by mass flow controllers' set to achieve this.

Using Ambient Air

If measurements are made on ambient air using the internal pumps, then Column 3 (Soda Lime) should be replaced with an empty column. Humidity control is still available. To ensure that changes in the REF concentration do not give rise to spurious differentials, it is important that the air is drawn in well away from any CO_2 sources such as car exhausts or boiler chimneys. It may also be necessary to put a smoothing volume before the AIR IN.

Figure 3 Air Supply Diagram

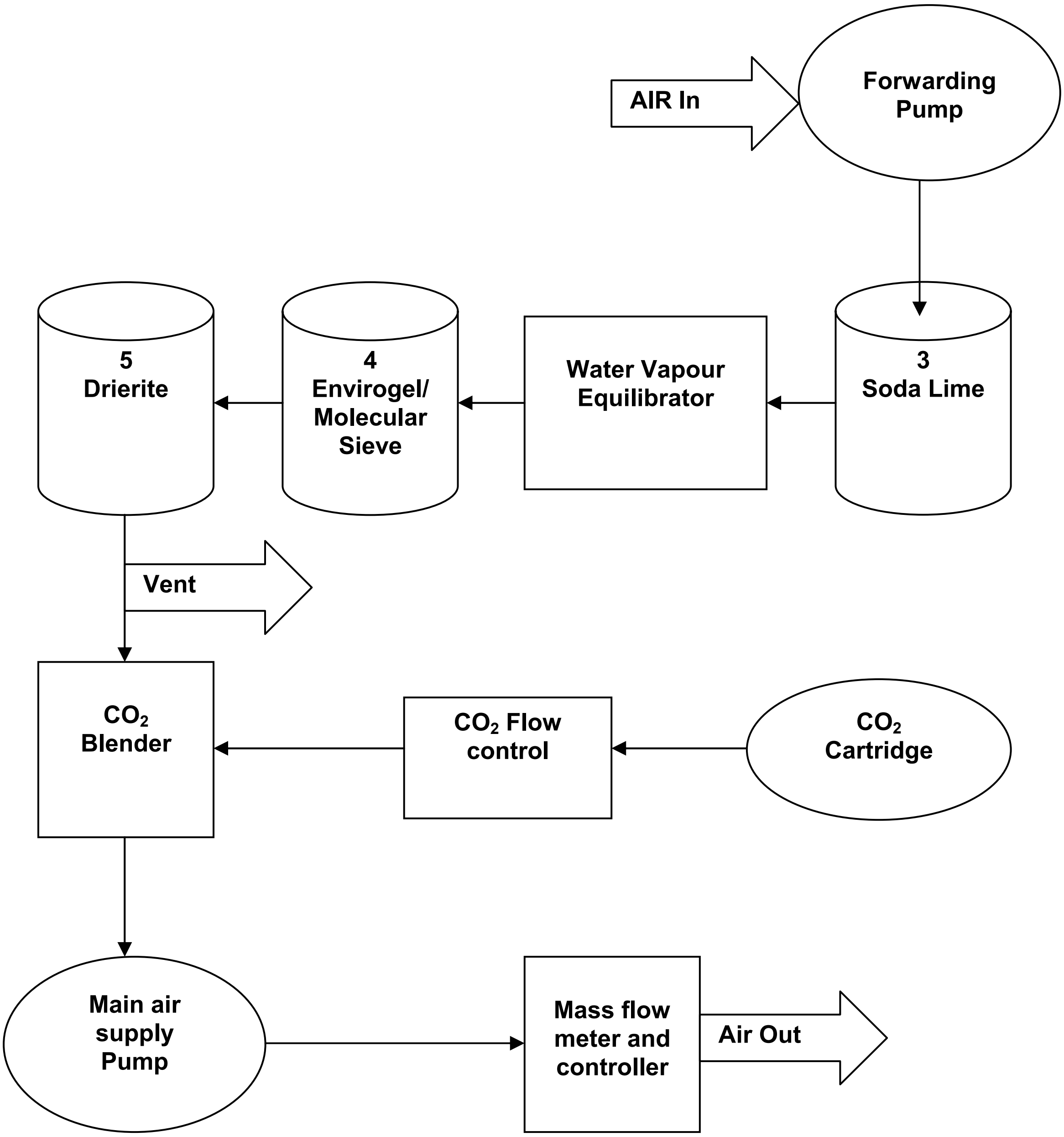
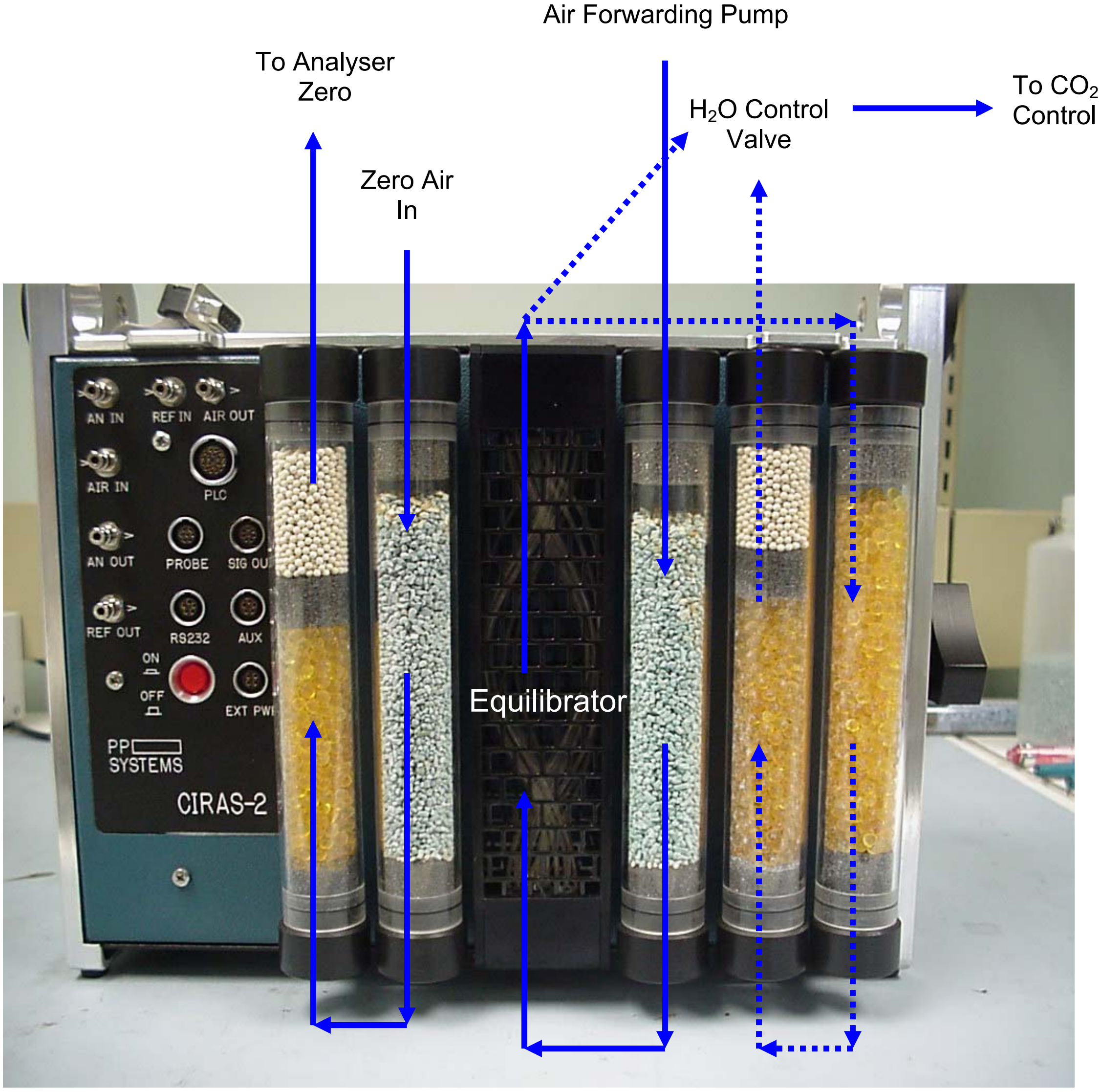


Figure 4 Absorber Column Layout and Flow directions.



CIRAS-2 Power Supply

!!! WARNING !!!

USE OF POWER SUPPLIES AND BATTERY CHARGERS OTHER THAN THOSE SUPPLIED BY PP SYSTEMS FOR THE CIRAS-2 WILL INVALIDATE THE WARRANTY.

CIRAS-2 may be powered using either the external power supply supplied with the analyser or from internal batteries.

CIRAS-2 uses Nickel Metal Hydride (NiMH) batteries, and because of the special charging characteristics of these cells, they are removed for charging. The chargers supplied by PP Systems **MUST** be the only ones used to charge these batteries.

CIRAS-2 may be fitted with one or two batteries. When two are fitted, it will start up on the one of greatest voltage. When this is discharged to its lowest operating voltage, the second battery will come into operation.
CIRAS-2 continually reports on the state of charge of the batteries fitted and which it is using. When several batteries are available then batteries can be exchanged without affecting the measurements.

When the available supply voltage drops to 10.5V, CIRAS-2 will send out a low battery warning and, if ignored, will automatically close down. To restart after this, it necessary to switch off the CIRAS-2, re-instate an adequate power supply and then switch on again.

When the CIRAS-2 is operating on an external power supply and this is switched off or the plug removed, CIRAS-2 will switch off even if a charged battery is present. If the power supply is then re-instated, though the LED on the CIRAS-2 will glow, CIRAS-2 will not re-start until it has been switched off and on again.

IF CIRAS-2 DOES NOT START UP WHEN SWITCHED ON, FIRST CHECK THAT EITHER THE POWER SUPPLY IS PRESENT AND POWERED OR THAT A CHARGED BATTERY IS FITTED.

The CIRAS-2 is fitted with an auto resetting thermal fuse and for further protection a fuse is mounted on the main board.

The CO_2 Regulator

The CO_2 regulator is located on the left-hand side of CIRAS-2. It consists of 2 parts:

1. Regulator base that is permanently fastened to the CIRAS-2 chassis.
2. Black cylinder holder that screws onto the regulator body.

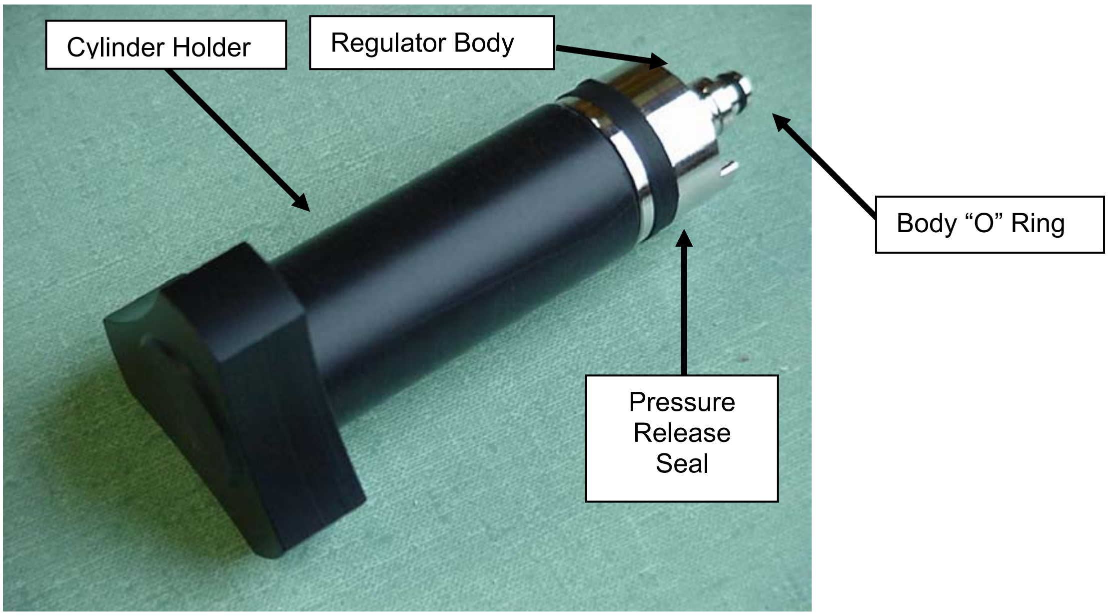


Figure 5 CO2 Regulator

!!! WARNING !!!

The CO_2 Regulator is not a user serviceable component and must not be dismantled. Any attempt to dismantle will invalidate the warranty.

The regulator body plugs into a socket on the base, located by two lugs, and is sealed in place by an “O” ring. To remove, the cylinder holder must be screwed onto the body and then a firm pull away from CIRAS-2 will disengage. To replace, insert the regulator body back into CIRAS-2. Rotate, gently pushing to locate the 2 lugs, then push in hard to seal. Regularly put a thin smear of silicone grease on the regulator body “O” ring.

The purpose of the removable body is for testing that the regulator is working; for easy replacement if defective; and for continuous working (using 2 in rotation). There is no need to remove the body to simply change a CO_2 cylinder.

The CIRAS-2 Portable Photosynthesis System contains an internal air-supply unit that is used to control the CO_2 concentration of the reference gas supply. The CO_2 is supplied from a disposable cartridge that is inserted into a regulator on the side of the instrument. Before inserting a fresh cartridge, it is always sensible to check that the “O” ring inside the regulator is properly seated. It can be deformed during accidental rapid discharge of the cylinder. If this is the case, it must be replaced (Part Number STD037). It is also useful to roll the neck of the cylinder between thumb and forefinger. This places a thin layer of grease around the neck of the cartridge, which helps to provide a good seal.

Refer to the Maintenance section of this manual for CO2 regulator servicing procedures.

Inserting a CO_2 Cylinder

!!! WARNING !!!

CO_2 CYLINDERS MUST ON NO ACCOUNT BE REMOVED UNTIL 24 HOURS AFTER FITTING.

Before inserting a new CO_2 cylinder, first unscrew the holder to safely release any existing cylinder. The holder will become harder to unscrew as the cylinder is pulled off the piercing pin. Remove the spent cylinder.

Rotate the narrow neck of the new cylinder between your thumb and finger, which will transfer an adequate amount of grease onto the cylinder. It is important that grease does not enter the regulator so we no longer recommend the application of silicone to the neck. Place the new cylinder in the holder with the cylinder neck at the open end. Present the cylinder holder to the regulator body. Initially rotate anti-clockwise with a slight pressure until a small forward movement is felt at the start of the thread. Screw in fully (clockwise) then back off one quarter of a turn.

If there is any doubt about the CO_2 flow, remove the regulator body as described in the previous section and dip the end of the regulator into a beaker of water and see if bubbles of gas slowly emerge (see below).

Figure 6 Testing CO2 Regulator Flow

If bubbles emerge at the rate of approximately 1 bubble per second, there is good flow coming from the regulator.

Chemicals and Absorber Columns

The CIRAS-2 has 5 absorber columns containing three different chemicals to condition the instrument air-supply:

Absorber Column Numbers are marked on the bottom of CIRAS-2

Column No.	Chemical	Function
1	1/3rd Molecular Sieve 2/3rd Envirogel	For Zeroing analysers
2	Soda Lime	For Zeroing analysers
3	Soda Lime	CO_2 Control
4	1/3rd Molecular Sieve 2/3rd Envirogel	H_2O Control
5	Envirogel	H_2O Control

Table 3 CIRAS-2 Absorber Columns

Soda Lime

Soda lime is used to remove CO_2 from air entering the CIRAS-2. It is supplied as self-indicating granules (1-2.5mm) which turn from green to brown as they become exhausted. The contents of the absorber column should be replaced when they are two-thirds exhausted. Soda Lime cannot be regenerated.

****** CAUTION ******

WASH YOUR HANDS AFTER HANDLING SODA LIME

Envirogel

Envirogel is silica gel with an indicator (orange changing to green) used for drying the air. It is a low cost alternative to a desiccant that we used to use (Drierite) which makes it a disposable item in most countries. However, it can be regenerated by heating in an oven if necessary (above 100° C but not exceeding 150° C). It is non-hazardous and can be easily disposed of when exhausted. Silica gel absorbs 27% of its weight in water compared with the 7% for Drierite. It is not quite as effective as Drierite giving an ultimate water concentration of about 0.04mb compared with 0.005mb but this is adequate for our measurements.

Molecular Sieve

Molecular Sieve is used to finally filter any remaining CO_2 and H_2O from the air supply during zeroing and from the water vapour control circuit. Unfortunately, Molecular Sieve is not self-indicating and there is no obvious way to see that it is exhausted. It is therefore best to change the Molecular Sieve when changing your other chemicals. **Please note that there is no foam pad at the Molecular Sieve end of the Envirogel / Molecular Sieve columns (Columns 1 and 4), so extra care must be taken when changing this column.**

Molecular Sieve can easily become contaminated through absorption of CO_2 and H_2O from atmospheric air. It is therefore **strongly recommended** that Molecular Sieve is decanted into small air-tight containers to minimise any exposure to air. The Envirogel/Molecular Sieve columns (Columns 1 and 4) should be placed in a sealed polythene bag if it is removed from the CIRAS-2.

ZERO Absorber Columns

****** WARNING ******

For accurate measurements and calibration, it is absolutely critical that the analyser ZERO columns (columns 1 & 2) are not exhausted. If the chemicals are becoming exhausted, it will cause the ZERO to be done on non-ZERO air causing error in the calibration. Pay special attention to the Molecular Sieve desiccant.

Therefore, the condition of the chemicals within the absorber columns must be regularly checked, and replaced as necessary. There are 2 ZERO columns (Labelled 1 and 2 on the bottom of CIRAS-2). Absorber column number 2 contains Soda-lime for CO_2 absorption. Absorber column number 1 contains 2/3rd Envirogel for H_2O absorption and 1/3rd Molecular Sieve for both H_2O and CO_2 absorption (gives a final polish before the analyser cell).

For more information on chemicals, absorber columns, material safety data information and service procedures, please refer to the Maintenance section of this manual.

CIRAS-2 Calibration

CO_2 Calibration

CIRAS-2 is a very stable instrument and should NOT require calibration

This is because the auto-ZERO function corrects for nearly all changes that give rise to drifts in calibration. The common cause of a drift in CIRAS-2 readings is an incorrect ZERO due to either exhausted chemicals or to leaks on the ZERO columns from rolled or damaged O-rings etc. This is therefore easily corrected. The second cause, which is more serious though fortunately less common, is liquid water passing through the cells affecting their reflectivity and therefore the linearity.

The only reason to re-calibrate CIRAS-2 is to use your own laboratory standard, rather than relying on our calibration.

Regularly check the CIRAS-2 calibration as changes signify instrument problems. For CO_2, use the internal checking against the mixture generated by CIRAS-2 or a standard gas and for H_2O check against an H_2O calibrator or other standard source. Another quick check for CO_2 is to use ambient air drawn from a position away from any CO_2 source such as cars, boilers, breath etc. Ambient air is in the range 340-360ppm.

CO_2 and H_2O calibrations and checking are done separately but they may be done consecutively in any order.

The procedure for checking or calibrating is similar.

The contents of the absorber columns must **NOT** be exhausted.
The analyser must have been switched on for at least 30 minutes minimum.

You will require:

A standard gas for CO_2 calibration or if using the internal standard, a CO_2 cylinder should have been recently inserted.
A source of known water vapour content for H_2O calibration (similar to our Water Vapour Calibrator).

****** WARNING ******

It is absolutely critical that the analyser ZERO columns (columns 1 & 2) are fresh before performing CO_2/H_2O calibrations. If the chemicals are not fresh, it will cause the ZERO to drift, thus causing the calibration to be off.

External connections for CO_2 Calibrations.

CO_2 calibrations using the internal standard.

Connect the cuvette air supply AIR OUT and the REF inlet through a T-piece with 30cms of vent pipe on the third leg.

CO_2 calibrations using a gas cylinder.

The gas cylinder must **not** be connected directly to the CIRAS-2.

Either: -

Connect through T-piece. One leg goes to the REF inlet, the 2nd leg to the gas cylinder, and the remaining leg to atmosphere through a 30 cm pipe. The flow rate from the gas cylinder should be set so that there is small excess, say 100-200 ml/minute, flowing to atmosphere. The total flow for is then 300 to 400 ml/minute.

****** WARNING ******

ON NO ACCOUNT USE GAS BUBBLING THROUGH WATER TO INDICATE SURPLUS FLOW. IF CIRAS-2 INGESTS WATER, IT IS LIKELY THAT THERE WILL BE DAMAGE TO THE CELL SURFACES, THE DETECTOR WINDOWS, THE IR SOURCE, THE PUMPS AND THE MASS FLOWMETERS.

Or preferably: -

Fill a gas sample bag with the calibration gas direct from the cylinder. Now attach the gas sample bag inlet to the REF AIR IN and the CIRAS-2 will draw out a sample without any risk of pressurisation. Gas sample bags are available from PP Systems.

If possible, the standards should have a concentration slightly greater than the usual measurement. It is better not to calibrate with a concentration much smaller than the measurements, i.e. do not use a 300-ppm standard when measuring 2,000 ppm.

H_2O Calibration Sources and Connections.

For H_2O calibration, an air supply of known water vapour concentration is required (mb).

There are a number of ways that this can be obtained: -

1. By bubbling air through water of a known temperature. Do make sure that there is a trap for liquid water before CIRAS-2. SEE ABOVE WARNING ABOUT CIRAS-2 AND WATER.
2. By passing air through a suitable $FeSO_4.7H_2O$ column at a known temperature. (See Table 4 FESO2 Temperature vs. Vapour Pressure in mb). This is best done on a closed circuit, combining the reference and analysis outlets and connecting to the column air inlet. The air should be in contact with the $FeSO_4$ for about 12 seconds, though recycling will help. Therefore, at a flow rate of 2x100cm³ minute, a volume of 40cm³ is required. $FeSO_4$ has the advantage that no liquid water is involved that can damage CIRAS-2. The PP Systems Water Vapour calibrator uses this system.

PP Systems' Water Vapour Calibrator

The calibrator consists of an insulated container filled with ferrous sulphate salt ($FeSO_4.7H_2O$) and can be used for automatic calibration of the H_2O IRGA's in CIRAS-2. The unit is fitted with thermistor temperature sensors measuring ambient air temperature and the temperature of the air emerging from the $FeSO_4.7H_2O$. The water vapour pressure above the $FeSO_4.7H_2O$ is a function of the salt temperature as shown in Table 4 FESO2 Temperature vs. Vapour Pressure in mb.

The salt can humidify many litres of air, and it should last many years as it is being used in a re-circulating mode. The degree of exhaustion of the salt can be determined by its weight as shown on the test certificate beneath its cap.

NB : New calibrators supplied with CIRAS-2 connectors are connected directly to CIRAS-2. Calibrators supplied for use with CIRAS-1 require an interface circuit as well as a plug adapter. Contact PP Systems if you have a CIRAS-1 Calibrator.

Ref Parkinson K.J. and Day W. (1981) Water Vapour Calibration using Salt Hydrate Transitions. J.Expt Bot. 32, 411-418.

The PP Systems H_2O Calibrator should be both stored and operated in a relatively stable temperature environment.

The calibrator and CIRAS-2 should be placed together in a stable temperature to allow their temperatures to equilibrate for several hours before use. If the equilibrator is warmer than CIRAS-2, there could be a risk of condensation.

Connecting the H_2O Calibrator to the CIRAS-2

Enter the appropriate calibration mode in the software and wait to ensure that no "FESO4 Temperature to High" messages are issued. When ready to proceed with calibration:

- Connect the H_2O Calibrator to the PLC electrical connector on CIRAS-2.
- The pipe emerging from the bottom of the calibrator should be connected to the REF air inlet (>REF) on the CIRAS-2.
- The two upper pipes should be connected to the REF air outlet (REF>) and the AN air outlet (AN>).
  Note. It does not matter which way around the two upper pipes are connected.

!!! WARNING !!!

Pipe connections should not be made until it has been ascertained that there are no error messages from CIRAS-2 that indicate the calibrator temperature is too high.

Table 4 $FESO_2$ Temperature vs. Vapour Pressure in mb

T	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	2.53	2.56	2.58	2.60	2.63	2.65	2.67	2.70	2.72	2.75
1	2.77	2.80	2.82	2.85	2.87	2.90	2.93	2.95	2.98	3.01
2	3.03	3.06	3.09	3.11	3.14	3.17	3.20	3.23	3.26	3.28
3	3.31	3.34	3.37	3.40	3.43	3.46	3.49	3.52	3.56	3.59
4	3.62	3.65	3.68	3.71	3.75	3.78	3.81	3.85	3.88	3.91
5	3.95	3.98	4.02	4.05	4.09	4.12	4.16	4.19	4.23	4.27
6	4.30	4.34	4.38	4.41	4.45	4.49	4.53	4.57	4.61	4.65
7	4.68	4.72	4.77	4.81	4.85	4.89	4.93	4.97	5.01	5.06
8	5.10	5.14	5.18	5.23	5.27	5.32	5.36	5.41	5.45	5.50
9	5.54	5.59	5.64	5.68	5.73	5.78	5.83	5.88	5.92	5.97
10	6.02	6.07	6.12	6.17	6.22	6.28	6.33	6.38	6.43	6.49
11	6.54	6.59	6.65	6.70	6.76	6.81	6.87	6.92	6.98	7.04
12	7.09	7.15	7.21	7.27	7.33	7.39	7.45	7.51	7.57	7.63
13	7.69	7.75	7.81	7.88	7.94	8.00	8.07	8.13	8.20	8.26
14	8.33	8.39	8.46	8.53	8.60	8.67	8.73	8.80	8.87	8.94
15	9.01	9.09	9.16	9.23	9.30	9.38	9.45	9.52	9.60	9.67
16	9.75	9.83	9.90	9.98	10.06	10.14	10.22	10.30	10.38	10.46
17	10.54	10.62	10.70	10.79	10.87	10.95	11.04	11.12	11.21	11.29
18	11.38	11.47	11.56	11.65	11.74	11.83	11.92	12.01	12.10	12.19
19	12.28	12.38	12.47	12.57	12.66	12.76	12.86	12.95	13.05	13.15
20	13.25	13.35	13.45	13.55	13.65	13.76	13.86	13.96	14.07	14.18
21	14.28	14.39	14.50	14.60	14.71	14.82	14.93	15.04	15.16	15.27
22	15.38	15.50	15.61	15.73	15.84	15.96	16.08	16.20	16.32	16.44
23	16.56	16.68	16.80	16.93	17.05	17.18	17.30	17.43	17.55	17.68
24	17.81	17.94	18.07	18.20	18.34	18.47	18.60	18.74	18.87	19.01
25	19.15	19.29	19.43	19.57	19.71	19.85	19.99	20.14	20.28	20.43
26	20.57	20.72	20.87	21.02	21.17	21.32	21.47	21.62	21.78	21.93
27	22.09	22.24	22.40	22.56	22.72	22.88	23.04	23.21	23.37	23.53
28	23.70	23.87	24.03	24.20	24.37	24.54	24.72	24.89	25.06	25.24
29	25.41	25.59	25.77	25.95	26.13	26.31	26.49	26.68	26.86	27.05
30	27.24	27.42	27.61	27.80	28.00	28.19	28.38	28.56	28.77	28.97
31	29.17	29.37	29.57	29.77	29.98	30.18	30.39	30.59	30.80	31.01
32	31.22	31.44	31.65	31.86	32.08	32.30	32.52	32.74	32.96	33.18
33	33.40	33.63	33.85	34.08	34.31	34.54	34.77	35.01	35.24	35.48
34	35.71	35.95	36.19	36.43	36.68	36.92	37.17	37.41	37.66	37.91
35	38.16	38.41	38.67	38.92	39.18	39.44	39.70	39.96	40.22	40.49
36	40.75	41.02	41.29	41.56	41.83	42.11	42.38	42.66	42.94	43.22
37	43.50	43.78	44.07	44.35	44.64	44.93	45.22	45.52	45.81	46.11
38	46.40	46.70	47.01	47.31	47.61	47.92	48.23	48.54	48.85	49.16
39	49.48	49.79	50.11	50.43	50.75	51.08	51.40	51.73	52.06	52.39
40	52.72	53.06	53.39	53.73	54.07	54.41	54.76	55.10	55.45	55.80
41	56.15	56.51	56.86	57.22	57.58	57.94	58.30	58.67	59.03	59.40
42	59.77	60.15	60.52	60.90	61.28	61.66	62.04	62.43	62.82	63.20
43	63.60	63.99	64.39	64.78	65.18	65.59	65.99	66.40	66.80	67.22
44	67.63	68.04	68.46	68.88	69.30	69.73	70.15	70.58	71.01	71.44
45	71.88	72.32	72.76	73.20	73.64	74.09	74.54	74.99	75.44	75.90
46	76.36	76.82	77.28	77.75	78.22	78.69	79.16	79.64	80.11	80.60
47	81.08	81.56	82.05	82.54	83.04	83.53	84.03	84.53	85.03	85.54
48	86.05	86.56	87.07	87.59	88.11	88.63	89.15	89.68	90.21	90.74
49	91.28	91.81	92.35	92.90	93.44	93.99	94.54	95.10	95.65	96.21
50	96.78	97.34	97.91	98.48	99.05	99.63				

The following table shows the FES04 temperature and the air temperature that give an air relative humidity of greater than 80%. The system MUST NOT be used if the ambient air temperature is **less** than the 80% RH Air Temperature, due to condensation.

FES04 Temperature (LCT)	80% RH AIR Temperature
15	8
16	9
17	10
18	12
19	13
20	14
21	15
22	16
23	17
24	19
25	20
26	21
27	22
28	23
29	24
30	26
31	27
32	28
33	29
34	30
35	31
36	33
37	34
38	35
39	36
40	37

Replacement of Ferrous Sulphate ($FESO_4.7H_2O$)

As described, the salt can humidify many litres of air, and it should last many years as it is being used in a re-circulating mode. The degree of exhaustion of the salt can be determined by its weight.

This is calculated to be as follows:-

H_2O Calibrator Serial No			
Weight of the container empty	=		g
Weight of the container filled with $FeSO_4.7H_2O$ (Including wire and plug but excluding pipes)	=		g
Therefore initial weight of $FESO_4.7H_2O$	F =		g
For 50% exhaustion of the $FESO_4.7H_2O$ (*) the expected weight loss of the salt is 10% (F * 0.1)	E =		g
Therefore replace $FESO_4.7H_2O$ when calibrator's weight is F - E	F – E =		g

(*) The $FESO_4.7H_2O$ should be replaced when it is 50% exhausted.

F = Fresh Weight
E = Exhausted Weight

$FESO_4$ Replacement Details

H_2O Calibrator Serial No			
Weight of the container empty	=		g
Weight of the container filled with $FeSO_4.7H_2O$ (Including wire and plug but excluding pipes)	=		g
Therefore initial weight of $FESO_4.7H_2O$	F =		g
For 50% exhaustion of the $FESO_4.7H_2O$ (*) the expected weight loss of the salt is 10% (F * 0.1)	E =		g
Therefore replace $FESO_4.7H_2O$ when calibrator's weight is F - E	F – E =		g

(*) The $FESO_4.7H_2O$ should be replaced when it is 50% exhausted.

F = Fresh Weight
E = Exhausted Weight

Up to date MSDS (Material Safety Data Sheet) for Ferrous Sulphate ($FESO_4$. $7H_2O$) is available directly from our web site for all registered CIRAS-2 users. If you are not registered with us, go to the User Registration section on page 10 and proceed to register your instrument. You must enter all information correctly, including the serial number of your CIRAS-2 which can be found on the bottom of the instrument.

CIRAS-2 PC Inter Connections

Introduction and Definitions.

CIRAS-2 requires connection to a PC running controlling software before it can function.

There are three RS232 sockets on CIRAS-2 that have different functions.

Top Panel Connection

A 9-pin socket on a cable positioned to suit the integral PC fitted to the top panel.
This PC is defined as the CIRAS-2 PC. Three connections only are made.

PIN 2 RXD.(Receive Data)
PIN 3 TXD (Transmit Data)
PIN 5 GND (Signal Ground)

Connector Panel RS232 Socket.

A 5-pin Lemo socket labelled as RS232. If it is wished to control CIRAS-2 with an External PC, then this socket should be used. The following connections should be made: -

PIN	LEMO	PIN	External PC
1	CONNECT TO 5 LEMO ONLY	1	NOT CONNECTED
2	CONNECT TO 2 EXTERNAL PC	2	CONNECT TO PIN 2 LEMO
3	CONNECT TO 3 EXTERNAL PC	3	CONNECT TO PIN 3 LEMO
5	GND	5	CONNECT TO GND LEMO

The 1-5 link in the LEMO plug disables the transmit line from the CIRAS-2 PC so that only the External PC is in control. Both will receive data from CIRAS-2.

Connector Panel FMS Socket.

This is primarily designed for connection to a Hansatech FMS fluorescence measuring system so that the CIRAS-2/EXTERNAL PC can control both the FMS and the CIRAS-2. Only three connections are made.

PIN 2 RXD.(Receive Data)
PIN 3 TXD (Transmit Data)
PIN 5 GND (Signal Ground)

The receive line of the PC is normally connected to CIRAS-2 but this is under CIRAS-2 control and on receipt of a special series of characters, CIRAS-2 will switch the line to receive data from the FMS socket. CIRAS-2 continues listening to the PC transmit line until the same character series is transmitted by the PC and then switches back to itself and resumes transmission. The code is ASCII CODES (128 129 130). The three characters must be sent sequentially.

PC Control Options

Control by CIRAS-2 Integral PC.

Plug the PC into the connector on the top panel. An External PC must not be plugged into the RS232 socket on the connector panel.

Control by External PC

The External PC should be connected to the connector panel socket labelled RS232 with the plug wired as described above. The CIRAS-2 PC can continue to receive data but cannot transmit instructions to CIRAS-2.

CIRAS-2/External PC control of both CIRAS-2 and FMS.

Connect the FMS to the similarly labelled socket on the connector panel. Normally the PC will receive and interact with CIRAS-2. When communication with the FMS is required then send the code to CIRAS-2 to switch communication to the FMS. On termination of FMS communication send the same code to switch back to CIRAS-2.

Program and Data transfer between CIRAS-2 PC and an External PC.

Connect the External PC to the FMS socket on the control panel. Use the same cable that is normally plugged into the RS232 socket as the Pin 1-5 connection is ignored. Sends to CIRAS-2, from the CIRAS-2 PC, the code to switch the FMS transmit line to communicate with the CIRAS-2 PC. On completion of communications remember to restore CIRAS-2 communications. (Switching CIRAS-2 off and on will also do this).

Measurements

Before Making Leaf Gas Exchange Measurements:

You must ensure that both the integral PC (if used) and CIRAS-2 NiMH batteries are fully charged prior to making measurements. To ensure that all are properly charged, we recommend charging the integral PC (with charger supplied) and both 12V NiMH batteries using the individual chargers supplied by PP Systems the night prior to making measurements. If the NiMH battery chargers are flashing, the batteries are fully charged. Assuming that this has been achieved, the following system checks should be made:

1. Check that the absorber chemicals are fresh, all of the absorber columns are properly sealed and inserted into their respective manifolds. Pay special attention to the "O" rings to ensure that they are properly seated in their grooves and not pinched off. Also ensure that the water vapour equilibrator is properly sealed and inserted into its respective manifolds.

2. Insert both fully charged 12V NiMH batteries to the CIRAS-2. At this stage, keep the battery charger connected to the integral PC to avoid the internal battery from draining.

3. Before going out to the field: connect the PLC electrically and pneumatically to the CIRAS-2. Switch on the integral PC and the CIRAS-2 and allow it to fully warm-up (30 minutes). Proceed into the measurement mode (data and graphics displayed). Set the reference CO_2 control to zero. The Cr (CO_2 reference) value should decrease to less than 10 ppm and remain steady. Next, set the CO_2 to 1,500 ppm. If the CO_2 value achieves or comes close to 1,500 ppm and remains stable, the CO_2 cartridge should **NOT** be removed as it still has some pressure left. You can begin measurements without changing the CO_2 cartridge at this time, but we recommend taking spare cartridges with you to the field in the event the cartridge starts to empty out.

   If the CO_2 value does not achieve 1,500 ppm and steadily drops, it is safe to change the cartridge even though there will be a slight residual. You **MUST** allow at least 24 hours to elapse before changing the CO_2 cartridge.

   To confirm that the cartridge has been successfully inserted, set the CO_2 control to the desired measurement value and check that it is maintained. The Maintenance section of this manual contains information on troubleshooting the CIRAS-2 CO_2 control system. (See Maintenance)

4. Check that the gaskets on the PLC (if used) are in good condition. Close the chamber without a leaf and run the system for two minutes. Check that the Cd (CO_2 differential) and Hd (H_2O differential) values stabilise at 000 ($^{+}/_{-}$ 1) ppm. Refer to the Troubleshooting and Maintenance section of this manual for information on servicing cuvettes.

After Making Leaf Gas Exchange Measurements:

At the conclusion of measurements:

1. Disconnect both the electrical and pneumatic connections to the cuvette from CIRAS-2.

2. Check that the cuvette is clean and leave the cuvette head in an open position so that the gaskets have a chance to recover and do not become crushed over-night.

3. **The CO_2 cartridge MUST be left in place over night to discharge safely whilst the instrument is switched off.** Avoid leaving the CIRAS-2 in its carrying bag, otherwise the CO_2 from the cartridge will build up in the absorber columns. This will cause premature exhaustion of the chemicals and slower instrument warm-up as excess CO_2 is flushed the next day.

4. Remove both CIRAS-2 12V NiMH batteries from the instrument and place them on their respective chargers. Before leaving the instrument, it is sensible to check that the red LED's on the charger units are a steady red and illuminated indicating proper connection. This indicates that the battery is drawing current. Next, place the Integral PC on its charger. It is **VERY IMPORTANT** to charge the Integral PC and CIRAS-2 NiMH batteries fully before storing the instrument for any significant period of time. The Integral PC battery and both CIRAS-2 NiMH batteries must be charged independently.

Start Up

Switch on the unit.
Please note that if the CIRAS-2 has switched itself off because of low voltage or by removal of external power with the ON/OFF switch left in the ON position, then the CIRAS-2 must first be switched OFF.

Initially CIRAS-2 switches off all the air pumps and transmits “F“ until it has completed its initial checks.
CIRAS-2 also checks the cuvette air temperature input. If it reads 800 then there is no cuvette connected and the PUMPMODE flag is set off (0), otherwise it is set to on (1). The PUMPMODE status determines whether the air supply will be on/off at the completion of the warm up.

The PC must not interrupt CIRAS-2 during the transmission of “F” but subsequent to that the PC can interrupt at any time.

The analyser now waits until the analyser cells reach their control temperature (Approximately 54^o C). During this period the analyser continually transmits "W,nnn" where nnn is the analyser temperature x10. When the temperature exceeds 50^o C then the rate of change is monitored. When the temperature is stable the analyser does a ZERO. During this period the analyser transmits "Z,nnn" where nnn corresponds with the data input cycle which takes 1.6 seconds (nnn=000 to 9.00 to 19.0). After 19 cycles the ZERO is complete but then there is a pause to flush the ZERO air from the cells. The complete ZERO process takes about 40 seconds.
The above temperature checking / ZERO cycle is then repeated. (This ensures that if the ZERO columns have just been changed then they get well flushed).

If the instrument has been turned off for a short time then the warm up tests on start up are omitted. However, it takes about 40 seconds before the a/d converters have completed their auto ZERO and are giving steady readings. During this period "W,nnn" is transmitted which is followed by a single ZERO.

On completion of the warming up phase, the air supply pumps are started only if the PUMPMODE is set to on (1). Measurements are done with data being transmitted through the RS232 port every 1.6 seconds.

Subsequently when a ZERO is done depends on the ZTYPE setting but the default on start up is ZTYPE 1 = Done by the analyser when required. Then ZEROs will continue to be done automatically after 5,10,20 and 30 minutes, and subsequently every 30 minutes. (See Table 8 Zero Options)

Depending on ZTYPE, about 40seconds after the completion of ZERO, there will be a DIFF-BAL. This will also be done if the CO_2/H_2O REF changes by more than 100ppm/5mb. **N.B.** the REF concentration is unsteady then DIFF-BAL is inhibited.

CIRAS-2 Parameters

Analyser and Air Supply Parameters.

Parameter	Function	Range	Default
AVLIMIT	The value controls the averaging process on the analyser measurements.	1-999	30 (= 3ppm)
CALCO2/H2O	Concentration of CO_2 / H_2O in the Calibration air.	CO_2 0-2500 H_2O 0-75	2000 50
PROBETYPE	Indicates the type of sensor, chamber or cuvette that is connected to CIRAS-2.	0-5	0
PUMPMODE	Switches the cuvette air supply On (1) or Off (0). Always Off with PROBETYPE 3.	0/1	0
RECORDTIME	Controls recording frequency. 0 = OFF 1 = Every 10 seconds, 360 = Every hour.	0-360	0
SAMPLEFLOW	Sets the analyser air sample flow rates. (0-100) Default is 100. Range depends on PROBETYPE(PT)	PT<3 0-100 Otherwise 50-100	
ZTYPE	Determines the manner and frequency of ZERO and DIFF-BAL	0-3	1

Analogue Output Voltage Control.

Parameter	Function	Range	Default
LOWC/LOWH	Reference concentrations for 0V output.	[C] 0 -(HIGHC-100) [H] 0 -(HIGHH-100)	0 0
HIGHC/HIGHH	Reference concentrations for 5V output (maximum).	[C] 100-2000 [H] 10-75	2000 50
CDFF/HDFF	Differential concentrations for 5V output (maximum)	[C] 25-2000 [H] 50-75	100 10

Parameters for leaf temperature and gas exchange calculations.

Parameter	Function	Range	Default
FLOW	If PUMPMODE (PM) ON then it is the requested airflow to the cuvette. If OFF then the calculations use this flow value	PM On: 100-470 PM Off: 100-2500	150
FLOW(X/ZERO)	Used in the calculation of the flow through Open System Canopy and inflatable chambers.	X 0.1-1000 Z 0-50000	1 0

Parameter	Function	Range	Default
LAR	Leaf area exposed in the cuvette or chamber.	PT>3 0.1-99.9 PT=3 1.0-999	100
LTCAL	Determines the type of leaf temperature calculation. 0=Energy balance 1=Thermistor 2=IR sensor.	0/1/2	1
PARTYPE	0= Use measured PAR, >0 then use entered value in energy balance calculation of leaf temperature.	0-3000	0
PARX	Factor for converting PAR sensor reading to PAR incident on the leaf.	0.1-5.0	1
RADX	Factor used in determining leaf temperature from the RAD reading that depends on the cuvette type.	0.5-5	1
RB	Cuvette boundary layer resistance.	0.1-0.99	0.3
RSFRACT	Distribution of stomatal resistance between the upper and lower leaf surface. 50%:50% = 0.5 etc.	0-1	0.5
TRANS	Factor applied to the PAR reading to convert it to the energy absorbed by the leaf.	0.1-0.4	0.15

Parameters for Cuvette Temperature and Light Control.

Parameter	Function	Range	Default
CONTROL(T/P)	Required temperature and light values	T 0-50 P 0-MAXQ	0 N/A
DELTACOOL	Used to determine the required peltier current for the temperature requested.	1-50	10
MAXCOOL	Setting of the peltier current that gives the maximum cooling. Above this value cooling will decrease.	100-255	200
MAXQ	Maximum PAR value that the light unit can deliver	1000-2000	2000
LIGHTTYPE	Source of the leaf illumination. 0=Sunlight, 1=LED and fluorescent, 2=Incandescent (Tungsten etc)	0-2	0

Parameters for control of the CO_2 and H_2O concentrations in the REF and cuvette air.

Parameter	Function	Range	Default
CONTROL(C/H)	Required CO_2 and H_2O concentrations	CO_2 0-MAXC H_2O 0-100	1000 100
CTYPE/HTYPE	Value determines the type of control.	CTYPE 1-3 HTYPE 0-4	1 1

The following parameter is measured by PP Systems then recorded in the CIRAS-2 firmware.

MAXC	Used in determining CO_2 controller setting. It is the CO_2 concentration with the CO_2 solenoid valve fully open.	1800-2800	N//A

On completion of the warming up phase, the air supply pumps is started. Measurements are done with data being transmitted through the RS232 port every 1.6 seconds.

Subsequently when a ZERO is done depends on the ZTYPE setting. Then ZEROs will continue to be done automatically after 5,10,20 and 30 minutes, and subsequently every 30 minutes. (See Table 8 Zero Options)

Depending on ZTYPE, about 40 seconds after the completion of ZERO, there will be a DIFF-BAL. This will also be done if the CO_2/H_2O REF changes by more than 100ppm/5mb.
Note. The REF concentration is unsteady then DIFF-BAL is inhibited.

Measurement Averaging

The CO_2/H_2O measurements are normally subjected to an averaging process. This consists of comparing the current reading and the stored average reading (both raw data). If the difference exceeds the AV LIMIT ppm then the current reading replaces the average, otherwise the current reading is incorporated into the average. The average reading is then linearised etc to give the measured concentration. The default AV LIMIT is 30 units corresponding to 3 ppm for CO_2 and 0.2mb for H2O. If the AV LIMIT is set to 1 then averaging is disabled, giving instantaneous readings. The averaging band is increased as AV LIMIT is increased, up to a maximum of 999 units. The AV LIMIT is set up from the PC (refer to the Remote Control Section).

Recording

The analyser records data internally at the interval set by the operator. When the database is full (820 records) then recording stops. The operator can initiate transfer of stored data to a PC as required. Refer to the Remote Control Section.

Use of Older Style Cuvettes and Chambers

It is possible to use all models of PP Systems cuvettes, chambers and probes with CIRAS-2.
These include:
PLCs, Chambers (Closed / Open Canopy and Soil Respiration) and Environmental Sensors.
Below is a table listing the changes required.

Identification of Leaf Cuvette Types

CIRAS-1 was introduced in 1992. Since that time, there have been several changes in the design of cuvettes. In the following, (U) refers to UNIVERSAL, (B) refers to BROAD, (R) to RICE , (N) to NARROW (C) CONIFER and (P) to POD style cuvettes.

Along with the CIRAS-2, we have produced a new type of auto-cuvette, the PLC6 (U) Universal which uses a series of inserts for differing types of leaves. Our CIRAS-2 will also work with any of our previous cuvettes. For safe and accurate operation, CIRAS-2 must be set up with control parameters for the type of cuvette that is in use. Cuvettes supplied with CIRAS-2 and the PLC6 (U) will already be labelled. But if you are using an older cuvette, you must identify it. The following tables will help.

Examination of the window material, its shape and size, and the size of the leaf aperture that can be seen beneath it, will lead to the identification of your cuvette.

Cuvettes fitted with a Flat Glass Window

Cuvette	Type	Dimensions of Window	Leaf Aperture
PLC4 (N)	Manual	50mm x 25mm	
PLC5 (N)	Manual or Automatic	85mm x 32mm	
PLC4 (B)	Manual	25mm x 25mm	18mm Diameter
PLC4 (R)	Manual	25mm x 25mm	7mm x 25mm
PLC5 (B)	Automatic	32mm x 32mm	18mm Diameter
PLC5 (R)	Automatic	32mm x 32mm	7mm x 25mm

Table 5 Identifying Cuvettes with Flat Glass Windows

Cuvettes fitted with a Plastic Hemi-Cylinder

Cuvette	Type	Diameter of Cylinder	Length of Cylinder
PLC4 (C)	Manual	50mm	70mm
PLC5 (C)	Manual or Automatic	50mm	85mm
PLC4 (P)	Manual	25mm	100mm
PLC5 (P)	Manual or Automatic	25mm	85mm
PLC5 (B)	Automatic	32mm x 32mm	18mm Diameter
PLC5 (R)	Automatic	32mm x 32mm	7mm x 25mm

Table 6 Identifying Cuvettes with Plastic Hemi-Cylinder Windows

Having identified the cuvette type, we recommend placing a label on your cuvette or document it somewhere in your operator's manuals for future reference.

CIRAS-2 Settings for Differing types of Leaf Cuvettes and Probes.

For CIRAS-2 to work correctly with the various types of cuvettes, the CIRAS-2 control parameters must set up accordingly. These values are listed in Appendix 2.

Apart from leaf area (cm^2), Rb (Boundary Layer) ($m^2\ s\ mol^{-1}$), flow (mls $minute^{-1}$) and TR (W μmol^{-1}), the remaining values are dimensionless.

The Rb values are typical for the cuvette type, though you may prefer to use the values recorded on the cuvette. The flow values are those recommended for that type of cuvette.

The area values should be set to the proper values, the values listed are to ensure that a typical value is there for the calculations.

SUN, LED, and QI refer to the type of light incident on the leaf. SUN values should be used under normal daylight, LED with the PP Systems LED light unit and with any fluorescent lights and QI with any incandescent lamps or quartz halogen bulbs.

If you are using PLC4 (B/R) or PLC5 (N) (C/P) with a CIRAS-2, then use the settings that are listed for these cuvettes when used with CIRAS-1

PLC	DELTA COOL	MAX COOL	MAXQ	RAD X	LAR	Rb	FLOW	SUN PARX	SUN TR	LED PARX	LED TR	QI PARX	QI TR
CIRAS-1 PLC's Adapted for CIRAS-2													
AUTO													
PLC5(B)	9	190	2000	1.0	2.5	0.3	200	1.0	0.17	1.0	0.14	1.0	0.16
PLC5(R)	9	190	2000	1.7	1.7	0.3	200	1.0	0.17	1.0	0.14	1.0	0.16
PLC5(N)	20	190	1000	(1.0)	10	0.15	300	1.0	0.17	1.0	0.14	1.0	0.16
PLC5(C/P)	20	190	1500	(1.0)	10	0.15	400	1.0	0.23	1.0	0.15	1.0	0.19
MANUAL													
PLC4(B)	(9)	(190)	(2000)	(1.0)	2.5	0.3	200	1.0	0.14	1.0	0.12	1.0	0.12
PLC4(R)	(9)	(190)	(2000)	(1.0)	1.7	0.3	200	1.0	0.14	1.0	0.12	1.0	0.12
CIRAS-2 PLC6(U) with INSERTS													
Broad	14	255	2000	2.5	2.5	0.3	200	1.0	0.17	1.26	0.14	1.26	0.16
Rice	14	255	2000	2.5	1.7	0.3	200	1.0	0.17	1.26	0.14	1.26	0.16
Large.	14	255	2000	2.5	4.5	0.3	300	1.0	0.17	1.26	0.14	1.26	0.16

PLC (B/R) MANUAL and PLC(N) (C/P) supplied with CIRAS-2 are Identical to those listed for CIRAS-1

The default setting of AVLIMIT is 30 (=3ppm) for all the above.

PROBETYPE 3 External Air Supply Open Systems. Parameter for PP Systems standard units.

Type	FLOWZERO	FLOWX	AVLIMIT
5 Litre	1250	7.63685	100
20 Litre	5000	30.5474	100

When using **CLOSED SYSTEMS**, the PROBETYPE should be set to 1 and the AVLIMIT to 1.0.

When the PROBETYPE is set to 1 or 2, the PARX value should be set to 2. The PAR will then be correctly output with RH/T/PAR sensors. For Oxygen, 30% will be equal to a PAR reading of 3000.

Adapters required for fitting older PLCs, Chambers and Sensors to CIRAS-2.

PLC5(B/R) Auto	New cable to plug into connector on the cuvette handle.
PLC5(N/C/P)	Return to PP Systems when a socket similar to that on the PLC5(B) will be fitted to the rear of the cuvette handle.
PLC4(B/N/C/P) (Standard Cuvettes) Closed Canopy and & Environmental Sensors	Requires an adapter box that plugs into the CIRAS-2 PLC connector. The cuvette /chamber/sensor then plugs into this box.
SRC-1 Soil Respiration Chamber	Requires additional interface cable which connects to the “Probe” socket.
Open Canopy and Inflatable Chambers.	Return to PP Systems for fitting of new circuitry and plug.

Simultaneous Measurements with CIRAS-2 AND FMS-2

The fluorescence probe fits into the light unit. The standard CIRAS-2 cuvette window is an interference filter that transmits only visible light. This must be replaced by plain glass when using the fluorescence probe.
Because of the increased heat load on the leaf with the plain glass the TRANS value must be changed as shown below.

WINDOW	SUN	LED	QI
CALFLEX	0.17	0.14	0.16
PLAIN GLASS	0.24	0.14	0.19

The connector to the FMS-2 plugs into the PROBE socket on the CIRAS-2. A pulse on the alarm line (about 140ms) triggers the FMS-2 to record a fluorescence trace.

The pulse is triggered when the cuvette record button is pressed, when CIRAS-2 records data direct into its memory or when the PC requests that it is sent.

Standard Serial Outputs.

All outputs are strings of 80 characters starting with a <SPACE> (<SP>) and ending with a <CARRIAGE RETURN> <CR>.
Extra spaces are inserted at the end of the string before <CR> to pack the string out to the correct length.

Output On Start Up (Warm Up)

<SP>W,+nnn<SPx72><CR>
Repeated at approximately 1.6 second intervals until the operating temperature is reached.
nnn is the Analyser Temperature x 10.

Output During ZERO

<SP>Z,+nnn<SPx71/72><CR>
Repeated at approximately 1.6 second intervals until ZERO is completed.
nnn is the count of the analyser read cycles going from 000 to 019.

Output During DIFF-BAL

<SP>Y,+nnn<SPx71/72><CR>
Repeated at approximately 1.6 second intervals until DIFF-BAL is completed.
nnn is the count of the analyser read cycles going from 000 to 029. The exact count depends on when CIRAS-2 is satisfied with the value.

Output During Measurement

During measurements CIRAS-2 transmits a complete data string every 1.6 seconds/(or 3.2 seconds).

BYTE		1		2		3		4		5		6	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
SP	M	D	D	M	M	H	H	M	M	S	S	P	P
		DATE		MONTH		HOUR		MIN		SEC		PROBETYPE	

* = Position of the decimal point.

BYTE	7		8		9		10		11		12		13	
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	C	C	C	C*	C	+/-	C	C	C*	C	Q	Q	Q	Q*
	REF CO_2					DIFF CO2					PAR			

BYTE	14		15		16		17		18		19		20	
	29	30	31	32	33	34	35	36	37	38	39	40	41	42
	H	H*	H	+/-	H	H*	H	H	T	T*	T	A	A*	A*
	REF MB			DIFF MB					PLC TEMP			##LEAF AREA		

##Position of the decimal point depends on the PROBETYPE setting.
Type 3, Open systems use 1 to 999 whist all others are 0.1 to 99.9

BYTE	21		22		23		24		25		26	
	43	44	45	46	47	48	49	50	51	52	53	54
	F	F	F	F*	E	V	A	P	Gs	Gs	Gs	Gs
	##FLOW				TRANSPIRATION				GS			

Flow= 0-9999 ml $min^{-1.}$ .With PROBETYPE 3, GS is the multiplier on the flow.

BYTE	27		28		29		30		31		32	
	55	56	57	58	59	60	61	62	63	64	65	66
	Ty	T	T*	T	+/-	A	A*	A	Ci	Ci	Ci	Ci
	LEAF TEMP.				ASSIMILATION				Cinternal			

33		34		35		36		37		38		39	
67	68	69	70	71	72	73	74	75	76	77	78	79	80
A	T	M	P	S	C	SB	L	B*	V	R	B*	V	CR
ATMP				S CODE		SB	LEFT BV			RIGHT BV			CR

The following describes each variable in the record.

M Start Character

DDMM Date (Day and Month) when the record was made.
HHMMSS Time (hour, minute and second) when the record was made.

PP PLC/Probe Type

Code	**Type**
0	Analyser Only
1	Environmental Sensors (RH/T/PAR)
2	Oxygen Probe
3	External Air Supply Open Systems with Flow read in on PLC RAD Input (PIN D) e.g. Inflatables/Canopy.
4	Standard Cuvettes
5	Auto Cuvettes

NB CIRAS-2 Air Supply is available only with Probe Types 4 and 5.

REF CO2 (nnnn.n) Reference CO2 concentration in ppm by volume, corrected to 1 bar atmospheric pressure and for cross sensitivity to water vapour

+DIFF CO2 (+/-nnn.n) Difference in the CO2 concentration in ppm between the analysis and reference corrected as above. If the analysis cell concentration exceeds the reference then the difference is positive

PAR (nnnn) Photosynthetically Active Radiation measured by the PAR sensor.
Units of measurement are micromol.$m^{-2}.s^{-1}$
N.B. If an Oxygen Tansducer has been set (Probe Type 2) then this value will be (%Oxygen x 10)

REF MB (nn.n) Reference water vapour concentration in millibars corrected to 1 bar atmospheric pressure

+DIFF MB (+/-nn.nn) Difference in water vapour concentration in millibars between the reference and analysis cells corrected as above.

PLC TEMP (nn.n) Cuvette air temperature in degrees Celsius

LAR (nn.n or nnn) Leaf Area entered by the user into the program

FLOW (nnnn) Flow rate in ml/minute at 20 ºC and 1 bar.
If the user has selected External pump then the flow is that entered by the user.
If Internal has been selected then the flow is that measured by the internal mass flow meters.

The following are calculated assimilation related parameters.

TRANSPIRATION (nn.nn) — Calculated transpiration rate from the leaf. In millimol (H_2O) $m^{-2}.s^{-1}$

GS (nnnn) — Calculated stomatal conductance in millimol. (H_2O) m^{-2} s^{-1}.

LEAF TEMPERATURE (0/1/2nn.n) — Type and magnitude of the Leaf temperature in ºC where:-
- 0 = Energy balance calculation
- 1 = Leaf thermistor measurement
- 2 = Radiation sensor measurement

ASSIMILATION (+/-nn.n) — Calculated assimilation rate in micromol (CO_2) m^{-2} s^{-1}. (+ = CO_2 uptake / - = CO_2 evolution)

CInternal (nnnn) — Calculated sub-stomatal CO_2 concentration in ppm by volume

ATMP (nnnn) — Atmospheric pressure in millibars measured at the reference cell outlet

SCODE (nn) — Status Code (See Status Codes for details)

SB (n) — Shows the current power source being used.
- 1 = Left Battery
- 2 = Right Battery
- 3 = External Power

LBATV and RBATV (nnn) — The respective battery voltages x 10.

Modification Of Record Structure Due To Accessories

RH/T/PAR Probes. (PROBETYPE = 1)
- TRANSPIRATION = %Relative Humidity (Max 99.9)
- PLCTEMP = Probe Temperature
- PAR = PAR measured by Light Sensor

Oxygen Sensor. (PROBETYPE = 2)
- PAR = %Oxygen x 100

External Air Supply Open Systems with Flow Read in on RAD Input (PROBETYPE 3)
E.g. Canopy / Inflatable chambers, Open System Soil Respiration Chambers.

FLOW = nnnn and the CI reading is the multiplier on the flow.
E.g. Flow =8971 and CI=1 = 8971 ml minute^{-1}.
Flow =1210 and CI=100 = 121,000 ml minute^{-1}

AREA is scaled 0-999cm^2.

Output of Stored CIRAS-2 Data

The record data string is similar to the measurement string except it starts with P rather than M and it terminates with the transmission of CInternal. The string is still 80 Characters long, packed out with <SP>.

PC/CIRAS-2 Communication Protocols.

To initiate communication the PC sends a single ASCII upper case alphabetic character to CIRAS-2 without a <CR>.

If a Q is sent or a character is not valid (that includes lower case!!) then CIRAS-2 will resume what it was doing.
Also if the PC fails to follow up with further characters, if these are required, then after a short time the same will happen

All data strings sent from CIRAS-2 start with a <SPACE> and end with <SPACES> to give a string length of 80 characters including the final <CR>.

Alarm Line Control

PC sends: <A>

CIRAS-2 responds with <SP><A><SPx77><CR>

PC then sends 1,2 or 3

1 = Alarm Line High
2 = Alarm Line Low
3 = High Pulse on Alarm Line of Approximately 140 milliseconds.

Request From PC For the Current Operational Parameters

PC sends: - <B>

CIRAS-2 responds with <SP><B><SPx77><CR>

Now the PC sends out <1 to 8> to indicate which parameters are required.

Each string returned by CIRAS-2 has a leading identifier of <SP><B><n>, where n is the string type.

If the PC requests 0 then strings 1 to 8 are consecutively sent.

After sending a string CIRAS-2 returns to the measure mode.

Analyser Settings

<SP>B1
ZTYPE
AVLIMIT
SAMPLEFLOW
PUMPMODE
RECORDTIME
<SP><CR>

Table 7 String 1: Analyser Settings

ZTYPE

This value controls the ZERO/DIFF-BAL. The following Table shows the 4 options.

ZERO Options

ZTYPE Value	CIRAS-2 Action
0	When ZERO or DIFF-BAL is required then an Error code 01 or 02 respectively is sent to the PC and is repeated until the PC initiates that action by transmission to the CIRAS-2.
1	When ZERO or DIFF-BAL is required the CIRAS-2 initiates immediately.
2	When ZERO is required then this is initiated by the CIRAS-2. DIFF-BAL offsets are calculated from values stored in the CIRAS-2 memory under PC control.
3	Both ZERO and DIFF-BAL are suppressed and the PC must determine when they are required and then initiates.

Table 8 Zero Options

After restarting CIRAS-2 defaults to Option 1.
NB Option 3 must be used with care.

AVLIMIT

The outputs from the CIRAS-2 analysers are normally subjected to an averaging process. This consists of differencing the linearised current reading and a stored average reading. If the difference exceeds the AV LIMIT then the current reading replaces the average, otherwise the current reading is incorporated into the average. The default AVLIMIT is 30 units corresponding to 3 ppm for CO_2 and 0.2mb for H_2O. If AVLIMIT is set to 1 then averaging is disabled, giving instantaneous readings. The averaging band is increased as AVLIMIT is increased, up to a maximum of 999 units.

SAMPLEFLOW

This is the flow through the analyser cells. The possible setting range is 50-100mls/minute when cuvettes are present. In analyser only mode it can be set to ZERO. The flow will always return to 100 for ZERO and DIFF-BAL.

PUMPMODE

0 CIRAS-2 air supply pumps off.
If a flow value is entered then this value will be used in any photosynthesis calculation.
1 Cuvette air supply pumps on.
The selected cuvette airflow value will set the main air supply pump's flow.

RECORDTIME

This is the setting for recording in CIRAS-2. If it is set to 0 then recording is off, otherwise records will be taken at time intervals indicated by the value of RECORDTIME.
The value is in 10 second intervals therefore 6 = one minute.
When the database is full (820 Records) then recording ceases.
If a PLC is connected and the record button on the cuvette is pressed then CIRAS-2 will transmit R<CR> but does not record the data in CIRAS-2.

Cuvette Parameters

<SP>B2,
PROBETYPE
PLCFLAG
LTCAL
TRANS
RB
PARTYPE
LIGHTTYPE
RSFRACT
<SP><CR>

Table 9 String 2 : Cuvette Parameters

These factors refer to CIRAS-2 operating as a photosynthesis system.

PROBETYPE

This is the current type of cuvette or chamber that CIRAS-2 believes is connected.

0 Analyser only.
1 PP Systems RH/T/PAR probe connected
2 PP Systems Oxygen Probe connected.
3 Inflatable and Open System Canopy Chambers.
4 Standard PLC's with no control of temperature or light.
5 Cuvettes with Auto control of light and, in some cases, also temperature.

PLCFLAG

Set by CIRAS-2 to inform the PC if a cuvette is present.
(CIRAS-2 determines the presence of a cuvette by reading the cuvette air temperature. Absence is indicated by a reading of 800.)

LTCAL

Type of leaf temperature determination.
0 = Energy Balance Calculation
1 = Leaf temperature measurement by thermistor
2 = IR thermometry.

TRANS

Conversion factor from PAR measured by CIRAS-2 to energy absorbed by the leaf.

RB

Boundary Layer Resistance for a Leaf Cvette in m^2 s mol^{-1}

PARTYPE.

This determines whether CIRAS-2 measures the PAR (PARTYPE = 0) or uses the PAR value entered into PARTYPE.

LIGHTTYPE

Signifies to CIRAS-2 the type of light unit in use. This is required for setting the light controls.
0 = Ambient light.
1 = LED
2 = Quartz Halogen

RSFRACT

This represents the ratio of the evaporation from the upper and lower leaf surfaces.
This MAY also represent the stomatal distribution. It can have values from 0 (= 0:100 = all stomata on one side) to 0.5 (50:50)

Auto Cuvette Control Parameters

<SP>B3
DELTACOOL
MAXCOOL
MAXQ
RADX
FLOWZERO
FLOWX
PARX
<SP><CR>

Table 10 String 2 : Auto Cuvette Parameters

DELTACOOL / MAXCOOL / MAXQ / RADX

These are factors used for setting the initial cooling/heating current and the maximum cooling current for the peltier elements, the maximum light intensity and the gain of the IR temperature sensor on PLC AUTO cuvettes.

FLOWZERO / FLOWX

These are used when CIRAS-2 is connected to PROBETYPE 3 chambers.
They are used in converting the flowmeter reading coming in on the RAD input into flow units.

PARX

This is a gain factor on the PAR reading. It is normally 1.

Flow, Leaf Area and Cuvette Controls

<SP>B4
LAR
FLOW
CONTROLC
CONTROLH
CONTROLT
CONTROLP
CTYPE
HTYPE
<SP><CR>

Table 11 String 4 : Flow, Leaf Area and Cuvette Control

LAR

This is the leaf area used in photosynthesis calculations.
The current range of setting is 0.1 to 999.9 $cm^{2.}$

FLOW

If PUMPMODE is set to 0 then the value entered is used in CIRAS-2 calculations.
The maximum entry is 2500 $ml.min^{-1.}$.
If PUMPMODE is set to 1 then the entered value will be used to set the flow of the cuvette air supply pumps. The maximum entry is 470 $ml.min^{-1}$.
See Analyser Settings for PUMPMODE

CONTROLC / H / T / P

These are the control values for the CIRAS-2 cuvette air supply system and the auto cuvettes.
C = CO_2, H = H_2O, T = Temperature, P = PAR.
If CONTROLT is set to 0 then temperature control of an auto cuvette is off.
If CONTROLT is set to 50 then the cuvette temperature will try and track the ambient.

CTYPE / HTYPE.

These control the type of CO_2 and H_2O control for the CIRAS-2 air supply.

Analogue Output Settings.

<SP>B5
LOWC
LOWH
HIGHC
HIGHH
CDFF
HDFF
CALCO2
CALH2O
<SP><CR>

Table 12 String 5: Analogue Output Settings

LOWC, LOWH, HIGHC, HIGHH CDIFF and HDIFF

Settings for the CO_2/H_2O analogue outputs in ppm and mb respectively.

CALCO$_2$ / CALH$_2$O

Calibration concentrations in ppm and mb

Time and Date Settings

<SP>B6
DD
MM
YY
HH
MM
SS
<SP><CR>

Table 13 String 6: Time and Date Settings

Data String

Day,Month,Year,Hours,Minutes,Seconds

These are the readings of the CIRAS-2 Real Time Clock.

Calibration Factors

<SP>B7
RSFACC
RSFACH
ASFACC
ASFACH
RCDEFAULT
RHDEFAULT
ACDEFAULT
AHDEFAULT
<SP><CR>

Table 14 Sting 7: Calibration Factors

RSFACC / RSFACH / ASFACC / ASFACH

Current IRGA calibration constants.
The initial letter (R or A) refers to the Reference or Analysis cell whilst the final letter (C or H) indicates whether it is a CO_2 or H_2O IRGA.

RCDEFAULT / RHDEFAULT / ACDEFALUT / AHDEFAULT

Calibration constants recorded in the factory when CIRAS-2 was initially calibrated and they correspond to the factor immediately above them.

System Identification and Initial Checks.

<SP>B8
CHECKSUM
RECPTR
FREEREC
PROM VER
SERIAL NO
CIRAS-2 TYPE
DATAFREQ
<SP><CR>

Table 15 String 8: System Identification and Initial Checks

CHECKSUM

This should be 123456. If it is 000000 then CIRAS-2 on starting up has detected that its data base is corrupted, and has reset all its variables to default.

RECORD POINTER

Decimal value of the memory address for the next unused new record.

FREE RECORDS

Number of records that can still be taken before the database is full.
These are related by the following: -

(RECORD POINTER) =
(START OF DATA BASE) + ((MAXIMUM RECORD NUMBER)-(FREE RECORDS * RECORD SIZE))

START OF DATA BASE = 6496
MAXIMUM RECORD NUMBER = 820
RECORD SIZE = 32

If the values do not agree then the record pointers are corrupted.

CIRAS-2 has two pointers to its record store. One is to the number of records currently stored, the other is the address of the next free record. Very rarely the pointers can get out of line if CIRAS-2 is switched off in the middle of recording, resulting in one being updated without the other. On start up, CIRAS-2 checks that the pointers agree. If they do not, then the pointers will be reset to the end of the database, and the above calculation will give an error. It is now possible to dump the complete database and examine the contents for valid records. When cleared the database is filled with 000, so it is easy to separate out valid records. Now the memory must be cleared.

PROM VER

Current version of the CIRAS-2 firmware.

SERIAL NUMBER

CIRAS-2 serial number.

CIRAS-2 TYPE

10	CIRAS-1	20	CIRAS-2
11	CIRAS-1 DC	21	CIRAS-2 DC
12	CIRAS-1 SC	22	CIRAS-2 SC

DATAFREQUENCY

CIRAS-2 normally sends out data at 1.6 second intervals. Slow PCs may have trouble keeping up so it possible to halve the rate. This shows the rate currently in use. (0 = 1.6, 1 = 3.2seconds)

PC/CIRAS-2 Interactions During Calibration

Calibration concentrations should be set up before commencing

Calibration starts with the PC sending C>.

CIRAS-2 responds with: -
<SP>C,RSFACC,RSFACH,ASFACC,ASFACH,RCDEFAULT,RHDEFAULT,ACDEFAULT,AHDEFAULT<SPACES><CR>
See Calibration Factors

CIRAS-2 will now ZERO and then return to the measurement mode with the solenoid valves set to Diff-Bal so that the REF air sample passes through both the reference and analysis analyser cells. Also the Diff-Bal factors are set to ZERO so that the true analyser readings are displayed.
At this stage CIRAS-2 does not know what type of calibration is proposed.

CIRAS-2 now transmits: -

<SP>C
CO_2 CALIBRATION VALUE
REF CO_2
AN CO_2
H_2O CALIBRATION VALUE
REF H_2O
AN H_2O
SOURCE BAT
BAT LEFT V
BAT RIGHT V
<SPACES><CR>

Table 16 Calibration String

EXPECTED CO_2

The calibration concentration or if the internal calibrator is used, then it is the factory determined value corrected for the current temperature.

EXPECTED H_2O

The calibration concentration or if the H_2O calibrator is used, then it is the value calculated from the FeSO4.7 H_2O temperature.

If using the H_2O calibrator check that ERROR CODE 83 is not being transmitted which means that the calibrator is too warm and there is a risk of condensation. Assuming there is no error code then connect the calibrator pipes.

When the readings are steady then the PC sends: -

FOR CO_2 CALIBRATION “1”
or
FOR H_2O CALIBRATION “2”

CIRAS-2 sends <SP>F<SPACES><CR> whilst it is determining the calibration constants.

On completion of calibration CIRAS-2 sends: -

<SP>C,(1 2or 3), RSFACC,RSFACH,ASFACC,ASFACH<SPACES><CR>

Where 1 and 2 refer to the type of calibration. 3 means that the values determined are outside the acceptable range and CIRAS-2 immediately returns to the normal measurement mode with the original calibration factors restored.
Otherwise CIRAS-2 continues sending the measurement string with the leading C until the PC sends "4", "5" or "6", when CIRAS-2 returns to the normal measurement mode. The scaling factors that CIRAS-2 uses depends on the value sent by the PC

"4"= Use values determined by the new calibration.
"5"= Restore to the previous calibration values.
"6"= Reset scaling factors to original factory determined values.

N.B. Only the CO_2 or H_2O will be involved depending on the type of calibration that has been done.

Sending Q will abort the calibration at any stage.

Setting CIRAS-2 Analyser Calibration Factors to the Factory Default.

This starts with the PC sending <C>.

CIRAS-2 responds with: -
<SP>C,RSFACC,RSFACH,ASFACC,ASFACH,RCDEFAULT,RHDEFAULT,ACDEFAULT,AHDEFAULT<SPACES><CR>
See Calibration Factors

CIRAS-2 will now ZERO and on completion transmits the data string starting with C, similar to that in the calibration mode, though the values at this stage are irrelevant.

<SP>C,EXPECTED CO_2, REF CO_2, AN CO_2, EXPECTED H_2O, REF H_2O, AN H_2O <SPACES><CR>

As soon as this is received then the PC should send <0>.

CIRAS-2 will then return to the measurement mode using the factory default calibration factors.

Diagnostics

PC sends D (without <CR>).
CIRAS-2 responds with <SP>D<SPx 77><CR>.
PC now requests the diagnostic string required by sending (1-5), again without <CR>.

CIRAS-2 will continue sending the string until stopped by the PC. (With String 1, a block of historic ZERO reads is first transmitted followed by the current analyser readings).

Each string starts with an identifier followed by comma delimited values.

To terminate transmission the PC sends:-
Either Q =QUIT
Or D = to continue with another Diagnostic String.

Analyser Readings in ZERO, DIFF-BAL and MEASURE

This is for checking the analyser functions and changes in the A/D values at ZERO can be a useful diagnostic tool.

Immediately after CIRAS-2 is made, there is an initial increase in the ZERO readings, which is possibly due to an increase in source intensity or an increase in cell reflectivity as volatile elements evaporate from the cell surfaces. This is followed by a gradual decline with age, probably due to decrease in source intensity and a gradual loss in reflectivity with the build up of contaminants.

Rapid changes could indicate problems with absorber chemicals, leaks or cell damage.

Whenever the CIRAS-2 does a new ZERO then the values are first checked that they exceed 33000 and they are then compared with the current ZERO. If they differ by more than 100 units an error is flagged and CIRAS-2 continues using the current value and not the new.

Whenever CIRAS-2 has been switched on for 20 minutes then the zero value at that time is stored. Six sets are kept (corresponding to the last six times the analyser was used). A quadratic fit of these values is done and the average difference between successive values must be less than 100 units otherwise an error is flagged.

In Diagnostics, CIRAS-2 is first switched to ZERO mode then the 6 stored sets are transmitted (oldest first) followed by the current ZERO. The CIRAS-2 then continues to transmit the current analyser readings = on going ZERO, to give the opportunity for trouble shooting.
If the instrument has been on more than 20 minute and no error has been flagged then the current and the latest in memory should be similar.

If the user has entered the Diagnostics because a ZERO error has been flagged then the user should try to correct the live ZERO measurement to align with the stored values. If the problem has been deterioration in the absorbers so that the live ZERO is significantly greater than the stored then on completion the user should opt to reset the store to prevent further error flags.

The Zero error messages at the end of the data string can only be cleared by going into Diagnostics or switching off and restarting CIRAS-2, or by re-initialising.

For further tests of the analyser operation the analyser can be switched to Diff-Bal and measure mode.

<SP>D1,	1,	RZH,	AZH	RZC,,	AZC	DAY,,	MN,	HR<SPs><CR>
<SP>D1,	2,	“	“	“	“	“	“	“
<SP>D1,	3,	“	“	“	“	“	“	“
<SP>D1,	4,	“	“	“	“	“	“	“
<SP>D1,	5,	“	“	“	“	“	“	“
<SP>D1,	6,	“	“	“	“	“	“	“
<SP>D1,	7,	“	“	“	“	“	“	“

Table 17 String 1: Diagnostics Stored Zeros

String(7) is the current ZERO values.

RZH / AZH / RZC / AZC

Stored ZERO values, R=REF, H=H_2O, and C=CO_2.

DAY / MN / HR

Day, Month and Hour when the ZERO was done.

This is followed by: -

<SP>D1
NN
RMH
AMH
RMC
AMC
ANT
ATP
DP
AFLOW
RFLOW
<SPs><CR>

Table 18 String 1 : Diagnostic Analyser Readings

NN

The current operational mode of the analyser.
1 = Measure
2 =Diff-Bal
3 = Zero.

RMH / AMH / RMC / AMC

Current analyser readings.

ANT

Analyser temperature in Degrees C x 10

ATP

Atmospheric pressure measurement in mb.

DP

Differential pressure between the REF and AN cells x 100 mb.

AFLOW and RFLOW

The analyser sample flows.

Control Options in Analyser Diagnostics

PC Sends:

1	CIRAS-2 valves to Measure
2	CIRAS-2 valves to Diff-Bal
3	CIRAS-2 valves to Zero
R	Reset the Zero Store. This is followed by Zero, then return to measure (Exits Diagnostics).
Q	Quit
D	See Above

NB All without <CR>.
Entering this Diagnostic or restarting CIRAS-2 is the only way to clear a ZERO Error Code.

System Temperature Sensors and Cuvette Outputs

(Also PP Systems Environmental Sensor Inputs.)

<SP>D2,
TAMBx10,
TCUVx10,
TLEAFx10,
BLENDERTx10,
RAD,
PLCSTATE,
PROBETYPE,
<SP><CR>

Table 19 String 2 : Diagnostic System Temperatures and Cuvette Outputs

TAMB

Ambient temperature measurement on the cuvette.

TCUV

Cuvette air temperature.

TLEAF

Either the temperature shown by the leaf thermistor or the base temperature of the IR thermometer if this is fitted.

BLENDERT

Temperature of the CO_2 mixer.

All temperatures are displayed as x 10. i.e. 500 = 50^{o}C and if the sensor is not connected the display is 800.

RAD

Reading of the IR temperature sensor.(0-1023 with a reading of 512 if the sensor target is at the same temperature as the IR sensor base).

PLCSTATE

Indicates whether the cuvette is Open (0), Closed (1), or the Record button is pressed (2).

PROBETYPE

Type of sensor or PLC that the CIRAS-2 believes is connected. The starting value in this section is 4, which is a Standard PLC.

NB Using a PP Systems RH/T/PAR Sensor and setting the PROBETYPE to 1, then RAD is the %RH, TLEAF is the Air temperature and PAR is itself.
An Oxygen sensor's input is read as PAR.
To see the PAR reading it is necessary to go to Auto Cuvette Controls.

(Only one sensor should be connected and the PROBETYE should be correctly set.

Sensor Type	**Input on**	**Range(1V=)**	**Display**	**Real Units**
PAR	PAR	3000mmol.$m^{-2}.s^{-1}$	0-1500	DISPLAY x 2
RH	RAD	100.0%	0-409	DISPLAY / 4.092
TEMPERATURE	TLEAF	50ºC	0-409	DISPLAY / 8.184
OXYGEN	PAR	30.0%	0-1500	DISPLAY x 0.02

See Cuvette Parameters for Possible Probe Types

Control Options in Temperature and Cuvette Diagnostics

PC Sends:

0-5	Probe Type
Q	Quit
D	See Above

NB All without <CR>

System Flows and Air Supply Controls

<SP>D3,
AFLOW,
RFLOW,
SAMDRV,
FFLOW,
CFLOW,
FLOW,
FLOWSET,
FLOWCN,
CO_2CN,
H_2OCN,
<SP><CR>

Table 20 String 3 : Flow and Air Supply Diagnostics

AFLOW / RFLOW

Flow rates through the analyser cells.(ml minute^{-1})

SAMDRV

Setting of the D/A converter whose output controls both the above.

FFLOW

Reading of the forwarding pump flowmeter.

CFLOW

Reading of the main air supply flowmeter.

FLOW

Conversion of the above to ml minute^{-1}.

FLOWSET

Cuvette flow currently requested.

FLOWCN

Setting of the D/A converter controlling the main air supply pump.

CO_2CN and H_2OCN

The settings of the D/A converters controlling the respective solenoid valves.

Control Options in Flow and Air Supply Diagnostics

PC Sends

1	Sample Flow D/A Value (SAMDRV) (0-255)
2	FLOWSET Values (0-470).
3	FLOWCN Values (0-120)
4	CO_2CN Value (0-255)
5	H_2OCN Value (0-255)
Q	Quit
D	See Above

In response, CIRAS-2 sends <SP>V<SPx77><CR> and then the PC sends the setting value followed by <CR>

Auto Cuvette Controls

These are all measurement and control signals for the Auto PLC's.

<SP>D4,
PAR,
TCUV,
LT1CN,
LT2CN,
TLCN,
TPOLARITY
<SP><CR>

Table 21 String 4 : Auto Cuvette Diagnostics

PAR

Reading of the PAR sensor.
(NB See System Temperature Sensors and Cuvette Outputs for modification of the PAR reading by RH/T/PAR and O_2 sensors.)

TCUV
Cuvette air temperature.(x 10 $^{\circ}$C)

LT(1/2)CN

Settings for D/A converters controlling the respective lamp current.

TLCN

Setting of the D/A converter controlling the peltier current.

TPOLARITY

Setting of the D/A converter controlling the direction of the peltier current that determines whether the cuvette is heated or cooled.

Control Options in Auto Cuvette Diagnostics

PC Sends:

1	LT1CN (0-255) (Lamp 1 AND LED)
2	LT2CN (0-255) (Lamp 2)
3	TLCN (0-255) (Peltier Drive)
4	TPOL (0 OR 255) (0=Cool / 1=Heat)
Q	Quit
D	See Above

In response, CIRAS-2 sends <SP>V<SPx77><CR> and then the PC sends the setting value followed by <CR>.

System Power Supplies

These relate to power supply voltages and power source.

<SP>D5,
BOARDV,
PLCV,
LEFTBATV,
RIGHTBATV,
SOURCEBAT
<SP><CR

Table 22 String 5 System Power Diagnostics

BOARDV

Voltage measured on the CIRAS-2 main PCB.

PLCV

Voltage of the external power source when it is connected to the Auto PLC.

The above voltages are x10.

LEFT/RIGHT BATV

Voltages of the CIRAS-2 batteries viewing CIRAS-2 in its normal operating position.
The voltages are x100.

SOURCEBAT

Shows the current CIRAS-2 power source.
1 = Left battery
2 = Right battery
3 = External Power supply.

Control Options in Power Diagnostics

PC Sends:
Q Quit
D See Above

CO_2 / H_2O Calibration Checking

These cannot be done simultaneously as the CO_2 checking makes use of the internal cuvette air supply whilst the H_2O checking requires the external connection of a PP Systems Water Vapour Calibrator. They can be done sequentially in either order without leaving the checking routine.

The CIRAS-2 should have been switched on at least 20 minutes.

Calibration checking starts with the PC sending <G>.

CIRAS-2 responds with: -
<SP>G,RSFACC,RSFACH,ASFACC,ASFACH,RCDEFAULT,RHDEFAULT,ACDEFAULT,AHDEFAULT<SPACES><CR>
and sets the cuvette air flow to 300mls/minute and the CO_2 flow control valve to fully open and then a ZERO is done. On completion of the ZERO the analyser control valves are set to DIFF-BAL mode so that the REF and AN air are both drawn from the REF inlet and the DIFF-BAL correction factor is set to 0.

Sending “Q” will terminate the checking mode.

CO_2 Calibration Checking

This should be done with a recently inserted CO_2 cylinder (< 12hours). The REF INLET and the CUVETTE AIR OUTLET should be connected to each other via a T-piece venting to atmosphere.

After the ZERO CIRAS-2 responds with: -

<SP>G,EXPECTED CO_2, REF CO_2, AN CO_2, EXPECTED H_2O, REF H_2O, AN H_2O, SOURCE BAT, BAT LEFT V, BAT RIGHT V <SPACES><CR>

Where: -
EXPECTED CO_2 is the factory determined value corrected for the current temperature.

The REF and AN CO_2 values should be within 1% of the EXPECTED.

If they are lower then check that there is flow from the CO_2 EXHAUST.
Check that all the ZERO columns are correctly inserted and not exhausted.
(Beware CO_2 in the Molecular Sieve)

H_2O Calibration Checking.

Initially only the electrical connector on the calibrator should be plugged into the PLC connection.

After the ZERO CIRAS-2 may respond with ERROR CODE 83 indicating that there is a risk of condensation then the checking must be aborted. Otherwise connect the calibrator air pipes. The REF INLET should be connected to the lower outlet pipe on the H_2O Calibrator and the REF and AN OUTLETS to the upper inlet pipes.

CIRAS-2 now transmits: -

<SP>G,EXPECTED CO_2, REF CO_2, AN CO_2, EXPECTED H_2O, REF H_2O, AN H_2O, SOURCE BAT, BAT LEFT V, BAT RIGHT V <SPACES><CR>
Where: -

EXPECTED H_2O is the value calculated by CIRAS-2 from the current ($FeSO_4.7\ H_2O$) temperature.

The REF and AN H_2O values should be within 0.5mb of the EXPECTED.
If they are lower then first check that all the ZERO columns are correctly inserted and not exhausted.

Initialise-Resetting The Operational Parameters To Default Values

PC sends:- <I>

Re-initialises CIRAS-2 to the factory defaults:-

Calibration Scaling Factors are not reset. They are always checked when CIRAS-2 is first switched on to ensure that they are within specification otherwise they are reset to the factory defaults.
The memory is cleared and recording is switched off.
Stored DIFF-BAL factors are cancelled and the Store Zero values used in Diagnostics are all set to 0.

The following are the parameter defaults.

ZTYPE	1
AVBIT	30
SAMPLEFLOW	100
PUMPMODE	0
RECORDTIME	0
PROBETYPE	0
LTCAL	0
TRANS	0.15
RB	0.30
PARTYPE	0
LIGHTTYPE	0
RSFRACT	0.5
DELTACOOL	10
MAXCOOL	200
MAXQ	2000
RADX	1
FLOWZERO	0
FLOWX	1
PARX	1
LAR	2.5
FLOWSTORE	150
CONTROLC	1000
CONTROLH	100
CONTROLT	0
CONTROLP	0
CTYPE	1
HTYPE	1
CALH2O	50
CALCO2	2000
LOWC	0
LOWH	0
HIGHC	2000
HIGHH	50
CDFF	100
HDFF	10

Table 23 CIRAS-2 Parameter Defaults

When completed, CIRAS-2 sends <SP><O><SPx77><CR>.(=O.K) and will restart in WARMUP.

Memory Clear

PC Sends: M

CIRAS-2 responds with <SP><O><SPx77><CR>. (=O.K) and clears the memory.
The memory is completely filled with 0000 etc.

CIRAS-2 then returns to the measurement mode.

Transfer To PC of Data Recorded On CIRAS-2

The maximum number of records taken and stored on CIRAS-2 is 820.

To start transfer PC sends <P> to CIRAS-2.

CIRAS-2 responds with:
<SP>P,nnn<SPACES><CR>

Where nnn is the number of records that will be transferred. If there are no records in memory then nnn=000.

CIRAS-2 then waits for the PC to send <P>.

If the PC does not respond within 10 seconds CIRAS-2 will return to the measurement mode.

On receipt of <P> CIRAS-2 then sends out the first record (The oldest in the database) and awaits <P> from the PC.

When there are no further records available the CIRAS-2 sends: -

<SP>P*<SPACES><CR>

and returns immediately to the measurement mode.

Quit Communication

If the PC sends <Q> then CIRAS-2 will always return to its normal measurement mode.

Set CIRAS-2 Operational Parameters

PC sends <S> to CIRAS-2 without <CR>.

CIRAS-2 responds with <SP><S><SP x 77><CR>.

PC now sends the data string. The first character in the data string must be the type of string that is being sent.

The string must only contain numeric characters and decimal points.

Values are separated by ",".

The last value must be terminated with <CR>.

For definition of the parameters see Request From PC For the Current Operational Parameters

STRING 1. Analyser Settings.

1,	ZTYPE,	AVLIMIT,	SAMPLEFLOW	PUMPMODE,
Cont	RECORDTIME<CR>			

STRING 2. Cuvette Parameters

2,	P,	LTCAL,	TRANS,	RB,
Cont	PARTYPE,	LIGHTTYPE,	RSFRACT<CR>	

STRING 3. Auto Cuvette control parameters

3,	DELTACOOL,	MAXCOOL,	MAXQ,	RADX,
Cont	FLOWZERO,	FLOWX,	PARX<CR>	

STRING 4. Flow,Leaf Area and Cuvette Controls

4	LAR,	FLOW,	CONTROLC,	CONTROLH,
Cont	CONTROLT,	CONTROLP,	CTYPE,	HTYPE<CR>

See Table 23 CIRAS-2 Parameter Defaults for details of default parameters for leaf cuvettes and sensors

STRING 5. Analogue Output Settings.

5	LOWC,	LOWH,	HIGHC,	HIGHH,
Cont	CDFF,	HDFF,	CALCO2,	CALH2O<CR>

STRING 6. Time and Date Settings

6,	DD,	MM,	YY,	HH,	MM<CR>

This is used for Clock Setting.
The date and time values must always be entered as 2 digits. e.g. 6,05,12,00,13,09<CR> = 5/12/00 13:09
The CIRAS-2 clock is reset to the new value.
After transmitting this string allow a few seconds until CIRAS-2 returns to measuring before interrupting again

STRING 8. Frequency of CIRAS-2 Data Transmission

8,	DATAFREQ<CR>

DATAFREQ controls the rate that strings are transferred to the PC.
0=1.6 seconds, for measurement strings and 300 millisecond delay between multiple parameter strings.
1=3.2 seconds and 600msecs.

After any input CIRAS-2 returns to the measure mode though, in the case of CLOCK SETTING, there is a few seconds delay.

Limits on Parameter Values.

ZTYPE	0 – 3 (see for description)	
AV.LIMIT	1 – 999 (ppm*10) 0=Averaging off	
SAMPLEFLOW	0-100ml/minute (PROBETYPE 0) 50-100 (Others)	
PUMPMODE	0=Air supply pump off 1= on (on only with PROBETYPE 4/5)	
RECORDTIME	0-360(0=off 360=Hourly)	
PROBETYPE	0-5	
LTCAL	0=Energy Balance 1=Leaf Thermistor 2=IR therrmometry	
TRANS	0.1 – 0.4	
RB	0.1 – 0.99 m^2 s mol^{-1}	
PARTYPE	0 OR ENTERED PAR UPTO 2500 micromol.m^{-2}.s^{-1}	
LIGHTTYPE	0=Ambient 1=LCD 2=Quartz Halogen	
RSFRACT	0-1	
DELTACOOL	1 – 50	THIS BLOCK OF PARAMETERS
MAXCOOL	100-255	ARE DETERMINED BY THE
MAXQ	1000-2000	TYPE OF PLC IN USE
RADX	0.5-5	
FLOWZERO	0-50000	
FLOWX	0.1-1000	
PARX	1-99	
LOWC	0 – (HIGHC-100)	
LOWH	0 – (HIGHH-10)	
HIGHC	100 – 2000 (ppm)	
HIGHH	10 – 75 (mb)	
CDFF	.25 – 999 (ppm)	
HDFF	5 – 50 (mb)	
CALCO2	0 – 2500 (ppm)	
CALH2O	10 – 75 (mb)	

Table 24 Limits on Parameter Values

Setting Up Stored DIFF-BAL Factors

On switch on CIRAS-2 always destroys the stored Diff-Bal factors, which therefore must be reset before that ZEROTYPE can be used.

Setting must be done either with the cuvette connected or with the CUVETTE AIR OUT connected to the REF IN through a vented T piece.

Setting requires 6 pairs of CO_2 and H_2O control values. These are normally sent in ascending order and each pair must be at least 15ppm and 0.5mb greater than the proceeding one.

To start the PC sends <X> to CIRAS-2 which will respond with <SP>X,0<SP x 77><CR>

The PC now sends S followed by string B4 to set the first set of CO_2 and H_2O control concentrations.

After the receipt of the first set, CIRAS-2 will ZERO. CIRAS-2 then sends out standard data-strings but with the leading <SP>M replaced by <SP>X. When the reference and analysis readings are steady the PC should send O (=OK). CIRAS-2 will now do a DIFF-BAL.

On completion CIRAS-2 sends <SP>X,1<SPACES><CR> and the PC should send the next control pair.

This is repeated for the remaining sets (X,2 to X,5).

On completion of the 6 sets, CIRAS-2 checks the differences between the pairs of reference values.(Measured not the set values) and if the values are less than required then CIRAS-2 sends <SP>E,77<SP x 76><CR> and returns to measurement mode.

Otherwise CIRAS-2 sends:-

<SP>X,6,AC,BC,CC,AH,BH,CH<SPACES><CR>

Where:-
A,B,C are the constant,1st order and 2nd order terms in a quadratic and C and H refer to H_2O and CO_2 respectively. The quadratic can be used to calculate the DIFF-BAL offset from the REF and AN concentrations. Please note the REF CO_2 must be in ppm/1000 and REF H_2O in mb/10.
E.G.

CO_2 DIFF-BAL OFFSET = AC + BC x (CO_2 / 1000) + CC x $(CO_2 / 1000)^{2.}$

H_2O DIFF-BAL OFFSET = AH + BH x (H_2O / 10) + CH x $(H_2O / 1000)^{2.}$

The PC should have noted the six sets of displayed REF and AN values and should now calculate from the REF values the DIFF-BAL offsets.

Meanwhile CIRAS-2 will have returned to the measuring mode set to the exact same state as it entered the DIFF-BAL SETTING routine.

If the results are satisfactory then CIRAS-2 can be reset to ZEROTYPE 2 , which will use the stored factors in determining the Diff-Bal offsets.

NB Sending Q at any time during the setting process returns CIRAS-2 to measuring in the same mode as it entered.

Initiate DIFF-BAL

PC sends <Y>

CIRAS-2 will immediately DIFF-BAL.

During DIFF-BAL CIRAS-2 transmits: -
<SP>Y,nnn<SPx75/76><CR
where nnn is the count of the measurement cycles (000 to 29.0) from starting DIFF-BAL. The count to completion varies depending on when CIRAS-2 judges that it has got a good value. If the criteria are not satisfied after 29 cycles then the DIFF-BAL is aborted.

Initiate ZERO

PC sends <Z>

CIRAS-2 will immediately ZERO during which it will transmit <SP>Z,nnn<SP x 75/76><CR>. ZERO is complete when the measurement cycle count (nnn) is 19.0.

Status and Error Codes

Status Codes are transmitted as part of the normal measurement string and represent information about the state of the system.

Status Codes

Code	Descriptor
00	System OK. Cuvette open if present [00]
01	Diff-Bal Required. Cuvette open if present [01]
02	Zero Required. Cuvette open if present [02]
10	Normal Running – PLC Closed [10]
11	Diff-Bal Required. Cuvette closed if present [11]
12	Zero Required. Cuvette closed if present [12]
20	Record Key Pressed, System OK [20]
21	Record Key Pressed, Diff-Bal Required [21]
22	Record Key Pressed, Zero Required [22]
70	
71	
72	
73	
74	
75	PLCTYPE set to Analyser only but there is an input from the air temperature sensor.[75]
76	PLCTYPE set to PLC but there is no input from the air temperature sensor.[76]
77**	Attempt by PC to initiate action before CIRAS-2 is warmed up.[77]
78**	Zero showing progressive changes. [78] ###
79**	New Zero significantly different from the previous one.[79] ###
80	Cuvette % Relative Humidity > 75% [80]
81	Forwarding Flow < Cuvette Flow [81]
82**	Stored Diff-Bal cannot be calculated.[82]
83**	Temp. of the $FESO_4$ too Hot. (Risk of Condensation) [83]
84	H_2O Control Out of Range [84]
85	CO2 Concentration Out of Range On Stored Diff-Bal [85]
86	H_2O Concentration Out of Range On Stored Diff-Bal [86]
87	Analysis/Reference Pressure Difference > 20mB [87]
88**	Time Out on Diff-Bal [88]
89**	Diff-Bal (CO_2) Out of Range [89]
90**	Diff-Bal (H_2O) Out of Range [90]
91	Cuvette Flow 20% out from set value [91]
92**	Zero too Low [92]
93**	Board supply voltage < 10.0 V [93].###
94	Flow Rate through the Reference Cell too High [94]
95	Flow Rate through the Reference Cell too Low [95]
96	Flow Rate through the Analysis Cell too High [96]
97	Flow Rate through the Analysis Cell too Low [97]
98	Analysis Temperature > 65° [98]
99	Analysis Temperature < 50° [99]

Codes marked ### are only cleared by entering Diagnostics or restarting.
Codes marked ** and the following are transmitted as a separate string of the following format: -
<SP>E,+NN<SPx73><CR>

See Also Status Codes: Diagnostics and Remedies.

Error Codes

Code	Descriptor
EC00	**Fatal BASIC error that has caused CIRAS-2 to re-boot.**
EC20	Divide by ZERO (CIRAS-2) [20]
EC30	Arithmetic Overflow (CIRAS-2) [30]
EC40	Arithmetic Underflow (CIRAS-2) [40]
EC50	Bad Argument (CIRAS-2) [50]

See Also Error Code Diagnostics

The following are transmitted during Warm-up, ZERO and DIFF-BAL.

<SP>W,+nnn<SPx 72><CR> where nnn is analyser cell temperature x 10.

<SP>Z,+nnn<SPx 71/72><CR> where nnn is the number of ZERO cycles going from 000 to 9.00 to 19.0/25.0
19 Cycles are taken for ZERO and this is done during the Warm-up. A further 6 cycles are added during the normal
ZERO to allow time to flush the cells with the REF / AN sample air.

<SP>Y,+nnn<SPx 71/72><CR> where nnn is the number of Diff-Bal cycles going from 000 to 9.00 to 29.0
The exact number depends on how soon a stable value is measured by CIRAS-2.

The following is transmitted when the cuvette record button is pressed.
<SP>R,<SPx 77><CR>.

Trouble-Shooting, Diagnostics & Servicing the CIRAS-2 System

The CIRAS-2 portable photosynthesis system is actually a number of instruments that have been combined into a single field-portable system. Often a problem with one component will manifest symptoms in other parts of the instrument. This can cause difficulty identifying the source of a particular problem. The best technique to over-come this is to isolate the system components and test each one separately. We recommend the following procedure:

1. Testing the CIRAS-2 as a CO2 / H2O Analyser Only
2. Testing the CIRAS-2 Analyser with the Integral Cuvette Air Supply
3. Testing the Leaf Cuvette with the CIRAS-2 System

Testing the CIRAS-2 as a CO_2 / H_2O Analyser Only

The CIRAS-2 IRGAs (infrared gas analysers) can be tested independently by disconnecting (electrically and gas lines) the leaf cuvette from the system. The reference and analysis ports should be connected together with a "Y" piece connector so they draw in air from a common gas stream (See below). Ideally, the gas should be of a known constant concentration. However, if this is unavailable, atmospheric air can be drawn in from a site that is located away from extraneous CO_2 sources such as roadways, vents or chimneys etc. It is often useful to pass this through a sealed smoothing volume to minimise fluctuations due to wind or pressure differences.

Figure 7 Tubing Connections to Test CIRAS-2 as an IRGA Only.

Once connected as shown above, the CIRAS-2 should be switched on and allowed to warm up for at least 30 minutes. Proceed into the measurement mode where both the data and graphics are displayed. Observe both the CO_2 and H_2O vapour reference values (Cr & Hr) and differential CO_2 and H_2O vapour concentrations (Cd and Hd).

The CIRAS-2 CO_2 readings should be steady and match the known CO_2 reference source that is feeding into the instrument. In the case of atmospheric air, this should be in the range 350 to 400 ppm. The reference H_2O reading will depend upon ambient conditions. Both CO_2 and H_2O vapour differentials should be 0 (+/- <1) ppm as the same gas stream is passing through both reference and analysis cells. If everything appears to be normal, proceed to "Testing the CIRAS-2 Analyser with the Integral Cuvette Air Supply". Otherwise, see Problems Normally Associated with the CIRAS-2 Analyser below.

Problems Normally Associated with the CIRAS-2 Analyser

Below is a list of symptoms whose cause is normally associated with the IRGA side of the CIRAS-2 system.

CIRAS-2 does not turn on when power is switched on.

Missing battery or batteries.

Fit battery or batteries. At least one NiMH battery must be fitted to operate the CIRAS-2.

Low battery voltage (< 10.5V).

Fit fresh battery or charge existing one using the chargers supplied by PP Systems.

Blown internal fuse.

The CIRAS-2 has two internal auto reset fuses and should not require replacement. Contact PP Systems.

CIRAS-2 NiMH battery does not charge.

Faulty charger or battery.

Check charger output. If OK, the battery is probably faulty. Contact PP Systems.

Low analyser temperature

Poor contact on the connector between the analyser optical unit housing and the motherboard.

Turn off CIRAS-2 and remove battery and fuses.

CIRAS-2 does not appear to connect with Integral PC

Serial cable between CIRAS-2 and integral PC not connected.

Check serial cable and make proper connection.

Unable to Communicate with Integral PC

Serial cable not connected

Check serial connection (RS232) and try again.

Incorrect COMM port selected

Select correct COMM port.

Incompatible Cable

Use the cable (Null Modem) supplied by PP Systems or make up proper one (see Operator's Manual for pin outs).

CIRAS-2 displays strange characters on the LCD.

EPROM is likely not fitted properly into its socket.

Check EPROM and make sure that all pins are properly fitted in the ZIF socket.

CO_2 levels are higher than expected considering the reference source.

Leak in the system

If reference source is of lower concentration than the air around the analyser.
Check all absorber columns for cracks and ensure that they are properly seated and that all O-rings are OK and slightly greased. Check all pipes and connectors.

Bad calibration

Initialise and recheck. Recalibrate against a known standard.

CO_2 levels are lower than expected.

Exhausted chemicals in zero columns

Replace chemicals in both absorber column number 1 and 2.

Leak

Check all absorber columns for cracks and ensure that they are properly seated and that all O-rings are OK and slightly greased

Bad calibration

Initialise and recheck Recalibrate against a known standard

Testing the CIRAS-2 Analyser with the Integral Cuvette Air Supply

The integral cuvette air-supply unit test below should only be completed once the CIRAS-2 analyser-only test is completed satisfactorily.

A special three-way gas connection must be made with wide bore Santoprene tubing for this test. It must be pneumatically attached to the reference, analysis and air inlet connectors on the CIRAS-2 unit. The electrical connector from the leaf cuvette must also be plugged into the PLC electrical connector. See below.

Figure 8 Electrical and Pneumatic Connections

Before starting the test, it is advisable to check that the consumable items associated with the air supply are in good condition. This includes:

- Installing fresh absorber column chemicals (Soda Lime, Drierite and Molecular Sieve)
- Installing a fresh CO_2 cartridge in the CO_2 regulator

The CIRAS- should be switched off before starting the test and re-started with the PLC electrical connection and
3 way gas connection in place. Power up the CIRAS-2 and proceed into measurement mode. You will also want to make sure that the integral air supply is on. When the 3 way gas connection is fitted, a sample of the cuvette air is drawn into the reference and analysis cells. The remaining cuvette air vents to the atmosphere. Both reference and analysis samples therefore measure the same gas stream from the air supply unit. Ensure that all parameters are correctly set and that the flow rate is set to 250 ml min^{-1}.

Testing Automatic Integral Cuvette Air Supply Unit.

The following procedure can be used to test the air supply. For this test, it is assumed that the control mode for CO2 and H2O is the system default which is:

CO_2 Control Type 1

The Reference CO_2 concentration (of the air entering the cuvette) is set approximately to the required value.

H_2O Control Type 1

The Reference H_2O concentration (of the air entering the cuvette) is set to a percentage of the humidity of the air that surrounds the Water Vapour equilibrator on CIRAS-2. This will normally be the ambient humidity.

1. After entering the measurement mode, select C to access the CO_2 and H_2O control settings. Enter "0000" for both the CO_2 and H_2O controls. Press OK to return to the measurement mode. After 2 - 3 minutes, the reference CO_2 (Cr) and H_2O (Hr) values should drop close to zero (<10 ppm CO_2 and < 0.1 mb H_2O). The values should remain steady with differentials of (+/- <1 ppm CO_2 (Cd) and +/- <0.2 mb H_2O (Hd)).

2. Return to the control settings mode by pressing the C key. Set the CO_2 control to 2,000 ppm and the H_2O control to 100 (% of ambient). Then press the OK key to return to the measurement mode. After 2 - 3 minutes the reference CO_2 and H_2O values should be approximately 2,000 ppm and 100% of ambient respectively. The values should remain steady (noise and drift/min with +/-0.1% of reading or +/- 1 ppm CO_2, +/- 0.2 mb H_2O Minimum) with differentials of (+/- <1 ppm CO_2 (Cd), <0.2 mb H_2O (Hd)).

Problems Normally Associated with the Integral Cuvette Air Supply.

Fluctuating Reference CO_2.

Faulty air forwarding pump

Replace if necessary.

Dirty air supply inlet filter

Clean filter.

Excess pressure entering the CIRAS-2 via the exhaust CO_2 port (normally on extremely windy days).

Place CIRAS-2 in a carrying bag or shield the CO_2 exhaust port from the external environment taking care not to impede gas discharge.

Low CO_2 reading regardless of setting.

Exhausted CO_2 cartridge.

Replace with new cartridge.

CO_2 cartridge not fully inserted.

Tighten the regulator holder until you hear the CO_2 cylinder pierce.

Thin tubing from regulator to air supply is disconnected

Open the CIRAS, locate the CO_2 regulator and re-connect tubing.

Pressure release seal on regulator failed.

Replace seal.

Incorrect calibration.

Check that chemicals are fresh, absorber columns are in the correct location, CIRAS-2 is warmed up and recalibrate.

High CO_2 readings.

Blocked CO_2 exhaust port. Any blockage will cause high CO_2 readings.

Check CO_2 flow at exhaust

Incorrect calibration.

Check that chemicals are fresh, absorber columns are in the correct location, CIRAS-2 is warmed up and recalibrate.

CO_2 exhausts in just a few hours after fitting new cylinder.

Cracked or damaged "O" ring in regulator.

Fit new "O" Ring and apply a very light smear of silicone grease for better seal .

Damaged regulator seal.

Replace seal.

Faulty regulator

Contact PP Systems.

CO_2 exhausts rapidly after fitting new CO_2 cartridge

Missing or damaged CO_2 cartridge "O" ring in regulator.

Fit new "O" ring and apply a very light smear of silicone grease for better seal.

Faulty regulator.

Contact PP Systems.

Erratic CO_2 differential

Faulty air forwarding pump

Replace if necessary.

Dirty air supply inlet filter

Clean filter.

Excess pressure entering the CIRAS-2 via the exhaust CO_2 port (normally on extremely windy days).

Place CIRAS-2 in a carrying bag or shield the CO_2 exhaust port from the external environment taking care not to impede gas discharge.

Faulty reference/analysis pump

Clean with alcohol.

Slow drift in CO_2 concentration

Please Note.

Slow drifts in CO_2 concentration are normal after:

- Setting [CO_2] set to a new value
- Changing the drier column
- Setting the humidity control
- Following changes in ambient temperature.

Exhaustion of soda lime causing the breakthrough of the atmospheric CO_2.

Replace the soda lime.

Slow decline in [CO_2].

CO_2 cartridge is exhausted.
Replace CO_2 cartridge.
CO_2 starvation.
Check for kinked pipes.

Fluctuating CO_2 readings.

Exhausted Molecular Sieve, which is liberating CO_2 into the air supply
Replace with fresh Molecular Sieve.
Exhausted soda lime
Replace with fresh soda lime.
Leak around the absorber columns.
Check all absorber columns for cracks and ensure that they are properly seated and that all “O” rings are OK and slightly greased.
Leak around water vapour equilibrator.
Check that all the tubing is connected on both ends of the equilibrator, and that it is seated.
Interaction between pulse frequency of the air supply pumps and the solenoid valve used to set the CO_2 concentration.
Change the CO_2 or flow rate by 10%.

Testing the Leaf Cuvette with the CIRAS-2 System

The leaf cuvette should only be tested once it has been determined that the CIRAS-2 analysers and cuvette air-supply are working properly.

Before starting this test, make sure that the leaf cuvette is both electrically and pneumatically connected to the CIRAS-2. When ready, switch on the CIRAS-2 and proceed into the measurement mode. Leave the instrument to fully warm up for half an hour before proceeding.

1. After entering the measurement mode, select C to access the CO_2 and H_2O control settings. Enter "0000" for both the CO_2 and H_2O controls. Press OK to return to the measurement mode. After 2 - 3 minutes, the reference CO_2 (Cr) and H_2O (Hr) values should drop close to zero (<10 ppm CO_2 and < 0.1 mb H_2O). The values should remain steady with differentials of (+/- <1 ppm CO_2 (Cd) and +/- <0.2 mb H_2O (Hd)).

2. Return to the control settings mode by pressing the C key. Set the CO_2 control to 2,000 ppm and the H_2O control to 100 (% of ambient). Then press the OK key to return to the measurement mode. After 2 - 3 minutes the reference CO_2 and H_2O values should be approximately 2,000 ppm and 100% of ambient respectively. The values should remain steady (noise and drift/min with +/-0.1% of reading or +/- 1 ppm CO_2, +/- 0.2 mb H_2O Minimum) with differentials of (+/- <1 ppm CO_2 (Cd), <0.2 mb H_2O (Hd)).

The presence of a differential during the test usually indicates a leak in the PLC. The following procedure can be used to confirm a leak.

1. Set the chamber flow rate to 150 ml min^{-1} and reference CO_2 (Cr) Control to 0000. Passing CO_2 free air through the cuvette with minimal positive pressure out of the chamber should maximise the effect of any leak. The differential values should be noted. Blow around and note if the differential increases. (NB If the cuvette has been exposed to high CO_2 it will take several minutes to equilibrate.)

2. Increase the chamber flow rate to 470 ml min^{-1} (maximum) and note the differential values. The increase in flow rate will increase the positive pressure out of the chamber and therefore reduce the effects of a leak. If the differential values decrease in response to increased flow rate, it is likely that there is a cuvette leak.

Problems Normally Associated with Leaf Cuvettes.

Fluctuating CO_2 differential with empty cuvette

Worn cuvette gaskets.

Replace. Refer to Leaf Cuvette Operator's Manual.

Cuvette head not properly aligned.

Align heads.

Kinked pipes or restriction in reference or analysis lines

Unkink pipes. If problem persists, blow into both lines to clear the pipes.
Please note that blowing into the pipes will cause a build up of condensation.

Not getting adequate mixing in the chamber

Check the impeller blade and replace motor if necessary.

Dirty cuvette head

Clean out with 90% ethanol and allow at least 1 hour for drying. Alcohol fumes will cause discoloration of the absorber chemicals.

Leak on the reference or analysis tubing where they attach to the CIRAS-2 air connection.

Unscrew the fittings at the tubing ends of the connectors to access the point where the tubing is fitted. Cut off the part where there is a leak and reassemble.

Leak around impeller motor

Remove the motor by unscrewing the 2 mounting screws. Apply silicone grease between mating surfaces and re-fit motor to cuvette.

Incorrect leaf temperature reading with thermistor.

Not properly plugged into connector.

Plug in properly.

Sensor is not in contact with leaf.

Align sensor so that the leaf comes in contact with the sensor when the cuvette is closed.

Faulty sensor

Replace.

PAR Sensor cannot display negative readings.

To prevent a negative zero offset, they should be set to read say +3umolm-2s-1 in the dark.
If at low light the PAR sensor reads zero then the zero offset is probably negative and the sensor should be re-calibrated.
Similarly if in the dark there is a large positive display then recalibrate.

Zero potentiometer requires adjustment

Cover PAR sensor and adjust the PAR zero pot until a slight positive reading is displayed.

Faulty PAR reading.

Out of calibration.

Recalibrate against a known standard.

PAR readings vary under constant lighting conditions.

Intermittent short

Check all wiring and re-solder if necessary. Contact PP Systems.

Positive CO_2 differential with a healthy leaf / plant enclosed in the cuvette.

Leak around the gaskets

Replace gaskets if worn or try and re-align leaf in the cuvette to get a better seal.

Status Codes: Diagnostics and Remedies.

Code 99 [Analyser Temperature Too Low]

Analyser temperature is less than 50°C.

Possibly caused by excessive high (>50) or low (<0) ambient.
Thermostat or heater failure. Contact PP Systems.

Code 98 [Analyser Temperature Too High]

Analyser temperature is greater than 65°C.

Possibly caused by excessive high (>50) or low (<0) ambient.
Thermostat or heater failure. Contact PP Systems.

Code 97 [AN Flow Too Low]

Code 96 [AN Flow Too High]

Code 95 [REF Flow Too Low]

Code 94 [REFFlow Too High]

Analyser flow rates more 20ml/minute above or below the set flow.

Flow too low means either an obstruction of flow or a leak, in which case the pump will be heard running flat out; or a seizure of the pump; or failure of the pump drive circuitry; or failure of the mass flow sensor.

Pump is running flat-out

Check for restriction of the inlet or outlet caused by blocked inlet filters, or kinked sample pipes. To test, first open up the unit. (See Maintenance Section). Check pipes for kinks. Check all pipe connections. Remove in-line inlet filter and replace with tube connector. If problem persists then check connection to the pressure transducer, which is on the bottom board.

Pump is not running.

Check pump plug correctly in place. Check voltage on plug pins with pump removed. If it is less than 6v, then problem is with pump control circuit or mass flow sensor. If the voltage is high then the pump has probably seized (pump will probably feel warm). Wash out the pump with alcohol. (See Maintenance Section)

Flow too high

Probably means that there is a high pressure at the REF/AN inlet a low pressure at the outlet.
Remove inlet/outlet pipes and check again.
If the problem persists then probably there is a failure of the mass-flow sensor or flow controller.

Code 93 [Voltage Measured On The Circuit Board Is Less Than 10.5V]

Failed or inadequate power supply.

First check the external power supply. Next, check the 12V NiMH batteries. If both of the above appear to be OK, contact PP Systems.

Code 92 [ZERO Reading Too Low]

ZERO readings are below 33000.

The ZERO signal should be the largest signal measured by CIRAS-2. It can decrease due to changes in the cell wall reflectivity (e.g. dirt or water in the cells), changes in the sources, detectors, reference voltages and amplifiers.
Use DiagnosticsS to check the ZERO readings.
Switch off CIRAS-2 and check analyser ZERO columns are in good condition. Try again. If the problem persists contact PP Systems.

Code 90 [DIFF-BAL Out of Range]

DIFF-BAL offsets are greater than 20ppm for CO_2 and 0.5mb for H_2O.

This can result from a poor calibration. It could also be an indication of deterioration of the cell surface. (Water??)
Use the checking routine to display the magnitude of the offset.
Re-initialise and check again. If problem persists then contact PP Systems.

Code 89 [DIFF-BAL Out of Range]

DIFF-BAL offsets are greater than 20ppm for CO_2 and 0.5mb for H_2O.

This can result from a poor calibration. It could also be an indication of deterioration of the cell surface. (Water??)
Use the checking routine to display the magnitude of the offset.
Re-initialise and check again. If problem persists then contact PP Systems.

Code 88 [Time Out on DIFF-BAL]

Fluctuating Reference Concentration

The REF concentration has been fluctuating during the DIFF-BAL cycle and CIRAS-2 has not been able to get a satisfactory fit.

Make sure REF concentration is steady. If problem persists then contact PP Systems. Also check that reference connector from PLC is properly secured to the CIRAS-2.

Code 87 [REF/AN Differential Pressure Too Large]

Pressure difference between the REF and AN cells is greater than 20mb.

Check for excessive inlet or exhaust pressure, kinked pipes or dirty inlet filters.

Code 86 [Concentration out of range on stored DIFF-BAL]

Failed Stored DIFF-BAL

Stored DIFF-BAL factors have been set up, but the current REF concentrations are <> the range used in setting them up.
When setting up the stored DIFF-BAL make sure that they encompass the measurement range.

Code 84 [H_2O control out of range]

Unable to achieve H_2O Control

It is not possible to achieve the requested humidity within the current settings of flow and air inlet humidity.
If the humidity is below the set point, decrease the flow or increase the inlet humidity. (Cover the equilibrator with wet filter paper.)
If the humidity is too high, check the Drierite columns are fresh and increase the flow.

Code 83 [$FeSO_4$. Humidity Calibrator Too Warm]

Danger of condensation.

Do not connect/disconnect air pipes to the calibrator. Leave for several hours to equilibrate with the ambient temperature.
(See CIRAS-2 Calibration)

Code 82 [Unable to calculate Stored DIFF BAL]

On completion of setting up stored Diff-bal factors, the range of the data points is not adequate for a good fit.
Repeat with a sensible spread of both CO_2 and H_2O concentrations. (See Setting Up Stored DIFF-BAL Factors)

Code 81 [Forwarding flow < Cuvette flow]

The forwarding pump delivers CO_2 free air of controlled humidity to the main air supply pump.

If the forwarding flow is too small then the main air supply pump will draw in ambient air and the cuvette air CO_2 concentration will be too high and variable.
Check for rolled O-rings on absorbers, and blocked filters. Check forwarding pump is working.

Code 80 [Cuvette % RH >75%]

Recent research has shown, that taking the typical accuracy of temperature sensors and humidity measurements, stomatal conductance determinations, which depend on both, become increasingly inaccurate when the chamber RH% exceeds 75%.
Lower input humidity and/or increase the cuvette flowrate.

Codes 78 and 79 [ZERO read errors]

ZERO read errors

Each time CIRAS-2 ZEROs the new values are compared with the previous and if there has been a change greater than 100 then CIRAS-2 flags up an error [79]. To look for long term drift in the readings, CIRAS-2 stores in memory the first set taken 30 minutes after CIRAS-2 has been switched on. Six sets are stored. If there are significant changes over time then this is again flagged.
The user should use Diagnostics to look at the readings, renew the absorber column chemicals and check the absorber columns for leaks.

Code 77 [Attempt by PC to initiate action before the CIRAS-2 is fully warmed up]

For Calibration, checking and setting up of Diff-bal factors, CIRAS-2 must be on at least 20 minutes. You must be patient. Allow enough time for CIRAS-2 to warm-up.

Code 76 [Cuvette not Present]

PC has instructed CIRAS-2 that it is working with a PLC but from the absence of a temperature reading, no PLC is connected
Either the PLC is not correctly plugged in or the temperature sensor is broken.
Use Diagnostics to check the temperature reading.

Code 75 [Cuvette Present]

PC has set CIRAS-2 to work as an analyser only but an air temperature reading suggests that a PLC is connected
If a PLC is NOT connected, there is a spurious reading on CIRAS-2 input.
Use Diagnostics to check the temperature reading.

Error Code Diagnostics

Error Code 00

This results from an error that the normal error routines have been unable to trap. The CIRAS-2 program will automatically restart but if the problem persists report the circumstances to PP Systems.

Error Codes 20-40

The Control Basic program that is running the CIRAS-2 detects these arithmetic errors. If one occurs then first check the CIRAS-2 set up. If the problem persists then please contact PP Systems.

Error Code 50

This is generally due to a defective statement in the program that is running CIRAS-2. Though the program has been extensively tested all possible combinations of events cannot be encompassed so please report the circumstance when it occurred to PP Systems.

Maintenance

Apart from the absorber columns ("O" rings, foam pads, content)s, maintenance requires access to the inside of the CIRAS-2.

The side panel containing the absorber columns gives access only to the microprocessor board (For EPROM changes) and to the pressure transducer. Access to the internal pumps, flow meters etc. is through the plain, flat side panel (with buttons).

Daily Maintenance Schedule

The CIRAS-2 is a sophisticated piece of equipment that is often operated under sub-optimal environmental conditions. It is therefore sensible to establish and follow a planned schedule of maintenance. The degree of maintenance required is determined by the extent of instrument use and the ambient operating conditions. However, PP Systems recommend the following schedule as a starting point.

Before Making Measurements:

You must ensure that both the integral PC and CIRAS-2 NiMH batteries are fully charged prior to making measurements. To ensure that all are properly charged, we recommend charging the integral PC (with charger supplied) and both 12V NiMH batteries using the individual chargers supplied by PP Systems the night prior to making measurements. If the NiMH battery chargers are flashing, the batteries are fully charged. Assuming that this has been achieved, the following system checks should be made:

A. Check that the absorber chemicals are fresh, all of the absorber columns are properly sealed and inserted into their respective manifolds. Pay special attention to the "O" rings to ensure that they are properly seated in their grooves and not pinched off. Also ensure that the water vapour equilibrator is properly sealed and inserted into it's respective manifolds.

B. Insert both fully charged 12V NiMH batteries to the CIRAS-2. At this stage, keep the battery charger connected to the integral PC to avoid the internal battery from draining.

C. Before going out to the field: connect the PLC electrically and pneumatically to the CIRAS-2. Switch on the integral PC and the CIRAS-2 and allow it to fully warm-up (30 minutes). Proceed into the measurement mode (data and graphics displayed). Set the reference CO_2 control to zero. The Cr (CO_2 reference) value should decrease to less than 10 ppm and remain steady. Next, set the CO2 to 1,500 ppm. If the CO2 value achieves or comes close to 1,500 ppm and remains stable, the CO2 cartridge should **NOT** be removed as it still has some pressure left. You can begin measurements without changing the CO2 cartridge at this time, but we recommend taking spare cartridges with you to the field in the event the cartridge starts to empty out.
If the CO2 value does not achieve 1,500 ppm and steadily drops, it is safe to change the cartridge even though there will be a slight residual. You **MUST** allow at least 24 hours to elapse before changing the CO2 cartridge.

To confirm that the cartridge has been successfully inserted, set the CO_2 control to the desired measurement value and check that it is maintained.

D. Check that the gaskets on the PLC (if used) are in good condition. Close the chamber without a leaf and run the system for two minutes. Check that the Cd (CO_2 differential) and Hd (H_2O differential) values stabilise at 000 ($^+/_-$ 1) ppm.

After Making Measurements:

At the conclusion of measurements:

A. Disconnect both the electrical and pneumatic connections to the cuvette from CIRAS-2.

B. Check that the cuvette is clean and leave the cuvette head in an open position so that the gaskets have a chance to recover and do not become crushed over-night.

C. **The CO_2 cartridge MUST be left in place over night to discharge safely whilst the instrument is switched off.** Avoid leaving the CIRAS-2 in it's carrying bag, otherwise the CO_2 from the cartridge will build up in the absorber columns. This will cause premature exhaustion of the chemicals and slower instrument warm-up as excess CO_2 is flushed the next day.

D. Remove both CIRAS-2 12V NiMH batteries from the instrument and place them on their respective chargers. Before leaving the instrument, it is sensible to check that the red LED's on the charger units are a steady red and illuminated indicating proper connection. This indicates that the battery is drawing current. Next, place the integral PC on its charger. It is **VERY IMPORTANT** to charge the integral PC and CIRAS-2 NiMH batteries fully before storing the instrument for any significant period of time. The integral PC battery and both CIRAS-2 NiMH batteries must be charged independently.

Monthly Maintenance Schedule

A. Check the air supply and inlet filters. These should be white; if they appear dirty, they need to be replaced.

B. Inspect absorber column "O" rings and lubricate/replace as required. A slight smear of silicone grease should be applied to "O" rings periodically. Also inspect the foam pads and replace if worn or damaged.
See Routine Servicing

C. Check the reference and analysis air sampling pumps (rotary type) and main air supply and forwarding pumps (diaphragm type. If the sampling pumps (reference and analysis) sound noisy or appear to be running rough (usually due to heavy use), clean the pumps.
Note: The main air supply pump and forwarding pump must NOT be cleaned with alcohol.

It is also important to ensure that the Handheld PC remains charged to avoid deep discharge and loss of the software from the device.

Annual Preventative Maintenance Service.

PP Systems offers full service on the CIRAS-2, including:

- Inspection of all internal plumbing,
- Inspection / replacement of all O-rings,
- Replacement of all filters,
- Replacement of all chemicals,
- Electrical checks, inspection and full calibration of CO_2, H_2O analysers and flowmeters.

If a leaf cuvette is part of the system, the service includes:

- Replacement of cuvette gaskets,
- Replacement of piping (if necessary),
- Checking and re-calibration of sensors.

Please consult with PP Systems or your local agent for more details regarding this service.

Tools Required For CIRAS Maintenance

Most of the routine maintenance tasks can be performed with standard tools found in any workshop and the spares that are supplied as standard with your CIRAS system. Certain items, such as a manometer and equilibrator substitute link pipe, for more in-depth repair can often be improvised. However, PP Systems also supply a CIRAS Test Kit (CRS063). The kit contains the following items:

Tools & Test Gear	**CIRAS-2 Spares**
• Manometer- used in conjunction with the syringe for leak testing. • Flowmeter- low resistance float type for monitoring CIRAS air supply and sample flows. • Flat blade screwdriver (4mm) • Posidrive screwdriver (Size 1) • Knife with snap-off blades • Potentiometer trim tool • Snipe nose pliers with smooth jaws for removing and replacing rubber pipes • O-ring hook -a flattened bent wire for easily replacing the CO_2 regulator "O-rings" • Syringe • Multimeter (Optional) • Equilibrator substitute link pipe • Socket with pipe connector for end of equilibrator/absorber tube • Rubber plug to seal off absorber manifold sockets • Pipe to cross-link absorber tubes • Plastic T-pieces (2 each) • Pipe reducers (2 each) • Pump/valve test lead (elect)	• Inlet Filters (6 each) • "O" rings for CO_2 regulator • "O" rings for absorber column • CIRAS-1 fuses • Selection of CIRAS screws • Silicone grease • Selection of piping • Screw in connectors (2 each) • Small sinters (2 each)  **Figure 9 CIRAS Test Kit**

Routine Servicing

The CIRAS-2 uses a number of consumable chemicals and parts during operation. This section covers replacement and servicing of these items under routine conditions.

Chemicals and Absorber Columns

The CIRAS-2 comprises 5 absorber columns containing three different chemicals to condition the instrument air-supply:

Soda Lime

Soda lime is used to remove CO_2 from air entering the CIRAS-2. It is supplied as self-indicating granules (1-2.5mm) which turn from green to brown as they become exhausted. The contents of the absorber column should be replaced when they are two-thirds exhausted. Soda Lime cannot be regenerated.

****** CAUTION ******

WASH YOUR HANDS AFTER HANDLING SODA LIME

Up to date MSDS (Material Safety Data Sheet) for this desiccant is available directly from our web site for all registered CIRAS-2 users. If you are not registered with us, go to the User Registration section on page 10 and proceed to register your instrument. You must enter all information correctly, including the serial number of your CIRAS-2 which can be found on the bottom of the instrument.

Envirogel

Envirogel is silica gel with an indicator (orange changing to green) used for drying the air. It is a low cost alternative to a desiccant that we used to use (Drierite) which makes it a disposable item in most countries. However, it can be regenerated by heating in an oven, if necessary (above 100° C but not exceeding 150° C). It is non-hazardous and can be easily disposed of when exhausted. Silica gel absorbs 27% of its weight in water compared with the 7% for Drierite. It is not quite as effective as Drierite giving an ultimate water concentration of about 0.04mb compared with 0.005mb but this is adequate for our measurements.

Up to date MSDS (Material Safety Data Sheet) for this desiccant is available directly from our web site for all registered CIRAS-2 users. If you are not registered with us, go to the User Registration section on page 10 and proceed to register your instrument. You must enter all information correctly, including the serial number of your CIRAS-2 which can be found on the bottom of the instrument.

Molecular Sieve.

Molecular Sieve is used to finally filter any remaining CO_2 and H_2O from the air supply during zeroing and from the water vapour control circuit. Unfortunately, Molecular Sieve is not self-indicating and there is no obvious way to see that it is exhausted. It is therefore best to change the Molecular Sieve when changing your other chemicals. **Please note that there is no foam pad at the Molecular Sieve end of the Drierite / sieve column, so extra care must be taken when changing this column.**

Molecular Sieve can easily become contaminated through absorption of CO_2 and H_2O from atmospheric air. It is therefore **strongly recommended** that Molecular Sieve is decanted into small air-tight containers to minimise any exposure to air. The Molecular Sieve/Drierite column (Column 1) should be placed in a sealed polythene bag if it is removed from the CIRAS-2.

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ZERO Absorber Columns

****** WARNING ******

For accurate measurements and calibration, it is absolutely critical that the analyser ZERO columns (columns 1 & 2) are not exhausted. If the chemical are becoming exhausted, it will cause the ZERO to be done on non-ZERO air causing error in the calibration. Pay special attention to the Molecular Sieve desiccant.

Therefore, the condition of the chemicals within the absorber columns must be regularly checked, and replaced as necessary. There are 2 ZERO columns (Labelled 1 and 2 on the bottom of CIRAS-2). Absorber column number 2 contains Soda Lime for CO_2 absorption. Absorber column number 1 contains 2/3rd Envirogel for H_2O absorption and 1 3rd Molecular Sieve for both H_2O and CO_2 absorption (gives a final polish before the analyser cell).

Servicing Absorber Columns.

We recommend monthly inspections of all absorber column foam pads, filter disks and “O” rings. Also check for cracks on the clear plastic column itself. Each absorber column is fitted with 2 black end caps containing 2 white plastic disks, 2 “O” rings and 2 foam pads at each end (the 1/3rd Molecular Sieve - 2/3rd Envirogel columns will have one foam pad at the Envirogel end only).

To remove the columns, first lay the CIRAS-2 on a flat surface so that you are looking down on the columns. Hold both ends of the column firmly, and pull upwards. **Do not lever out one end only, as this will damage the end fitting.** The end fitting(s) can then be removed and the contents tipped out. Columns are fitted with foam pads at each end to stop the contents spilling out if the ends are inadvertently pulled off during removal. **Note, there is no foam pad fitted at the Molecular Sieve end of column 1 and column 4 containing the 1/3rd Molecular Sieve - 2/3rd Envirogel. Extra care must be taken when replacing this desiccant.** When replacing the contents, the columns should be tapped to ensure tight packing, and the foam replaced as found. The "O" rings on the end fittings should be occasionally lightly smeared with silicone grease to aid ease of fitting.

Take care when replacing the end fittings as the "O" rings can roll up and out of the groove. This will give rise to leaks and the CIRAS-2 will not work properly.

There can be a very tight fit between the tubes and end fittings. Pushing the end fittings on without proper care can cause the tubes to crack. Again this will allow air to leak in and out of the column.

It is sensible to examine the absorber columns each time the contents are replaced as any leakage of ambient air into the gas circuits generally causes error messages during “Autozero” operation or fluctuating reference CO_2 concentration during measurement.

There are three items that should be checked after re-filling a column:

Foam Pads

The foam pads become worn over time and should be inspected regularly and replaced when torn or reduced in size. The foam must be of an open celled type, such as packing foam.

Absorber Filters

Each absorber end cap contains a white plastic filter disk. Generally these do not need to be replaced. However, they must be present to prevent any of the column contents being drawn with the gas stream into the instrument.

“O” Rings

The “O” Rings on the end caps of the columns should be very lightly smeared with silicone grease to aid ease of fitting and improve the seal. Once sealed, end fittings should be checked to ensure that the O-rings are seated correctly in their groove and that they are not trapped or pinched.

There is also a small O-ring on each of the absorber end cap fittings. These seal the absorber column into the CIRAS manifolds. These should be in good condition. Replacement O-ring and filter sets can be ordered from PP Systems (Part Number STD017). See figure below for location of “O” rings and foam pads. The white plastic filter disks are located on the black end caps inside the absorber column.

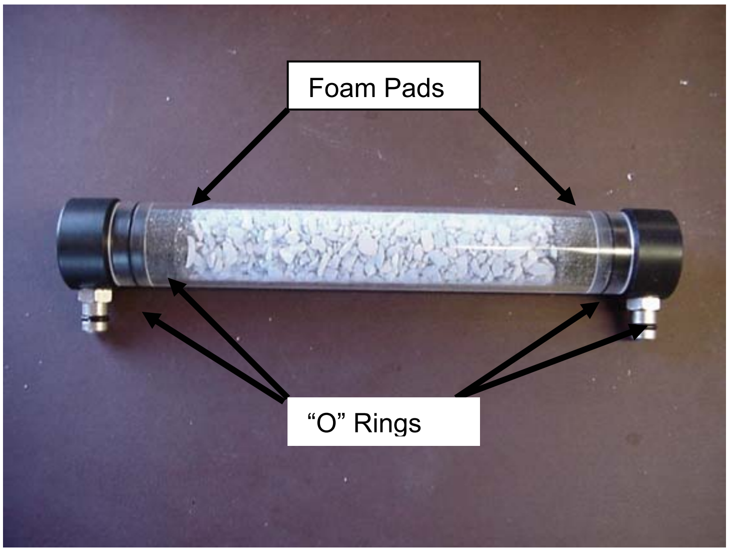

Figure 10 Servicing Absorber Columns

CO_2 Regulator

The CO_2 regulator is located on the left-hand side of CIRAS-2. It consists of 2 parts:

1. Regulator base that is permanently fastened to the CIRAS-2 chassis.
2. Black cylinder holder that screws onto the regulator body.

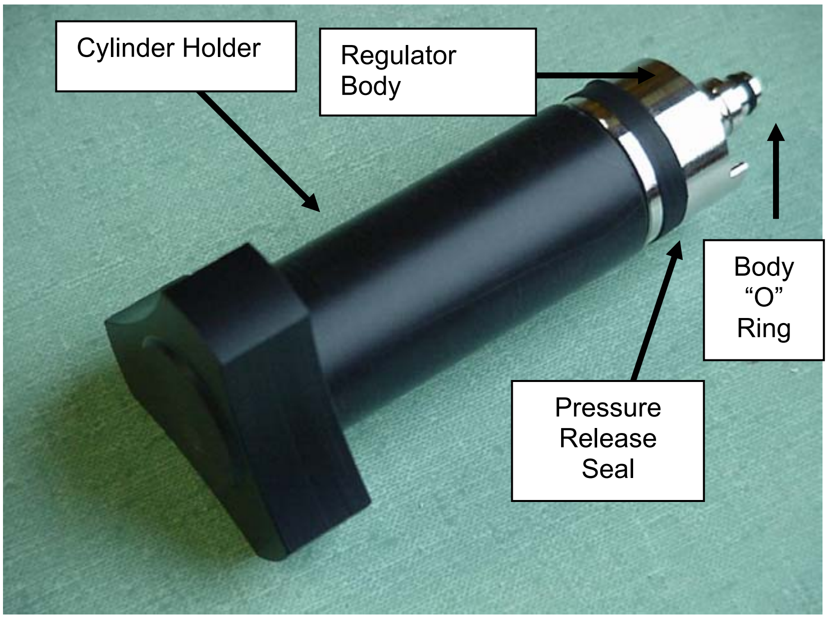

Figure 11 CO2 Regulator

The regulator body plugs into a socket on the base, located by two lugs, and is sealed in place by an “O” ring. To remove, the cylinder holder must be screwed onto the body and then a firm pull away from CIRAS-2 will disengage. To replace, insert the regulator body back into CIRAS-2. Rotate, gently pushing to locate the 2 lugs, then push in hard to seal. Regularly put a thin smear of silicone grease on the regulator body “O” ring.

The purpose of the removable body is for testing that the regulator is working; for easy replacement if defective; and for continuous working (using 2 in rotation). There is no need to remove the body to simply change a CO_2 cylinder.

The CIRAS-2 Portable Photosynthesis System contains an internal air-supply unit that is used to control the CO_2 concentration of the reference gas supply. The CO_2 is supplied from a disposable cartridge that is inserted into a regulator on the side of the instrument. Before inserting a fresh cartridge, it is always sensible to check that the “O” ring inside the regulator is properly seated (see below). It can be deformed during accidental rapid discharge of the cylinder. If this is the case, it must be replaced (Part Number STD037). It is also useful to roll the neck of the cylinder between thumb and forefinger. This places a thin layer of grease around the neck of the cartridge, which helps to provide a good seal.

Figure 12 CO_2 Cartridge "O" Ring

If there is any doubt about the CO_2 flow, remove the regulator body as described above and dip the end of the regulator into a beaker of water and see if bubbles of gas slowly emerge (see below).

Figure 13 Testing CO2 Cartridge Flow

If bubbles emerge at the rate of approximately 1 bubble per second, there is good flow coming from the regulator.

Periodically inspect the following components related to the CO2 Regulator:

- Regulator body "O" ring.
- Pressure release seal.
- CO2 cartridge "O" ring.

Inlet Filters

The CIRAS-2 air supply section and analyser optics are protected by three in-line polypropylene sinter filters inside the unit. They can be cleaned by washing in alcohol and drying thoroughly. The inlet filters are located inside the air-inlet manifold, which is located behind the black connector plate next to the absorber columns. The following procedure can be used to access the filters:

Place the CIRAS on a flat table with the absorber columns facing you.
Remove the absorber columns.
Identify the plate covering the inlet manifold and remove the two Philips type access screws that secure the plate to the manifold (see figure below).
Gently prise the plate out with a flat blade screwdriver until it can be gripped and pulled off with fingers.

Figure 14 Removal of Back Plate to access Filters

Once the black plate is removed, the filters can be accessed.

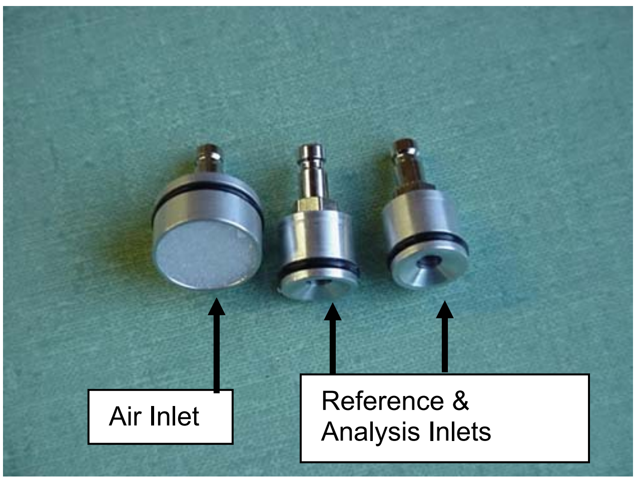

Figure 15 Air, Analysis and Reference Inlets

The air inlet, reference and analysis gas fittings can all be removed to access the inlet filters. Note, the Air Inlet filter is built into the gas fitting and can be cleaned with alcohol.
Inspect the “O” rings associated with the gas entries. If necessary, apply a slight smear of silicone grease on all “O” rings.

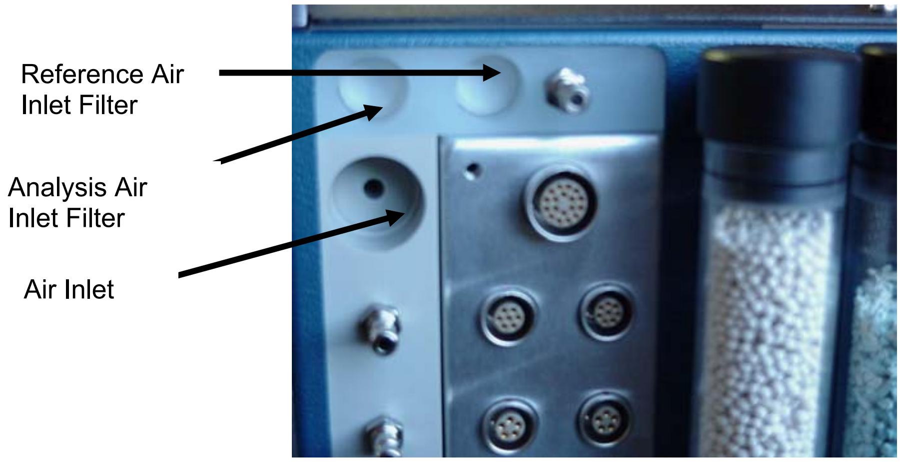

Figure 16 Location of Filters

The reference and analysis air inlet filters are white paper-like polypropylene discs (5 micron) at the bottom of the manifold recesses. They should be white if clean. The Air inlet does NOT have a 5 micron polypropylene disc fitted. Instead, the filter is built into the air inlet gas connector (see above).

If the reference and/or analysis inlet filters appear dirty, they should be replaced (Part Number STD004). Blocked filters will impede the airflow to the cuvette air supply and cause the CO_2 concentration of the reference/analysis gas to fluctuate.

The filters may be removed by lifting them up with a fine screwdriver and replaced by lowering a new filter into position with tweezers.

After inspection of inlet filters and associated “O” rings, refit the gas entries to their respective manifolds, place the black plate up against the CIRAS-2 manifolds and secure by fitting the 2 access screws.

Batteries

The CIRAS-2 uses two Nickel Metal Hydride (NiMH) batteries, and because of the special charging characteristics of these cells, they must be removed for charging. Only use the chargers supplied by PP Systems when charging the NiMH batteries. To charge the batteries, they must first be removed from the CIRAS-2. To remove the NiMH batteries, pull on the battery release knob and slide out of the CIRAS-2 (see below):

Figure 17 Charging Batteries

Next, unscrew the protective cap that covers the battery charger connector on the battery itself (see above). There are 3 pins that need to be lined up with the 3 sockets on the PP Systems NiMH battery charger. Fit the charger socket onto the 3 pins on the battery and tighten to secure connection. Check to make sure that the “Charge Indicator Light” LED is a steady red after connection. If the LED does not come on or it fluctuates, there may be a bad connection. Contact PP Systems.

When the battery has been fully charged the red LED on the charger should flash steadily indicating “trickle-charge”. If it is flashing very quickly, there may be a problem with the charger and/or the battery. Contact PP Systems.

Pumps

The CIRAS-2 Analyser section uses two rotary vane type pumps, one to sample Reference air (Reference Pump) and the other to sample Analysis air (Analysis Pump).

The CIRAS-2 Air Supply section uses one single diaphragm type pump for Air Forwarding and additionally, one diaphragm pump providing the main air supply flow. To access all pumps:

Switch off the CIRAS-2 and place it on a flat table in its normal upright position (Integral PC on top)
Remove the 2 Phillips type access screws that secure the flat cover on CIRAS-2 (opposite side to the absorber columns). See below

Figure 18 Accessing CIRAS-2 Pumps

Remove both NiMH batteries.
Next, gently pry the cover loose and fold down to access the pumps.

Figure 19 Position of Pumps

All pumps are connected electrically to the PC062 circuit board and labelled accordingly. The electrical connections for the pumps to the circuit board are as follows:

Pump	2 Pin Electrical Connector on PC062 Board
Reference Pump	REF PUMP
Analysis Pump	AN PUMP
Air Forwarding Pump	FWD PUMP
Main Air Supply Pump	ASU PUMP

Note, pump polarity is very important. Take caution when removing pump electrical connections.

Rotary Vane Pumps (Reference & Analysis)

Rotary vane pump components wear with prolonged use and material from the vanes may build up within the pumps. The risk of this situation occurring can be minimised by regular pump servicing.

Typically, the following symptoms are attributed to a worn of faulty reference or analysis pump:

1. **Noise** – a worn pump usually sounds rough or vibrates.
2. **Temperature** – the outer casing (near the pump serial number) feels warm compared to other pumps.

Removing a Pump.

It is very easy to remove a pump for servicing. First, trace the electrical connection to the pump and disconnect the 2-pin connector from the terminal on the CIRAS-2 Flowmeter board. The connector is removed by gently bending back the connector lock and sliding out the connector. **Please note the orientation of the red and black wire for correct re-fitting of the pump**.

The pump itself is secured in position by the gas tubing. These are un-done by gently pulling the pump from the rubber tubing.

Servicing a Rotary Vane Pump (Reference & Analysis).

During pro-longed operation the vanes inside the pump will wear and deposit material inside the pump. It is sensible to clean the pump by flushing it through with iso-propyl alcohol. The following procedure can be adopted:

1. Connect the pump to a 6-12V source and fit a 30mm tube to the pump inlet.
   (N.B. the CIRAS-2 can be used to supply power via the pump electrical connector.
   It is, however, essential that the flushing is done outside of the CIRAS-2 to avoid spillage into the instrument.
2. Hold the pump above a beaker of iso-propyl alcohol and dip the tube into the alcohol (see below). Run the pump to draw alcohol through it. A small roll of cotton wool in the inlet pipe can act as a filter for the re-circulating alcohol.

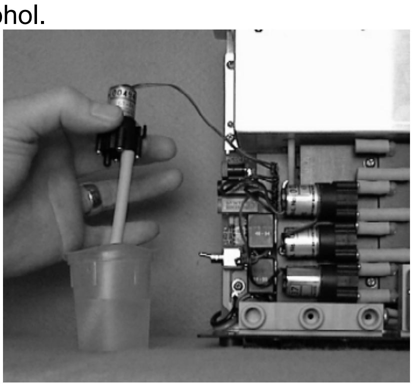

Figure 20 Cleaning Rotary Pumps

   If the pump is seized, it may be freed by tapping it on the bench or by reversing the voltage to run it backwards. If this does not work, pump replacement is required.

3. Run alcohol through the pump for a minute or two to ensure that any material is removed. Please note that the CIRAS-2 pumps are not sealed, so it is normal to see alcohol leak through the sides of them during this procedure. When finished, run the pump in air for at least 15 minutes to allow

any residual alcohol to evaporate. Ideally, let the pumps dry outside of the CIRAS-2 overnight. If the pumps are reconnected prematurely, the absorber chemicals will be exhausted quicker than usual.

Fitting All Pumps (Rotary Vane and Diaphragm Types)

The pumps are held in place by the santoprene gas tubing which join the pump inlet and outlet connectors to the CIRAS-2 gas circuit. These should be connected with the flat back of the pump oriented flush with the manifold. The 2-pin electrical connector should be re-connected. The two notches on the connector latch with the corresponding lock.

It is also important to check that both the electrical and gas connections to the pumps are satisfactory before sealing the enclosure to CIRAS-2.

Diaphragm Type Pumps (Forwarding & Main Air Supply)

These pumps do not require regular maintenance and should last for many years. **DO NOT** flush these pumps with alcohol or you will damage them. Spare seals are supplied for the diaphragm type pumps and can easily be fitted if required.

Fitting Spare Seals

If the seal is broken or worn on the diaphragm type pump, it can be replaced. Spare seals are provided with this style pump.

Removing a Diaphragm Type Pump.

It is very easy to remove a diaphragm type pump for servicing. First, trace the electrical connection to the pump and disconnect the 2-pin connector from the terminal on the CIRAS-2 Flowmeter board. The connector is removed by gently bending back the connector lock and sliding out the connector. **Please note the orientation of the red and black wire for correct re-fitting of the pump**.

The pump itself is secured in position by the gas tubing. These are undone by gently pulling the pump from the rubber tubing. Note the orientation of the pump to the tubing to avoid reversing the inlet and outlet gas entries.

Do not clean Diaphragm Pumps with Alcohol.

Water Vapour Equilibrator

Periodically inspect and confirm that the equilibrator is pushed firmly into its manifold and that all of the internal tubing is seated properly in the equilibrator blocks. In addition, periodically inspect the two “O” rings and apply a slight smear of silicone grease if required.

Figure 21 Water Vapour Equilibrator

Integral PC Computer

The integral PC should require minimal maintenance. We recommend using the protective plastic overlays to protect the LCD display (supplied with each system). In addition, it is recommended that the internal battery is charged fully before storing the PC away for any length of time. For further information regarding the integral PC, please refer to its own documentation supplied.

Fuses

There are two automatic reset fuses located inside the CIRAS-2. The analyser circuitry is protected by one fuse and the other protects the supply. These fuses should never require servicing. If you suspect a bad fuse, please contact PP Systems.

EPROMS

The instructions and factory measured calibration factors for the CIRAS-2 are stored on a pair of memory chips (EPROMS) inside the instrument. These should never require maintenance but they may need replacement if the firmware is upgraded in the future. The EPROM chips that are used in CIRAS-2 must be protected from static electricity. As a result, there are several precautions that the customer should take before removing EPROMS. The risk of damage can be minimised by earthing both the operator and the lab bench surface. This can be done by covering the surface of the bench with a conductive material (*e.g*. aluminium foil) that is electrically connected to an earthing point such as metal water pipe or tap. The operator should also be earthed using a wrist strap or by holding a wire that is connected to the same earthed point. Please contact PP Systems for further information.

The EPROMS are located on the main circuit board (PC060). To access the main circuit board, you will need to remove the CIRAS-2 cover that is covered by the absorber columns.

1. Make sure that the CIRAS-2 is powered OFF.
2. Remove all absorber columns and equilibrator.
3. Remove black connector cover plate as described in Section of this m annual.
4. Remove the 5 Philips type screws that secure the cover to CIRAS-2.
5. Gently prise the cover off the CIRAS-2.

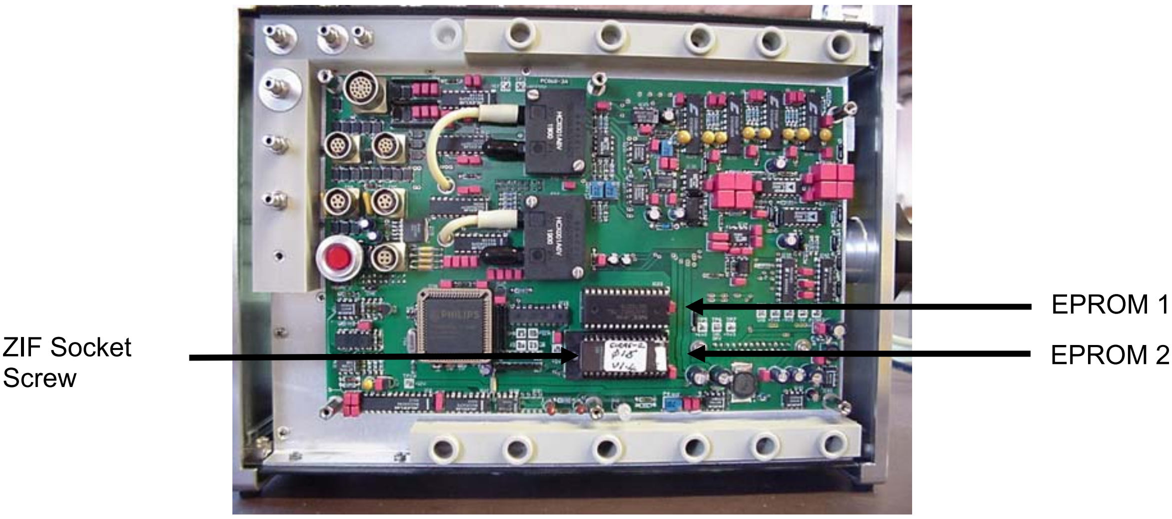

Figure 22 Location of EPROMS

Replacing EPROMS

NB. Before removing the EPROM, note the orientation.

Once suitable earthing arrangements have been made, the CIRAS-2 case can be opened and the rear panel removed to reveal the main motherboard. The position of the EPROMS is shown above. They are the only chips that have an adhesive label on them. **NOTE**: CIRAS **MUST** switched off before EPROM replacement.

Each EPROM is located in specific orientation on a ZIF socket. Before starting to remove the chip, note the position of the notch on the end of the chip relative to the rest of the instrument.

Current instruments have a screwdriver slot that is used to remove/secure EPROMS. To remove an EPROM, turn the ZIF socket screw ¼ turn counter-clockwise. This will release the pressure on the legs of the EPROM allowing you to remove it from its socket. The replacement EPROM should then be inserted into the socket in the correct orientation and secured by turning the screwdriver slot ¼ turn clockwise to grip the legs.

Leaf Cuvettes

The leaf cuvette should be routinely checked, after use, for debris such as dirt, broken off leaves / needles, etc. If debris is found, it should be removed carefully with a soft brush or lint-free cloth.

The cuvette head should be stored in an open position. This prevents the gaskets from becoming permanently crushed. The gaskets should be regularly inspected for leaks and tested by running the system with the heads closed and no leaf present in the chamber. Under these conditions the CO_2 and H_2O differential should be 000 (+/- 1 ppm). Breathing around the cuvette should not result in an increase in the measured differential. Leaks are usually easy to localise by gently blowing around the cuvette through a fine piece of tubing and monitoring the position that results in a large differential measurement.

For more information on servicing leaf cuvettes, please refer to the Leaf cuvette Manuals.

Regular maintenance should ensure that the CIRAS-2 provides many years of trouble-free operation. However, as with any piece of sophisticated instrumentation, components have a finite life that will vary depending upon the intensity of use and operating environment. The aim of this manual is to aid the operator in identifying the cause of any symptoms and where possible, resolve the problem on-site.

User Notes