ACE

Automated Soil CO2 Exchange Station

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CONTENTS

Level 1 packing
(Showing Spares kit, Soda Lime {Only supplied with ZERO Option}, Insertion pad & cables, Collar [1])

Level 2 packing
(Showing manual and second layer of packing)

Level 3 packing
(Showing the ACE Station with Parasol fitted – at this stage the collar will also have been fitted)

Level 4 Packing
(Showing level 3 packing pieces supporting the Station's Arm & Head

Level 5 packing
(Showing the protective packing over the Control box)
(There is a final layer of packing that goes over the entire area before the box is closed)

[1] The collar is clamped into the ACE Station's chassis, providing additional support to the chassis.

SECTION 1. INTRODUCTION

This manual covers the operation and maintenance of the ACE Automated Soil CO_2 Exchange system station. There are also references to the ACE Network system.

1.1 Equipment list

The ACE station is supplied complete with the following items:

ACE soil collar
ACE Collar Insertion pad
ACE Radiation Parasol (Metal Chamber heads only)
Compact Flash data storage card (Part of spares kit)
ACE "User guide" manual (This manual)
Heavy duty protective box (cardboard) with foam inserts.[2]

In addition to the above items there is a "Spares kit" (SKF-124 for Stations fitted with the Zero function or SKF-125 for Non-zero function Station)
An "Installation kit" (SKF-126) is included one per Sales Order.

Please refer to the pictures on the opposite page when repacking the ACE Station for transit to the site of an Experiment. It is important that the box and foam pieces are kept and the Station is packed as shown in order to provide protection and prevent movement of the Station's arm during transit.

[2] A heavy duty reinforced transit case may also be purchased (see Appendix 11 – Spares & Accessories)
The foam inserts should always be used when transporting the station.

1.2 Description

The Automatic CO_2 Exchange System (ACE) is used to measure CO_2 exchange in soil (soil respiration).
Each ACE Station consists of an Electronics Box (containing a 240 x 64 pixel LCD display, a five-button keypad and a microprocessor control system (the electronics box may also contain a fixed or programmable Air Supply Unit (ASU) depending on the hardware configuration) and a motorised moveable arm containing an infra-red gas analyser (IRGA) to measure CO_2 and carrying an analysis chamber on the end.

The ACE Station's arm would normally be open, that is to say raised from the ground where the measurement is to be made, thus exposing the soil to natural conditions. The Station makes periodic measurements (Assays) at set intervals decided by the user. During the periodic measurement time the motorised arm closes, enclosing the area of soil being measured. The recorded measurements consist of the soil CO_2, ambient CO_2 (if a zero function option is fitted), PAR (Photosynthetic Active Radiation) and up to 6 temperature and 4 soil moisture readings.

The ACE Station includes a collar for insertion in the soil to be measured and a pair of spiked feet for positioning the station on the ground. The feet can be inserted into the ground providing a firmer installation or reversed so that the flat end rests on the ground.

The ACE Station is designed to operate either independently for a single point measurement or from a central control unit (master). See Section 2 - Operational Modes
A complete system (network) consists of a Master Control Unit and up to 32 Stations.

In a typical networked system, the ACE Master is used as a central point to download data, set-up the ACE Stations and monitor their status. Power to each ACE Station is provided by the ACE Master in a star system, the power source normally being a battery. Communication between the Master and each Station is via a serial modem, the signal being superimposed on the power lines. (See Appendix 4 - Power Connection.)

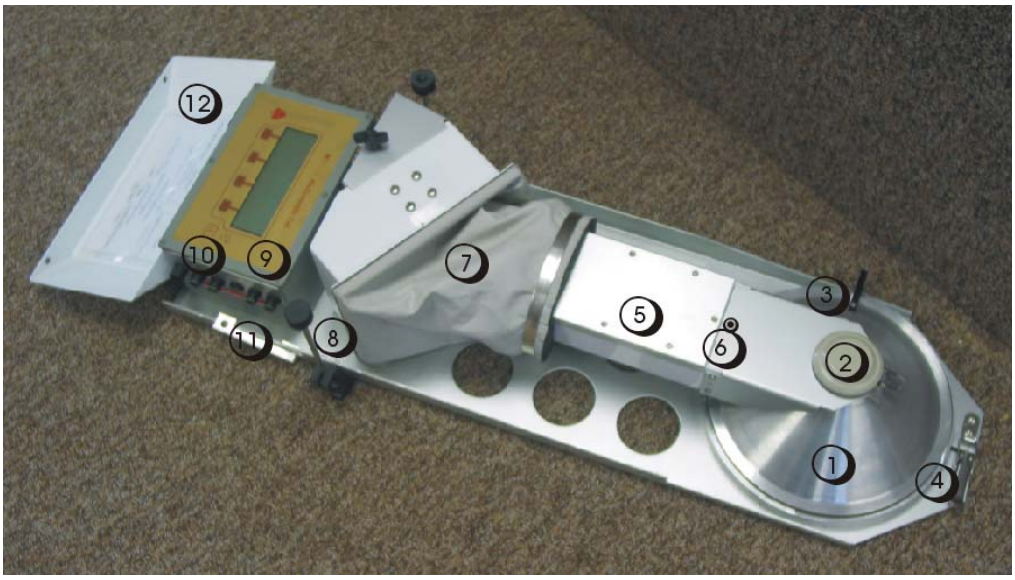
In a typical networked system the results from the last assay are sent to the Master on demand. If the station is operating independently, the data is logged to a Compact Flash (CF) card after the measurement sequence.

There are 2 basic modes of CO_2 measurement, each of which can have a zero function added for the measurement of ambient CO_2.
To obtain a Net CO_2 Exchange Rate (NCER) reading the lid is closed and a measurement is made of either

1) The difference of the CO_2 concentration of the gas in the chamber between the start and the end of the assay (closed mode).

or

2) The rate of change of CO_2 concentration of the gas in the chamber during the assay (open mode).



ACE Station layout and external functions

1. Soil Chamber The example shown is a small (Open mode) metal chamber. The chamber and arm assembly houses the integral CO_2 infrared gas analyser (IRGA).

2. Pressure release vent Supplied with Open mode chambers to ensure that no pressure gradients build up within the chamber.

3. Chamber guide Ensures consistent smooth closing and sealing of chamber.

4. Collar fixing clip Fasten to secure stainless steel collar to underside of ACE Station chamber area.

5. ACE Station arm Pivots to control console to cover and expose soil measurement area.

6. PAR sensor Fixed to ACE Station arm.

7. Station arm casing and jacket Robust, flexible, weatherproof protective cover for ACE Station pivoting mechanism. The soda lime column is fixed under the cover if zero/ambient mode option has been fitted.

8. Positioning feet Adjustable ACE Station feet with spikes allows secure positioning of the ACE Station even on rough terrain.

9. Control console Programming and control of the ACE Station using just 5 keys driving a series of easy to use menus.

10. Additional sensor connectors Weatherproof plug in connections for up to 6 soil temperature and 4 soil moisture sensors per Station.

11. Compact Flash card drive Data storage via the Compact Flash card supplied.

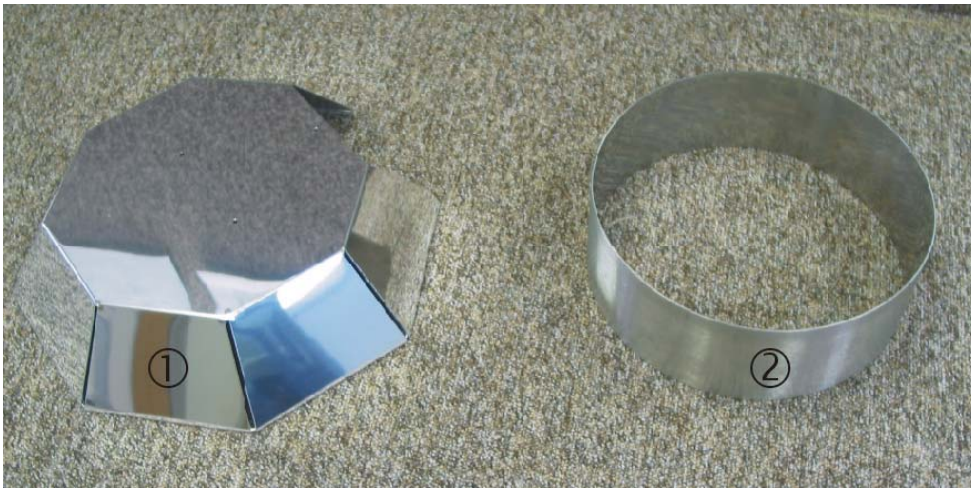
12. Control console lid Keep closed for field security and durability.

13. Control console lid strap Used with a padlock to lock the console lid closed.

ACE Station auxiliary items

1. Radiation parasol When attached above the soil chamber, the parasol provides protection from solar radiation, minimising increased temperatures inside the chamber when covering the soil measurement area.

2. Soil chamber collar Stainless steel soil collar accurately defines the soil area being analysed. Collar is placed into soil sometime prior to measurements commencing and before ACE Station is placed on and sealed to the collar.



1.3 Installation / Deployment

1.3.1 Installation

Choose a location where the ACE is not in an obvious local depression otherwise it might be flooded during a downpour. The risk of damage due to flooding can be reduced on those instruments which have a pumped fresh air inlet by positioning the inlet at a higher level. The ACE types that have a pumped inlet are the closed with zero, and both the open types. The closed without zero does not have a pumped inlet. To re-position the inlet, connect one end of short piece of 6.4mm bore pipe (supplied in the spares kit) to the inlet side of the filter located under the cover, and arrange the open end of the pipe to be in an inverted U at the top of a post pushed into the ground. The open end of the U should be 10 to 20 cm above ground level.

The collar should be inserted into the soil as far as is necessary to eliminate diffusion through the soil away from the measurement area, which could result in underestimating soil flux. For example, if the soil is loose, the collar should be inserted quite deeply. *Note: It is recommended that the insertion pad provided is used to insert the collar as this will minimise any possible damage to the collar. In Closed mode the distance from the top of the collar to the soil surface should be noted. This will need to be entered into the HEIGHT parameter on the configuration page of the software (see Section 2.2 - Operating in Closed mode).*

The collar which is supplied is 8cm tall. A taller collar (28cm) ACE-200 which is also available is intended for investigating fluxes on soils which have large clods eg after ploughing.

The process of inserting the collar into the soil will disturb the soil and the CO_2 fluxes that are taking place. It is therefore recommended that the soil collar is positioned a few hours before any experimental measurements are made. The collar should be inserted so that the rim is horizontal (also see locating the ACE station – below)

Hutchinson & Livingston (2001)[3] showed that 2.5cm insertion depth is sufficient to limit lateral diffusion errors to 1% in simulated fluxes from soils of low to moderate porosity, but that 9cm was needed for very porous soil.

Underestimations of flux in closed chambers can be caused by lateral diffusion. The effect is less in low porosity soils (fine textured and/or wet), and greater in high porosity soils (dry, coarse, or highly aggregated).

When moving the ACE, do not lift it with the arm or the chamber as this may cause damage, especially if it is fitted with a clear plastic chamber. Locate the ACE Station onto the collar and secure using the collar fixing clip.
When the Station is connected to the collar, ensure that it is also horizontal. The seal will slide much easier if lubricated with silicone grease.

Use the positioning feet with or without ground spikes to secure the ACE Station in a horizontal plane. Any deviation from horizontal will affect the PAR reading and, if the deviation is large, may also affect the way the arm opens and closes.

[3] See Hutchinson & Livinston reference in Appendix 3 – Calculations & References

Insert the Compact Flash card into the drive slot. (See figure on page 8).

It is possible to have the station switched off and the lid closed. This mode is only intended for transportation. If the station is left inactive on soil with the lid closed, lots of water vapour will probably condense in the lid and cause problems.

1.3.2 Connecting things up

Connecting the Power leads

Using the power leads provided, connect up the ACE Station to a suitable power supply (See Appendix 4 – Power connection).. For example, this can be an external battery charged by a solar panel or wind turbine. As a general guide a typical 40Ah car battery will provide power, for a single ACE Station, for approximately 28 days of continuous use.

Connecting the Air supply (Note that this paragraph does not apply to basic closed system)

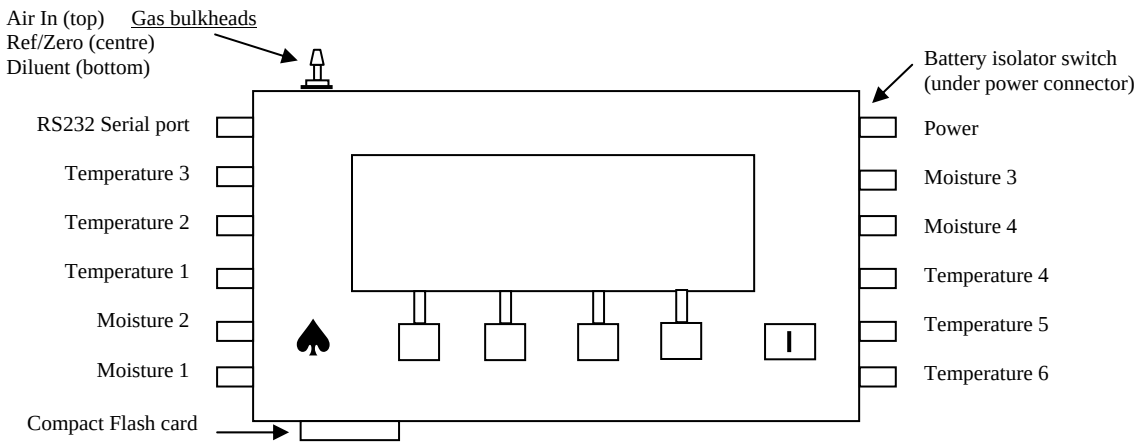
If you so wish an external 6mm bore pipe may be connected to the input of the cartridge filter in order to obtain air from a stable source away from the Station.

Checking the Chemicals

If your ACE Station is fitted with the optional CO_2 zero column for ambient CO_2 reading, (located behind the Station's arm casing), ensure that the column is filled with fresh Soda Lime. The Soda Lime supplied by ADC BioScientific has an indicator that is green when fresh and light brown when exhausted.
There are two ways to check to see if the ambient reading option is fitted to your ACE Station.

1/ Check to see if the chemical column is fitted behind the Arm casing.
2/ In the diagnose menu the InCfg (initial config) variable will give you the factory configuration of the hardware.

Note: It is possible to change the operating mode so that hardware is not used even though it is fitted. To do this, press PAGE I to turn the ACE Station on. Then press PAGE config select. Continue to press select until you reach Mmode. Pressing + or – keys will enable you to select Open or Closed (without Zero).



1.4 Switching on

1. Switch the ACE Station on using the ON I button.

2. The ACE Station will boot up whilst initially displaying the software version number and instrument serial number before displaying the first menu page. An "accessing CF memory card" message may also briefly appear on the status line at the top of the display.

1.4.1 Setting the Date & Time

On receipt of your ACE Station the date and time will have been set to either GMT (Greenwich Mean Time – now known as Universal Time) or BST (British Summer Time); the latter being GMT + 1 hour.
The Station will probably need to have its date and time set to suit your locality.
To do this, press the PAGE I key twice to reach the settings page. Press the time+date key then press the select key to select each component of the date & time in turn, using the + & - keys to change each value in turn. Note that the seconds go to zero when changed.

1.4.2 Connecting/configuring Sensors

The ACE Station is not necessarily supplied with temperature or soil moisture sensors and the customer can select/purchase his own. The sensors should be connected to the Station's Control box as shown in the figure on the previous page.
If ADC BioScientific is requested to supply sensors with the ACE Station then the Station will be configured to suit the types of sensors ordered prior to despatch otherwise the Station may need to be configured to suit the selected sensor(s). Please refer to Appendix 5 – Sensors for further details.

The PAR (Photosynthetically Active Radiation) sensor is fitted and calibrated as standard.

1.4.3 Security

The ACE Station operating system can be locked out from accidental interference using the Lock command. (See section 3.1. (6b))

In addition to the operating system lock (above) the Control box cover can be locked in place over the control box's keypad using the built-in locking and a padlock (padlock not supplied).

It is recommended that the lid be kept shut when unattended because it will protect the front panel against mechanical damage from animals and falling branches, and will prevent rainwater entering via the CF card slot.

1.5 Switching off

Press the PAGE key repeatedly until the measurements1 page is displayed (See Appendix 9 – Menu tree) then press the power off key to display the power off options page.
Alternatively, if the PAGE is held down for two seconds the Station will automatically enter the power off options from any page.

From the Power off options page you can either press cancel to return to normal mode or select the open or closed options. These options will power down the Station; after first ensuring that the arm is placed in the open or closed position.

The open option would normally be selected when entering standby mode, exposing the soil to ambient conditions and leaving the Station to automatically begin an assay at a pre-programmed time.

The closed option would normally be used to ensure the arm is closed prior to transporting the Station to a new site.

There is a battery isolator switch on the side of the control box (see diagram on previous page) which is arranged in series with the internal battery (*the internal battery is normally only fitted if the ACE Station is operated as part of a Network and therefore under the control of a Master*). This switch allows the user to switch off the station with certainty for transportation. Otherwise there is the possibility that the period has been set to a non-zero value and the instrument will continuously switch on and try to move the arm when inside its transportation box. This will drain the battery and could also put excessive strain on the motor assembly.

Total removal of power from ACE stations is not a problem. If an assay is in progress when the battery is removed, the results from that assay will be lost. No other data will be lost, and the internal clock will continue. Upon reconnection of the supply, an assay will start immediately if one was scheduled to occur during the power out.

If an assay is currently running, and the user wishes to avoid time gaps in the data record, then the user should wait until the current assay is complete. Alternatively, the user can disconnect anyway, and press the start key when power is restored to initiate an assay immediately.

SECTION 2. OPERATIONAL MODES/MEASUREMENT MODES

2.1 Measurement Modes

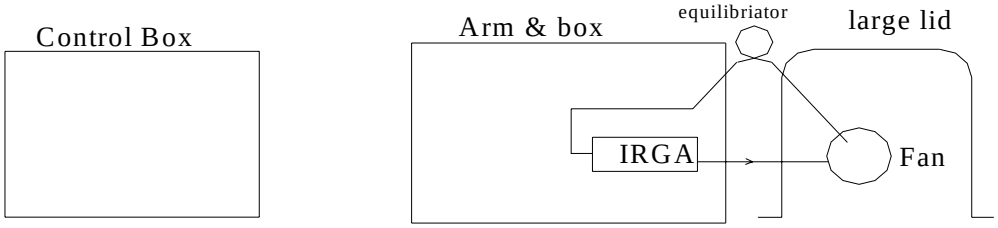
The Station has two main modes of measurement dependant on the hardware.
These are closed (C) or open (O). In both modes a CO_2 delta is obtained and the ambient concentration at the start is known as the 'reference' CO_2 and that at the end is 'measure' CO_2.
Both of these modes can also have the hardware option of a zero (Z) mode, (to provide ambient CO_2 measurements) making four modes as follows:
closed (C), closed with zero (CZ), open (O) and open with zero (OZ).

In the closed mode a sealed lid is used so the CO_2 increases in the lid due to the activity of the soil. After a period the CO_2 is measured and the rate of increase determined. The user determines the period by specifying a rise (delta) in CO_2 and an elapsed time, the final measurement occurring at the first of these two events.

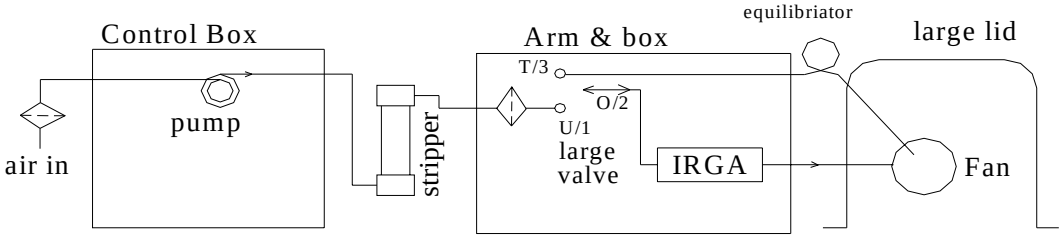
In the open mode the lid is fitted with a vent so there is a negligible pressure rise above ambient. Fresh air is pumped into the lid at a controlled set flow. This mixes with the CO_2 from the soil and after a period equilibrium is reached. This period is determined by the user specifying a rate of change in the form of a delta between successive readings, and an elapsed time. During the assay the rate of change slowly reduces until it meets the customer's rate of change criteria or the time runs out.

The Station has its hardware configuration stored in non volatile memory. It can be configured for another mode provided that the hardware that is fitted will support it. It can be seen from the diagrams on the following page that an instrument built for OZ mode can be configured for any of the others provided that the user also changes the chamber lid if necessary.

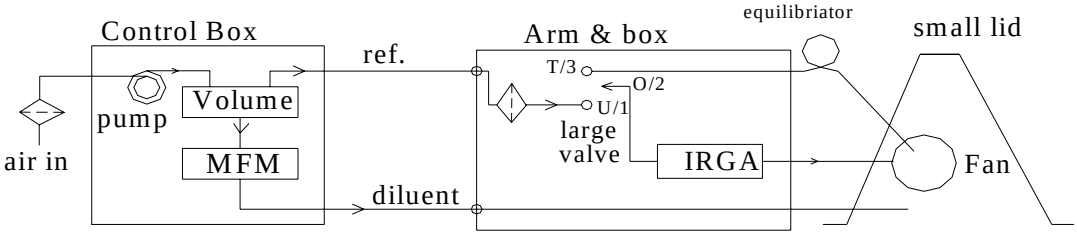
Basic closed (CO2 ramp) configuration



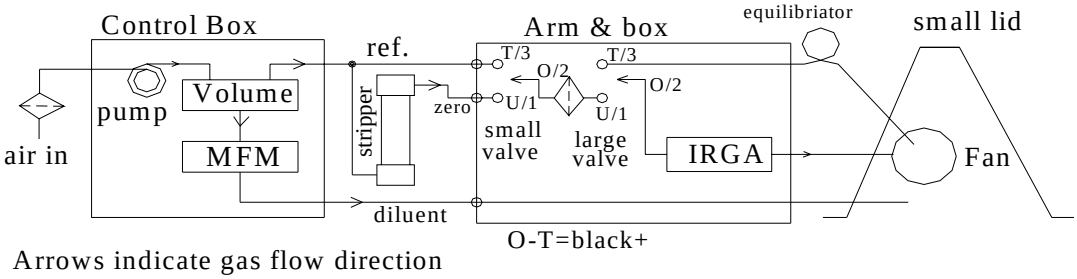
Closed configuration with zero



Open (equilibrium) configuration



Open (equilibrium) configuration with zero



Arrows indicate gas flow direction

SV =Solenoid Valve, both latching. O=out,T=top in, U=in.

MFM=Mass Flow Meter

IRGA= Infra Red Gas Analyser

=25mm 1um hydrophobic filter

=47 mm cartridge filter.

All Modes

In all modes the length of the assay is determined by the value set for either ΔC set or LimT, whichever comes first. These two values can be set by the user from the configuration menu. During the assay readings are taken every 10 seconds and stored in RAM. In all configurations the ambient CO_2 level is assumed to be 16mmol m^{-3} (358ppm @STP) but may be adjusted by the user. config more Camb. This value is also used to calculate an approximate live CO_2 reading which is displayed so the user can check progress during the assay.
In Configurations that have the Zero function the value for ambient CO_2 is recalculated using the zero measurement made prior to the final calculations being made.

Mode C CLOSED MODE <u>without</u> ZERO option

In this mode only the increase in CO_2 in the lid from soil activity is measured. As there is no measurement of absolute levels of CO_2, the assumed ambient CO_2 value as above is used.
Firstly the fan is turned on to purge the cell. The fan is then turned off and the lid is closed. A CO_2 measurement (C0) is then made. This is used to determine the delta at which the assay is stopped. (See section 2.2 measurement modes). The fan is then turned on and CO_2 measurements continuously made every 10 seconds and stored until the first of either the delta or the time limit is reached. The raw CO_2 measurements are converted into linearised CO_2 readings using the five sums S1-S5 method of Pedersen. (See appendix 3 – Calculations & References). The rate of increase is determined and NCER calculated. The interim measurements are then discarded. The lid is then opened and the Station returns to idle.

Mode CZ CLOSED MODE <u>with</u> ZERO option

The operation is as above except that a zero measurement is made by switching on the pump and changing the state of a solenoid valve so that CO_2 free air is passed through the cell. This zero measurement is made at the end of the assay after the lid has opened and is the value used to recalculate ambient CO_2 and position the stored values on the linearization curve so that a new delta CO_2 and hence a NCER value can be calculated.

Mode O OPEN MODE <u>without</u> ZERO option

Firstly the cell is purged with ambient gas to remove any soil gas remaining in the lid from the preceding assay. The lid is then shut and the pump turned on to pass ambient air into the lid at the set flow rate. The CO_2 concentration in the chamber will rise then gradually settle to a value which is dependant on the flux of CO_2 from the soil and the set flow of the pump (u), but is independent of the volume of the chamber.
Measurements are continually made (on the assumption that the first CO_2 reading represents the 16mmol m^{-3} ambient value) to determine when stability has been reached, i.e. if measurements can stop because the rate of change has become low enough. Then a measurement is made of the soil CO_2. Next the solenoid valve is changed to ambient and a measurement made after enough time has passed for the cell to be purged. NCER is calculated from the difference between ambient and soil CO_2.

Mode OZ OPEN MODE <u>with</u> ZERO option

The operation is as Mode O above except that the soil and ambient readings are temporarily stored as in Mode CZ and a zero measurement performed at the end of the assay. As in Mode CZ the zero is used to recalculate a new ambient CO_2, delta CO_2 and NCER.

2.2 Fan and pump operations in the different modes

Note: During an assay the ACE station cycles around steps 1. to 6. continuously. The other conditions shown are seen during the described action which may be initiated by the user.

Mode / description	pump	fan
Closed Zero (during assay)		
1. arm open & initial purge	off	**ON**
2. arm closing	off	off
3. 1st measurement of gas (reference)	off	off
4. measure soil gas (readings every few seconds)	off	**ON**
5. zero	**ON**	off
6. arm opening	off	**ON**
Closed Zero (other conditions)		
Idle	off	off
Span	off	off
Set phase	**ON**	off
Calibrate zero (adjust pot)	**ON**	off
Flow check 1) measure	off	**ON**
Flow check 2) zero	**ON**	off
Open Zero (during assay)		
1. arm open & initial cell purge	**Max**	off
2. arm closing	off	off
3. 1st measurement of gas (reference)	off	off
4. measure soil gas (readings every few seconds)	**Set**	**ON**
5. zero	**Max**	off
6. arm opening	off	off
Open Zero (other conditions)		
Idle	off	off
Span	off	off
Set phase	**Set**	off
Calibrate zero (adjust pot)	**Max**	off
Flow check 1) measure reference flow	**Set**	off
Flow check 2) zero	**Set**	off
Flow check 3) measure soil gas flow	off	ON

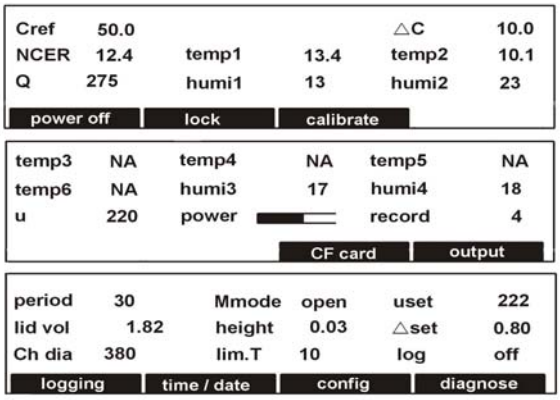
SECTION 3. SOFTWARE OPERATION

3.1 Description

The ACE station display consists of a 240 x 64 dot LCD which is updated every second.
The keyboard has 5 buttons, four of which are allocated as soft keys whilst the fifth is a power on key. The fifth button also acts as a PAGE or enter (↵) key. When used as an enter key it selects a single highlighted parameter on the current page and then exits the page.
Note: A highlighted parameter is displayed in inverse video, i.e. white text on a black background.

There are three main pages that the user can cycle between.
These are measurements1, measurements2, and settings.
The measurement1 & measurement2 pages display measured and calculated parameters whilst the settings page is the top level for all the sub-menu pages from which change to parameters and configurations can be made.
(See appendix 9 - menu tree for how the functions flow together).

On some menu pages it is possible to select a number of different parameters and update them in turn without exiting that page. In these instances one of the soft keys is used as an OK button to complete each individual parameter's update. On these pages the page button is not a soft key and is only pressed to exit the page.
Only the currently highlighted parameter can be changed. e.g. a numerical value or the units of a value. The parameter to be changed is selected by using the up/down and/or left/right keys until it is highlighted. Press OK then make the changes then press OK again. Another parameter may now be selected for change if desired. Once all changes have been made the PAGE key can be pressed to exit the menu page.



Switching on

1. Switch the ACE Station on using the ON PAGE I button.

2. Initially the ACE Station will boot up whilst displaying the software version number and instrument serial number. An "accessing CF memory card" message may also briefly appear.

3. You are now in the **first display screen**. Here you will find:

Cref:	Ambient CO_2 concentration entering chamber. (displayed in mmol m^{-3}.)
NCER:	Will be displayed when in an experimental mode.
Soil temp 1 & 2:	Displayed as a temperature in ^{o}C.
Soil moisture 1 & 2:	Displayed as a voltage. (See Appendix 5 – Sensors)
Q:	PAR displayed in µmols m^{-2} sec^{-1}

During an assay you will, in addition, see on the first display screen:

CO2:	The CO_2 concentration inside the chamber. (in mmols m^{-3})
Delta CO2:	In the Open mode, this value is the measured CO_2 concentration inside the chamber for the first 9 measurements. It is then a running average of the differences between the last 6 CO_2 readings inside the chamber. In Closed mode it is the difference between Cref and the CO_2 concentration in the chamber . It is displayed in mmols m^{-3} .
Rdngs:	The number of measurements (every 10 seconds) taken in current experiment.

4. By pressing the ON/PAGE I button again you access the **second display screen**. Here you will find:

Soil temp 3 – 6:	Displayed as a temperature in °C.
Soil moisture 3 & 4:	Displayed as a voltage. (See Appendix 5 – Sensors)
U:	Flow rate into the chamber in µmol s^{-1}. (Open mode only).
Battery power:	As a bar graph. (empty bar = <11V : full bar = >13V)
Record:	The number of records in the currently selected data file.

5. To access the **third display screen** press the PAGE button again. This is the configuration screen. (See Appendix 2 for defaults). The majority of experimental programming is performed from this screen. Press config to change parameters. On the configuration screen is:

Period: Time between the start of measurement assays.
Range 0 then 4 to 99 minutes in 1 minute increments then 200 to 2400 in 100 increments where each 100 equals an hour.
The period should not be set lower than Lim T unless set to zero to indicate no timed measurement cycles.

Lim T: Maximum time that a single measurement assay can run. A single measurement assay by an ACE Station is normally terminated by the ΔCset function; this timed function allows the assay to terminate should, for example, the soil become inactive. The range is 1 to 40 minutes in 1 minute increments.
LimT should always be set to a value less than the Period.

Uset: (This is applicable to Open mode only) Sets flow rate of ambient air into chamber (µmols sec^{-1}). The flow rate set is dependent on the soil activity.
The range is from 200 to 3720 µmols sec^{-1} in 10 µmol increments.

lid. vol: Volume in litres of the soil chamber being used.
The Open chamber is 1.0 litres. The Closed chamber is 2.6 litres.
The range is from 0.50 to 5.00 litres in 0.01 litre increments.

height: The distance from the soil to the top of the collar (in mm).
This is used to determine the total volume, when added to the volume of the chamber.
The range is 0 to 99 mm in 1mm increments.

ch.dia: Internal diameter of chamber. Should always be set at 230 (230 mm) when using any of the standard ACE chambers manufactured by ADC BioScientific, unless otherwise advised.
The range is from 100 to 600 mms in 1mm increments

Log: Name of data file currently selected to store data.

Mmode: Selects measurement mode e.g. Open with zero.

ΔCset: The point at which the measurement assay terminates. The value for ΔCset is in µmol m^{-3} or mmol m^{-3} (see below) and 10 is a reasonable starting value. The setting of this value will depend on the soil activity.

<u>In the Closed mode</u> this value is displayed in mmol m^{-3} and refers to the difference between the CO2 concentration at the start of the assay (ambient) and that at the end of the assay and can be set to about 10 for very active soils.

In the Open mode this value is displayed in µmol m^{-3} and refers to the average of the delta CO_2 between successive readings (ΔC/ΔT).
If ΔCset is set too large, the assay will terminate early, before the CO_2 concentration in the chamber has reached stability, and the calculated NCER will be too low.If ΔCset is set too small, rapid, small changes in CO_2 causes by fluctuations in the diluent air will prevent the assay terminating for a long time. This means that the soil will be covered by the lid for longer than necessary, and the soil will not be exposed to the natural environment for as long as possible. Therefore the ΔCset value is a compromise. The compromise value can be investigated by comparing the effect of different ΔCset values in a spreadsheet.

6. By pressing config more you can access:

Camb: Manually entered value used for ambient CO_2 at start of assay when the ambient reading option is not fitted.
The default value is set to 16 mmols m^{-3}
The range is from 12.0 to 20.0 mmols m^{-3} in 0.1 increments.

cmt: The comment field which is recorded to the CF card at the end of each assay is also copied here at the same time. This allows the user to investigate the last assay even if no CF card was present. The old comment is deleted immediately that a new assay is started.

name: The name of the station, editable by the user. This is read and stored by the Master in a networked system.

a lock: This is a software lock to prevent tampering of settings.
When the lock is enabled the screens can still be viewed but no settings may be changed. The lock remains enabled even if the power supply is removed/switched off and then re-instated.

a) To activate press select until **a-lock** is selected, then press + to lock software.
If you now turn the ACE Station off, when it next turns on a “PANEL IS LOCKED” message will appear where the menu soft keys are displayed.
The station can also be locked immediately without switching off with the lock key.
In a networked system, the Master controller is able to lock all the stations by switching on the **a.lock**. This may be disabled at individual stations.

b) To deactivate press PANEL IS LOCKED. You are now asked to enter the PIN. Using the > to select each position and the + and – keys to select the alpha-numeric character enter the PIN.

The PIN is the same for all ACE Stations, adcb (ADC Bio).

Press PAGE to exit and return to fully functional first screen.

7. At any time, the software may be interrupted and reset to the opening menu by pressing the left hand two buttons and the PAGE button simultaneously.

Tip: When accessing lower levels of the software pressing the PAGE button will return you to the previous top screen.

SECTION 4. DATA LOGGING & COMMUNICATIONS

Important Note

From software version 1.05 onwards a 'Euro' data format option is available for the convenience of customers in countries where a comma is used in place of a full stop to denote decimal values. For further details of this facility please read Appendix 1 - File format and Contents

4.1 Logging and File manipulation

Formatting the Compact Flash (CF) card

The data on the CF card is stored in a DOS FAT12/16 compatible format.
New cards may require formatting before use on the ACE Station, especially larger cards which, if already formatted, may be in FAT32 format which will not be recognised by the Station. An unformatted (or unrecognised format) card will cause the Station to display a message saying that the card is unformatted. It will then take you directly to the Format card page.
To manually enter the format card page; select cfcard format yes
When format is selected a warning message indicating that all data will be erased will appear giving you the option not to proceed. During the process, the capacity of the card is displayed (e.g. 1Gb) and free space in bytes.

Reading the Compact Flash (CF) data storage card

When the ACE Station is first switched on, the processor will read the CF card to determine its size and what files it contains. This process can take a few minutes with a large card, so it is best to use the smallest CF card that will hold the anticipated data. In practice CF cards have such a high capacity that even the smallest will hold year's worth of data, so use the smallest that you can easily obtain.
Note that cards can be obtained in smaller capacities but 1Gb is the current size of the card supplied with your ACE Station.
Fast CF cards tend to use more power than ordinary types. In the ACE application the additional speed is of no advantage so this type of card is not preferred.

Data logging

If a Station is networked to a Master Controller and has been set to log to the CF card the Master Controller will also record a log. However, if the Station is not connected to a Master Controller, the logging is done locally as described below.

Logging can be sent to the CF card or to the RS232 serial port. Records are taken at the end of each measurement, and the time and date is added to each log.
When logging to the RS232 port the headers (See Appendix 1 – File format & contents) are sent as soon as RS232 logging is enabled. (See Section 4.2 – Sending a Log File)
Log files that have been sent to the card may be reviewed a record at a time on the display, and may be downloaded from the CF Card via the RS232 port.

At start up the logging mode defaults to the last mode that was set. If the mode was set to send data to the CF card then any further recorded data appends to the last file used.

If a card is fitted but the filename does not exist a new filename will be created when the first data set is ready. Under normal operation the logging would be set to send to the CF card.

Selecting a File

Press set file from the logging menu.
Choose a file using the arrow keys, then press set log. If you leave the arrow key pointing to *new file* the ACE will provide a default file name with a value one higher that that currently on the card.
If you select an existing file, records will be added to it.
The filename can be changed if desired by using the select, + and - keys to scroll through the alpha-numeric characters. If the cursor is on the last (eighth) character pressing the select key will scroll round to the first character.

Renaming a File

Files may be renamed as described above but they cannot be called ‘new’ as this is a reserved word.

Delete (Erase) Existing Files

Note: *A file cannot be deleted whilst it is currently active. Press* no log *then follow the instructions below..*
Select logging set-file *(select)* [options] [delete]
The selected log file is then displayed. If none is selected, a warning is given.
Press OK to acknowledge the message then either press PAGE to abort or delete to continue deleting the file. The message ‘File erased’ will be displayed to confirm that the file has been deleted.

Reviewing Log Files

Pressing logging set file options review calls up the file review menu.
The more key toggles between the first and second pages of parameters.
The data may be reviewed sequentially using the next and previous keys or switched between first and last record using the 1st-last key. Holding down the next or previous keys for one second will increase the steps to ten at a time (or return to single steps if pressed again for one second).
Note: Reviewing a log file in reverse previous takes longer to step through. Depending on the length of the file and the position of the record to be reviewed it may be preferable to select the first record then step through using the next key.

The end of each log record has an 8 character label which contains information about the assay as follows:

1st character indicates type of assay
[O] open mode
[C] closed mode

2nd character indicates status if zero estimation
[E] error estimating the zero
[O] no error
[_] zero estimation not attempted (due to cancel or error)

3rd character in closed mode relates to curve fitting
[E] in CLOSED, error during NCER calculations
[G] in CLOSED, NCER etc calculated OK
[_] in CLOSED, NCER calculations not attempted (cancel or error)

3rd character in open mode indicates flow error
[F] in OPEN, flow not as set

4th character shows the status of any zero adjust at the end of the assay.
[F] zero adjust failed
[Z] zero adjust succeeded
[N] zero adjust not required
[_] zero not attempted

5th, 6th and 7th characters show the number of readings taken.
[123] 3 digit count of readings
[ ] space if the assay failed at an early stage

If the hardware indicates source fail, then position 5 is overwritten by 'S'. NOTE: Added at version 1.03.
[Sxx] Source Fail.
As indicated above, the remaining two digits in position 6&7 may not be present.

If an arm jam occurs, then position 5 is overwritten by 'J' jam whilst arm closing and 'j' for opening.
NOTE: Added at version 2.00.
[Jxx] Arm jam closing.
[jxx] Arm jam opening.
As indicated above, the remaining two digits in position 6&7 may not be present.

8th character shows the status at the end of the assay
[T] ended due to time out
[D] gas end condition was satisfied
[C] general error, cancelled or otherwise failed to complete
[R] ended with error; reading over or under range.

e.g. [COGN123D] = Closed mode; No error; NCER OK; Zero OK;
123 records stored; satisfactory assay.

4.2 Data output and serial communication

Protocols

The serial output is RS232 compatible with hardware handshake options of CTS, none (no handshake) and Xon/Xoff.
The baud rate is selectable between 300, 1200, 2400, 4800, 9600, and 19200.
The default protocols are none (no handshake) and 9600 baud.
If logging is set to serial, the serial protocol is set to hardware handshake and there is no connection to the serial port, then the ACE Station will halt when the first data record is ready to be sent. The ACE Station will stay waiting indefinitely for a connection to be made.

The serial cable supplied is wired as follows:

9 pin D type		5 pin Binder	
Pin	Duty	Pin	Duty
2	RX (Receive Data)	3	TX (Transmit Data)
3	TX (Transmit Data)	4	RX (Receive Data)
5	Ground	5	Ground
6	DSR (Data Set Ready)	2	DTR (Data Terminal Ready)
7	RTS (Ready To Send)	1	CTS (Clear To Send)

Sending a Log File (RS232)

On the PC run HYPERTERMINAL™ by clicking on Start / All Programs / Accessories / Communications
Ensure that HYPERTERMINAL™ protocols and those set in the ACE Station match (see above for default settings and Appendix 7 –Setting up HYPERTERMINAL for further information)
On the ACE Station Select logging set file (use the Up & Down arrows to select the file to be downloaded) then press options send ASCII
The data will download to the PC followed by the message “Transfer completed OK”

SECTION 5. SETTING UP/PERFORMING AN ASSAY

5.1 Operating in Closed mode

5.1.1 Running a single Closed-mode experiment

1. On the first display screen press /start/

2. If the chamber is in the closed position it will now open to uncover the soil area. A status message "waiting for purge" will appear. Air is now circulated inside the chamber to ensure that the CO_2 concentration is at ambient prior to the experiment taking place. This should take in the region of 45 seconds.

Note: LIM.T will commence as soon as the chamber starts the purge sequence.

3. The chamber will close and cover the soil area. The first display screen will now appear together with the status message "experimental assay now taking place".

4. The first display screen will continue to be shown until the assay is completed due to either LIM.T or ΔCset being reached. At this point the status message "performing calculations" appears.

4. The chamber will open to uncover the soil area.

5. Running a single experiment will not affect a programmed experiment (See setting PERIOD in next section). Should a programmed experiment be due whilst a single experiment is running then it will take place after the single experiment has completed.
6. To stop an assay which is already proceeding press cancel. This will terminate the measurement of CO_2 in the chamber but the measurements for ambient and zero CO_2 will proceed normally.

5.1.2 Programming a Closed Mode experiment

1. Press PAGE to select third display screen. Press config
2. Press select to move cursor to MMODE. Use + and – keys to select CLOSED without ambient option or CLOSZ if your ACE Station has the ambient reading option fitted.

3. Press select to move cursor to PERIOD. Use + and – keys to select time between measurement cycles in minutes. For most applications it is unlikely that this will be less than 60 minutes.

4. Press select to move cursor to LIM.T. Use + and – keys to select maximum time for each measurement assay in minutes. For a Closed mode experiment we recommend that LIM.T should be set to a minimum of 10 minutes.

5. Press select to move cursor to ΔCset. Use + and – keys to select at which differential CO2 reading the measurement assay should terminate. A value of 10 is a reasonable starting point.

6. Press select to move cursor to LID.VOL. Use keys as above to select 2.6

7. Press select to move cursor to HEIGHT. Measure and enter distance in mm from the soil surface to the top of the soil chamber collar.

8. Press select to move cursor to CH.DIA. Ensure this is set at 230

9. Press select to move cursor to LOG.
   Press + or – key to select log file that you wish to record data onto.
   Press set file. Use the arrow keys to select log file then press set log
   Alternatively, select new file set log
   Now use >, + and – keys to name new file.
   Press PAGE to create new file.

10. Press more then press select to move cursor to CAMB.
    Unless known, enter value of around 16mmol m^{-3}.

11. Press select to move cursor to A-LOCK. Select yes or no

12. Turn the ACE Station off by pressing power off then open arm and the first assay will occur ‘PERIOD’ minutes later (this puts the ACE in to a dormant state and will conserve power).

5.2 Operating in Open mode

5.2.1 Running a single Open mode experiment

1. On the first display screen press start

2. If the chamber is in the closed position it will now open to uncover the soil area. A status message “waiting for purge” will appear. Air is now circulated inside the chamber to ensure that the CO2 concentration is at ambient prior to the experiment taking place. This should take in the region of 20 seconds.

Note: LIM.T will commence as soon as the chamber starts the purge sequence

3. The chamber will close and cover the soil area. The first display screen will now appear together with the message “experimental assay now taking place”.

4. The first display screen will continue to be shown until the assay is completed due to either LIM.T or ΔCset being reached. At this point the status message “performing calculations” appears.

5. The chamber will open to uncover the soil area.

6. Running a single experiment will not affect the experiment programmed by setting PERIOD. Should a programmed experiment be due during a single experiment is running then it will take place after the single experiment is completed.

5.2.2 Programming an Open mode experiment

1. Press PAGE to select the third display screen.

2. Press config

3. Press select to move cursor to MMODE. Use + and – keys to select OPEN without the ambient option or OPENZ if your ACE Station has the ambient reading option fitted.

4. Press select to move cursor to PERIOD. Use + and – keys to select time between measurement cycles in minutes.
   For most applications it is unlikely that this will be less than 60 minutes.

5. Press select to move cursor to LIM.T. Use + and – keys to select maximum time for each measurement assay in minutes. For an Open mode experiment we recommend that LIM.T should be set to a minimum of 5 minutes.

6. Press select to move cursor to ∆cset. Use + and – keys to select at which differential CO2 reading the measurement assay should terminate. A value of 5 is a reasonable starting point.

7. Press select to move cursor to LID.VOL. Use keys as above to select 1.0

8. Press select to move cursor to CH.DIA. Ensure this is set at 230.

9. Press select to move cursor to USET. This should be set depending on the activity of the soil. The more active the soil the higher USET should be. We would recommend starting with a flow rate of around 300 µmol sec^{-1}.

10. Press select to move cursor to LOG. Press + or – key to select the log file that you wish to record data to. Press set file then use the arrow keys to select log file then press set log Alternatively, select new file set log Now use >, + and – keys to name new file. Press PAGE to create new file.

11. Press more then select to move cursor to CAMB. Unless known, enter a value of around 16mmol m^{-3}.

12. Press select to move cursor to A-LOCK. Select yes to lock or no to cancel.

13. Turn the ACE Station off. (This puts the ACE into a dormant state which conserves power). The first assay will occur ‘PERIOD’ minutes later .

5.3 Lastrun.log

The lastrun.log file is written to the card at the end of each assay. At the start of a new assay the file is cleared. The file contains all the CO2 readings which were taken during the assay, and their new values, corrected where appropriate, with the new zero value after the end of the assay. This means that for the closed with zero mode setup, the lastrun.log file will have the readings twice, with one offset from the other when the zero option is fitted.

The file can be loaded into a spreadsheet and the CO2 values examined.

In the case of a closed mode assay, the values should have reached their final value at the end of the assay, and if they have not, future assays should be allowed to proceed longer.
The final value will never be perfectly stable due to fluctuations in ambient CO2, so the delta should not be set so sensitively that the assay is prolonged by ambient noise. If the assay takes an unnecessarily long time, it will result in the soil being covered for longer than necessary, and not being exposed to natural atmospheric conditions.
To change the duration, check how the assay has been terminated by examining the comment field at the end of the file. The last character of the comment field is a T or D for time or delta termination. If the assay has been terminated by the time limit, LimT can be changed. If the assay has been terminated by the delta, the delta can be changed.

For a closed mode assay, the values will increase exponentially. The final NCER value will be more repeatable with a larger number of readings, and 10 should be considered a minimum, but there is not much advantage to be gained from more than around 40 readings. The duration of an assay with more that 40 readings will cause the soil to be covered for longer than is necessary.
The NCER is calculated from the slope at the start, and this is obtained by calculating an exponential which is a best fit to the data. The first few measured values dominate the final NCER, so it is important the start of the curve has a good exponential shape. The first value which is used for calculations is the Cref value (default 16), but this value is not recorded to the file. To check that the curve has a good shape, add the Cref value to the start of the data before creating a spreadsheet graph from the data.

When the lid of the chamber shuts at the start of an assay, the exact point of closure is uncertain, and a software delay is added to the measurement cycle so that subsequent readings all lie on an exponential. This delay is factory set to get a good shape.

SECTION 6. CALIBRATION

Important Note: The ACE Station is factory calibrated prior to despatch. This calibration can not easily be improved upon except under laboratory conditions. Recalibration should not be necessary. Performing a Zero or Span gas calibration should therefore not be undertaken lightly and should only be considered if there is some cause for concern that assay measurements are not as expected or if a component such as the infrared source has failed and been replaced. Before proceeding with a Span calibration, check that Ambient pressure "P" and temperature "T" are correct. Also check that the Date and Time are correct so that date of calibration is correctly stored.

Zero:

CO_2–stripped gas (Zero gas) is passed through the analysis cell and a potentiometer adjusted to achieve the best (minimum) value (OK displayed).

Note: *If the Station has the zero option fitted the gas circuit is changed appropriately. If not then it is expected that zero gas is manually supplied as described below and a message to this effect is displayed before proceeding.*

The calibration is done by entering the do cal page and highlighting "zero" using the select key. yes – Apply --- yes – Zero. A highlighted value will appear.

On instruments before serial number 33426 (pre version 2.04 software): Remove the black belt from the flexible weatherproof cover, either by unclipping it or by sliding it forward onto the arm. Slide the flexible weatherproof cover down the arm (away from the chamber end of the arm) until all 7 cover screws are exposed. Remove the 7 screws and washers and store them safely. Slide the cover out. The zero potentiometer, RV14 can now be accessed. (It is located at the end of the board nearest to the chamber)

On instruments after serial number 33426 (post version 2.04 software): Remove the lid of the control box as described in section 5, and adjust RV27 on the analogue board, i.e. the board which does not have the display and keypad. RV27 is in the corner, near the SD card slot, under the red heart symbol.

Adjust the potentiometer until the highlighted value reduces towards zero and "OK" appears next to it. (Adjust the potentiometer clockwise if the arrow is pointing up.)

Note: *Due to electronic filtering of the Infrared detector's signal the response to adjustments made to the potentiometer are slow. Make an adjustment then wait a few seconds to see how much the value has changed before any further adjustments are made, otherwise it is very easy to "overshoot".*

Once the adjustment has been made satisfactorily, press the OK key to end the calibration.

If you have an ACE without zero, it is not necessary to set the zero pot with any great accuracy. This is just to ensure that analogue signal at the A-D converter is sensibly within its dynamic range. It does not affect the accuracy of the reading.

Remove the pipe at the motor end of the cell. Then if you have some zero gas eg nitrogen, or can make some by pumping air through a soda lime column, connect this to the cell. In the zero adjust menu page, adjust the pot at the head end of the arm to get a displayed value of less than 300.

If you do not have zero gas, do not remove any pipes. Set the ACE above the ground and get it to do an assay so it collects fresh air. The NCER value will be meaningless, but it will leave fresh air in the cell at the end of the assay. In the zero menu, set the count to about 4000, arrow down, with the zero pot. When leaving the calibribration page, a message will say that the calibration failed – reading too low, but do not worry. If outside working is not possible, get the ACE to do an assay indoors, preferably with the window open, invoke the zero menu, and set the zero pot to about 5000, arrow down. Again there will be an error message. This method will work as well as the method with zero gas unless the local CO2 concentration is very uncertain, eg downwind from volcanic activity or heavy industry.

Span:

Reference span gas is manually connected to the cell at the same end as zero gas (above) with the consideration that the calibration gas is supplied from a regulated outlet at a maximum flow rate of 800ml min^{-1}. This is to avoid pressurising the IRGA and causing a false calibration.
A span must immediately be preceded by a zero for the two types where a zero column is not fitted. This is to prevent zero drift upsetting the span. The Station types with a resident zero column will do their own zero before a span.
The Span gas should ideally be between 750ppm and 1000ppm. To convert volumetric value to a molar value (see Appendix 3 – Calculations & References)

SECTION 7. MAINTENANCE

Air Inlet Filter: The filter helps to prevent plant debris (pollen etc) and dust from entering the ACE Station's gas circuit. Except for the basic Closed without Zero hardware configuration it is recommended that the filter is regularly checked and a new one fitted if necessary. We advise that this is done regularly, perhaps once a month if the local environment is dusty.
There are two spare filters in the Spares pack.

Hydrophobic filter Except for the basic Closed without Zero configuration there is also an internal hydrophobic filter inside the Arm. This filter will become blocked if water enters the system. This filter may eventually become blocked with fine dust. Early symptoms of a heavily contaminated filter may be that the pump can be heard to strain or the value for u (Flow) is noticeably less than Uset in Open configuration Stations. (especially at higher flow rates).
The filter can be visually examined by removing the cover from the Arm. (7 screws). If it is noticeably blacker than a new one it should be changed. There are 2 spare hydrophobic filters in the spares pack.

Soda Lime: On hardware configurations that are fitted with a Soda Lime column the Soda Lime should be inspected and replaced if there is any doubt about whether it is still active. The Soda Lime supplied by ADC BioScientific is of a self-indicating type. It is green when fresh and turns to a light brown colour when exhausted.

Analysis fan: It is worth checking prior to performing an assay in a new soil area that the fan can be heard (and possibly seen) to be running. It may also be inspected to make sure that it is free of plant debris (grass, leaves etc). It can be easily cleaned with a small artist's brush.

Nafion equilibriator: The equilibriator tube is a delicate item and can be easily damaged. If removing it (when for example performing a Span calibration) it should only be held by the white plastic stem and not by the tube itself.

APPENDIX 1. FILE FORMAT AND CONTENTS

File Format

Data files are of one of two formats (hereafter referred to as UK mode or Euro mode). The type of format currently in use can be readily determined by examining the displayed parameters. If in UK mode the decimal point will be shown as a full stop. If in Euro mode the decimal point is displayed as a comma.

UK mode is the default format and is an ASCII file consisting of a header listing the parameter names followed by the records with parameters separated by commas and each record by CR <carriage return>. The file is automatically given a .csv extension (comma separated variable). This allows it to be readily imported into most spreadsheets.

Euro mode is the alternative format and is the same as the UK mode but with the file parameters separated by tabs. The file is automatically given a .txt extension (text file). This allows it to be readily imported into most spreadsheets with only minor set-up required on entry.

Important notes

When in UK mode, the instrument will not see 'Euro mode' format log files (since the extension is different). Also the instrument cannot correctly display .txt log files.

Similarly when in Euro mode, the instrument will not see 'UK' format log files.

Changing the File Format

The File format can only be changed by connecting the ACE Station's serial port to a COM port on a PC (Personal Computer) and running the HYPERTERMINAL™ program to reprogram the ACE Station's mode.

Refer to Appendix 7 "Setting Up Hyperterminal" and follow the instructions in paragraphs 1,2,4 & 5

Type ^ (Shift+6) to enter FORTH CLI mode (FORTH Command Line Interpreter)

HYPERTEMINAL™ will display the ACE Station's details then await commands.

Type "SET-EURO-DATA" to switch from UK (default) mode to Euro mode.

Type "SET-UK-DATA" to switch from Euro mode to UK mode.

Type "START" to exit FORTH CLI. (The ACE Station will re-boot).

File Contents

Under range and over range parameter values are indicated by a symbol or a specific number.

The header will change slightly depending on measurement modes and will include O, OZ, C or CZ. (See Section 4.1 – Reviewing log files)

The parameters are saved (or sent) in the order shown below, preceded by a header listing the parameter names. The order is the same whether logging to the local CF Card or transmitting to a PC via the RS232 serial link.

Record Number
Date
Time
Ref CO2
Δ CO2
NCER
PAR
Flow
Internal battery voltage
Soil temperature 1
Soil temperature 2
Soil moisture 1
Soil moisture 2
Soil temperature 3
Soil temperature 4
Soil temperature 5
Soil temperature 6
Soil moisture 3
Soil moisture 4

APPENDIX 2. RANGE OF PARAMETERS/DEFAULT CONFIGURATIONS

Parameter	Symbol	Minimum	Maximum	Units
CO2 ref (molar) *		0	50	mmol m^{-3}
CO2 ref (volume) *		0	1000	ppm
CO2 meas.		0	50	mmol m^{-3}
CO2 Delta (Closed)	ΔC	-50	50	mmol m^{-3}
CO2 Delta (Open mode)	ΔC	-30	30	µmols m^{-3}
NCER	NCER	0	100	µmol m^{-2} sec^{-1}
Soil Temp (1-6)	Temp1 etc	-10	50	^{o}C
Soil Moisture (1-4)	Mois1 etc	0	10	V
PAR	Q	0	3000	µmol m^{-2} sec^{-1}
Flow (actual)	U	0	5000	µmol sec^{-1}
Set Flow	Uset	200	5000	µmol sec^{-1}

* The relationship between molar and volumetric measurements is dependant on the ambient temperature and pressure (see Appendix 3 – Calculations & References) Note that CO_2 ref (volume) only appears in the CO_2 span calibration page.

ACE Configurations (default settings)

(O) = Open ; (C) = Closed; Flow only available in "With ZERO" configurations.

First page

Period	0 * (30)	LimT	10	Flow	3000
Lid Vol	1.0 (O); 2.6 (C)	Height	30	ΔC Set	20.0 (O); 5.0 (C)
Ch Dia	230	Log	Off	Mmode	Open / Closed

Second page

C amb	16.0	A Lock	No
cmt.	User input		
name	User input (default = "location")		

* The period is initially set to zero to prevent an Assay from starting when the ACE Station is first switched on after receipt from ADC. In practise this value will be determined by the user and depend on the experiment conditions but a good starting value would be 30.

APPENDIX 3. CALCULATIONS & REFERENCES

Net CO_2 Exchange Rate

symbol: ***NCER*** (µmol m^{-2} s^{-1})

$$NCER = \frac{V}{a}(\Delta c)10^3$$

where ***V*** volumetric flow of air, m3 s^{-1}

Δc difference in CO_2 concentration through soil chamber mmolm-3

a difference in CO_2 concentration through soil chamber

Converting molar to volumetric CO_2 values

$$D = \frac{273CP}{22691.2(273+T)}$$

Where:

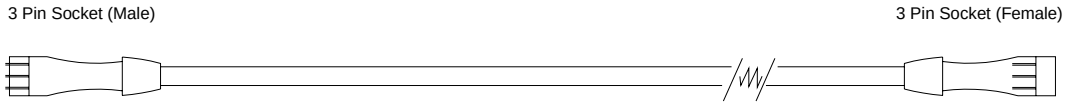
D = Gas density (mmol m^{-3})
C = Gas concentration (ppm)
P = Atmospheric pressure (mb)
T = Ambient temperature (^oC)

References

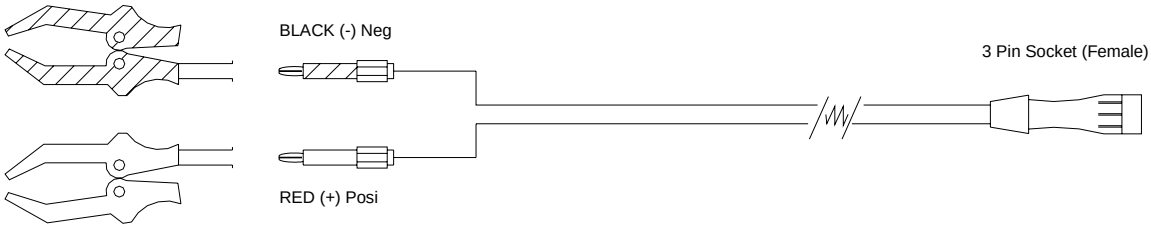
1. Hutchinson,G.L, and G.P.Livingston. 2001. Vents and seals in non steady-state chambers used for measuring gas exchange between soil and the atmosphere. European Journal of Soil Science S2 (4),675-682. doi:10.1046/j.1365-2389.2001.00414.x

2. Pederson,A.R., S.O.Peterson, and F.P.Vinther. 2001.Stochastic diffusion model for estimating trace gas emissions with static chambers. Soil Science Society of America Journal 65:49-58 (2001)

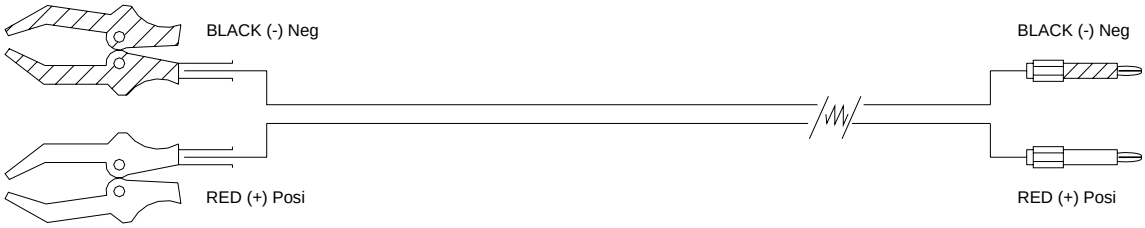
ACE-080 / 081 - Available in 10m or 100m lengths



ACE-084 / 085 - Available in 10m or 100m lengths



ACE-086 - Available in a 2m length



ACE-087 - Available in a 50m length

Contact ADC BioScientific for further details.

APPENDIX 4. POWER CONNECTION

Independent Station

When an ACE Station is used independently, the internal battery is omitted. Power can be supplied from an external 12V lead acid battery. It is also possible to supply the Station from any DC supply giving between 30 and 40V and capable of 0.5 amps. This 30 – 40Volt DC supply may also be used to charge a backup battery, when excess power is available.

The external 12V battery may be charged by a battery charger giving a voltage between 13.5 and 14.8 or it can be swapped with a charged battery as needed.

ADC BioScientific can supply a 13.5V 2A 110/230V 50/60Hz charger that can be used to float charge the external battery.
Note that this charger is not waterproof and is not intended for outdoor operation.

The external battery may also be kept charged with a solar panel or wind turbine or from the 30 – 40Volt DC supply as described above.

As a general guide a typical fully charged 12Volt 40Ah car battery will provide power for a single ACE Station for approximately 28 days of continuous use.

Connection between the external battery and the ACE Station is via a 2 x crocodile to 3 pin socket 10m lead ACE-084, or ACE-085 for 100m. (See diagram opposite)

Networked Station(s)

When using the ACE Station in a network, leads are available from ADC BioScientific (Part No's ACE-080 / 081 -10m and 100m) to connect between individual stations and the master.

The Master Controller supplies each station with a high voltage (around 40 Volts DC) and low current in order to minimise losses along the cables. Each station takes the power from the Master, reduces and regulates it with a low loss converter, and uses it to supply operating power (and power to float charge the Station's internal lead acid battery).

The power connection is also used for data and control communications between the Master and each Station by superimposing the signal upon the DC supply voltage.

Other leads

Customers wishing to use leads other than those supplied by ADC BioScientific should contact ADC for further advice and information.

APPENDIX 5. SENSORS

PAR (Photosynthetically Active Radiation)

A single PAR sensor is supplied as standard on every ACE station. The PAR reading has a range of 0-3000 umols m^{-2} sec^{-1} and is factory calibrated.
It is mounted on the ACE station close to the chamber at the end of the arm. It cannot be easily detached and is permanently connected into the internal electronics.
The value (Q) is shown on the first page of the display. (Units = µmols m^{-2} sec^{-1})

Temperature

It is possible to connect up to 6 temperature sensors to the ACE Station (three on each side of the control box).See figure on page 8.
The value for sensors 1 & 2 are shown on the page one and sensors 3 to 6 on page two.
The displayed value for each temperature sensor is in degrees Celsius (°C)

The sensors are of the thermistor type and have to be supplied by ADC BioScientific as they require a suitable lineariser circuit in the ACE Station.

ADC BioScientific can supply a sensor matched to a correction curve in the instrument. The accuracy is ±0.5 deg C.
Further information regarding the resistance/temperature characteristics of the thermistor provided by ADC BioScientific may be obtained by request.
Although we expect the sensors to normally be soil temperature sensors, it is also possible to connect air temperature sensors providing they are of the same type.

Limited data is also shown in Appendix 6

Moisture

It is possible to connect up to 4 moisture sensors to the ACE Station. The sensors can either be supplied by ADC BioScientific, a distributor or a customer.
ADC BioScientific can also supply suitable plugs that match up with the sockets on the ACE Station if the sensors are obtained elsewhere.

The values of moisture sensors 1 and 2 are displayed on the first page of the display and the remaining two on the second page.
The sensor readings are displayed as a voltage.

The ACE Station uses moisture sensors that require an excitation (supply) voltage and give an analogue voltage output proportional to the relative mass of moisture in the soil. Although it is possible to connect different types of moisture sensor to a single Station, there are restrictions.

1/ Sensors 1 and 2 must have the same excitation voltage requirement.
Sensors 3 and 4 must have the same excitation voltage requirement.
However, the two pairs may be different. (see Moisture sensor configuration)

2/ The analogue output voltage must not be greater than 2.5V at maximum (100%) moisture/soil mass ratio) and ideally give 0V at minimum (0%) ratio. The gain can be set to give the best resolution, for each sensor connected, within the control console.

Typical sensors are Aqua Pro, Delta T Thetaprobe, Delta T SM200 or Decagon Echo probes. The data sheets supplied with the sensors (if not purchased directly from ADC BioScientific) will supply the information regarding excitation and output voltage range as well as connections.
The connections for the moisture sensor are:
pin 1 = 0V; pin 2 = output; pin 3 = supply (excitation voltage).
ADC BioScientific can supply moisture sensors on request.

Although we expect the moisture sensors to normally be soil moisture sensors (measuring relative mass of moisture in the soil), it is also possible to connect air %RH sensors (providing they conform to the restrictions given above on a single ACE Station).

Moisture Sensor configuration

The ACE Station may be configured to match various makes/types of moisture sensors.
If the Station has been supplied complete with sensors then it will already have been configured to match their specific requirements.
If sensors are chosen at a later time by the customer it may be necessary to reconfigure the switches to suit. For safety reasons any unused sensor inputs have the switches set to a default position giving the minimum output gain and excitation voltage.

The configuration is done by setting four 4-way DIP switches which select the gain and excitation voltage that is suitable for the sensors.
These switches are located on the two interface boards which are mounted at each end of the control box. To access and reconfigure the switches it is necessary to switch off the ACE Station and set the battery isolator switch to the off position, and then

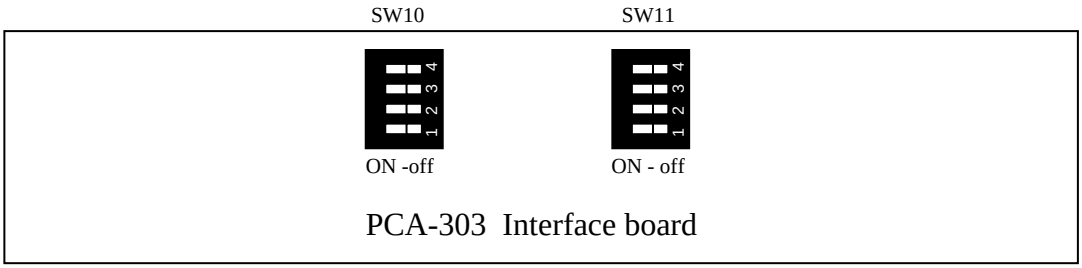
remove the 6 screws which retain the display and keypad. When refitting the lid, be sure that the ribbon cable rests in its slot, otherwise the insulation may be damaged. When lifting the lid, do so carefully so that no connectors are pulled off. When lifted, the two PCA-303 interface boards are exposed.
Each Interface board controls either sensors 1 & 2 or 3 & 4 depending at which end of the control box it is mounted. (See figure on page 8)

SW10-1 to 3 and SW11-1 to 3 are used to set the Gain and SW10-4 is used to set the Excitation voltage to suit the chosen sensor(s) by setting the switches as shown in the table below. Switches are ON when set to the left (See figure below). The default settings are shown in **Bold** print giving a gain of 1 and excitation voltage of 2.5V

SW11-4 is factory set to determine the function of each of the PCA-303 boards (either RS232 connection or Power connection) and should not be disturbed.

* When SW10-1 or SW11-1 is set to ON the position of Switches SW10-2 & 3 and SW11-2 & 3 are effectively disabled. i.e. gain = 1 regardless.

Switch	**Gain** (SW10 = Sensor 1 & 3; SW11 = Sensor 2 & 4)			
	x 1	**x 2**	**x 5**	**x 10**
1	**ON**	off	off	off
2	n/a *	ON	off	off
3	n/a *	off	ON	off
4	**Excitation Voltage (SW10-4 only)**		**Board selection (SW11-4 only)**	
	ON **2.5 Volts**	off 10 Volts	ON Power	OFF Serial



The Analogue to Digital converter in the ACE Station is referenced to 2.5 Volts.
This means that the sensor's output times the circuit gain shown in the table above must not exceed 2.5V otherwise it is possible that the reading may read over-range (o/r).
However, the gain should be set as high as possible (without exceeding the 2.5V) in order to provide the best resolution. See example set-up on next page.
For both the moisture and temperature sensors, the excitation voltage is applied immediately before and then during the measurement period, a total time of 800 mSec. The moisture sensor excitation voltage for M1 & M2 may be adjusted by adding a resistor (R) between T1 pins 2 and 1, and for M3 & M4 voltages between pins T4 pins 2 and 1. The voltage obtained is calculated by (10R+2209)/(R+1697) with SW10-4 in the 10Volt position. The 2.5V reference which is used for the A-D converter and for the thermistor excitation is available on pin 2 of T5 connector.

Example set up:

The Delta-T SM200/300 moisture sensor requires an excitation (supply) voltage in the range of 5-14V @ 15mA and provides a 0-1 Volt output (Equivalent to 0% to 100% moisture).

The excitation voltage should therefore be set to 10V by setting SW10-4 to off.

The gain may be set to X2 by setting SW10-2 to ON & SW10-1 & 3 to OFF (sensors 1 or 3) and SW11-2 to ON & SW11-1 & 3 to OFF (sensors 2 or 4).
This will provide an optimum displayed range of 0-2V (Equivalent to 0% to 100%)

A gain of X5 could be used if soil moisture readings are expected to be consistently less than 50% (giving less than 2.5Volt) by setting SW10-3 to ON and SW10-1 & 2 to Off.

In practice all switches 1 to 3 will be set to the same configuration on both PCA-303 interface boards in the expectation that only one kind of sensor will be connected to the Station.

APPENDIX 6. THERMISTOR DATA

Temp (°Celsius)	Resistance (Ohms)
-20	96976
-15	72895
-10	55297
-5	42314
0	32650
5	25395
10	19903
15	15714
20	12493
25	10000
30	8056
35	6530
40	5325
45	4367
50	3600

APPENDIX 7. SETTING UP HYPERTERMINAL™

This applies to Windows 95, 98, NT and XP. For non-Windows systems, you will need to use a terminal emulator.

1. Select Hyperterminal from the start menu: “START”, “PROGRAMS”, “ACCESSORIES”, In WIN95 select “HYPERTERMINAL”, in later versions select “COMMUNICATIONS”

2. Select (double click on) the Hypertm.exe icon.

3. Name your new connection e.g. ACE Assays, and choose a different icon if desired. Click on “OK”.
   This will save all your settings so that it is easy to repeat the transfer.

4. The next window will ask you to type in a phone number as it assumes you will be connecting via a modem. Ignore this and click on the “connect using” option window.
   Select the COM port number that you intend using on your PC. (*The other options on this window will then be automatically deselected*).
   Click on “OK”. A new window will then appear asking you to set the COM port settings.

Select :	bits per second	9600 (or matching the Station’s setting)
	data bits	8
	parity	none
	stop bits	1
	flow control	Xon-Xoff (or match the Station’s setting)

5. Click on “OK”
   Ensure the settings match those on your ACE Station before transmitting data (see section 4.2)

6. Click on the “transfer” button and select “capture text”.

7. Enter a filename and click on “start”
   Tip: if you give your file a “.csv” extension you will be able to import it directly into most spreadsheet programs.

8. The PC should now be ready to receive data from the ACE Station, which can be sent by pressing send ASCII on the ACE Station.

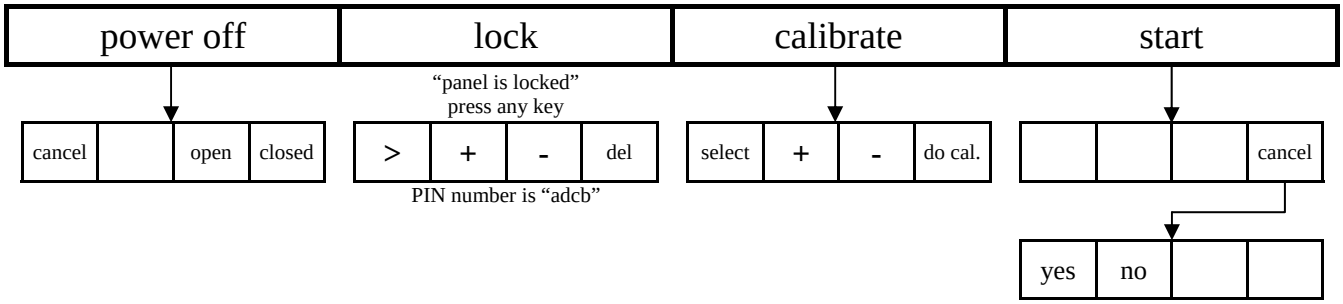
9. To stop data transfer click on “call”, “disconnect”.

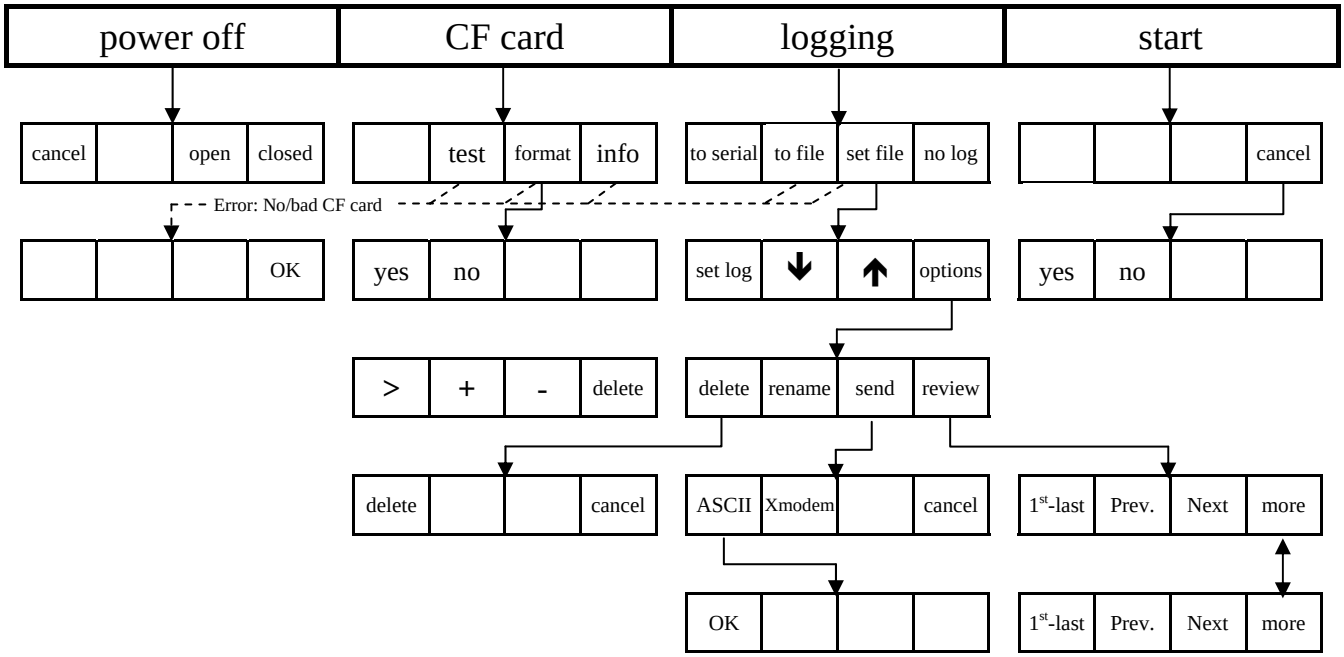
APPENDIX 8. TECHNICAL SPECIFICATIONS

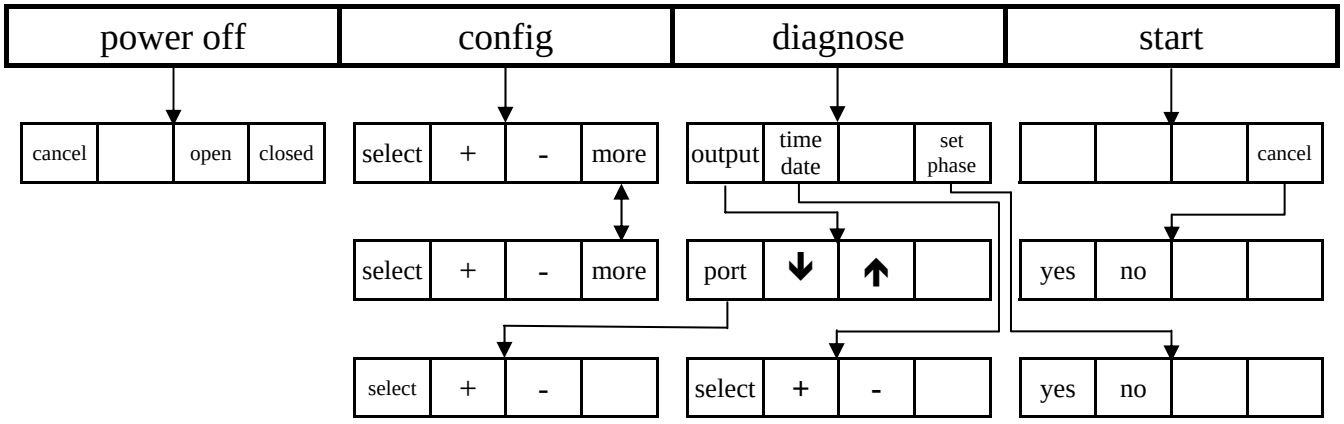
Measurement of CO_2	Standard range: (Molar) approximately 40.0mmols m^{-3}. (Equivalent to 896ppm at standard temperature and pressure) 0.1mmols m^{-3} resolution Standard range: (Volumetric) 1000ppm 1ppm resolution. Infrared gas analyser housed directly adjacent to soil chamber. Differential open or closed system.
Measurement of PAR:	0-3000µmols m^{-2} sec^{-1} Silicon photocell
Measurement of soil temperature:	6 selectable inputs for thermistors
Measurement of soil moisture:	4 selectable inputs for industry standard sensors
Flow control to chamber: Flow control accuracy:	200 -5000 ml min^{-1} (137-3425 µmols sec^{-1}) ± 3% of f.s.d.
Display:	240 x 64 dot matrix LCD.
Programming:	User-friendly interface driven by only 5 keys.
Recorded data:	Removable CompactFlash (CF) cards.
Internal battery:	12V 1.0Ah standby battery back-up (networked Station only)
Power supply:	External source battery, solar panel, or wind turbine. One 40Ah car battery provides power for approximately 28 days of continuous use.
RS232 output:	User selectable rates from 300 to 19200 baud. Handshakes CTS (hardware), Xon/Xoff or none.
Electrical connections:	Robust, waterproof 3 pin DIN.
Station Weight/Dimensions:	7.5Kg (*Closed with zero*) / 82 x 33 x 13 cms
Chamber volume:	Closed type 2.6 Litre / Open type 1.0 Litre
Soil collar diameter:	230 mms
Packed Weight & Dimensions:	17 kg – 95 x 40 x 40 cms

APPENDIX 9. MENU TREE

Pressing the “Page” key in “sub-level” menus returns to previous level except where shown. Pressing the “Page” key in the “top-level” menu steps through the three main pages.







APPENDIX 10 CHAMBER HEAD REMOVAL AND REFITTING

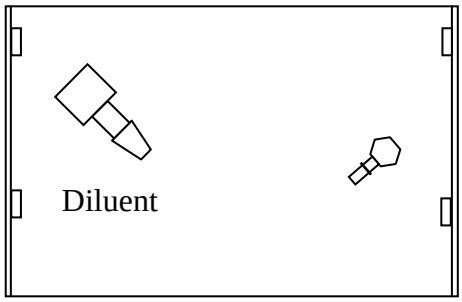
WARNINGS & ADVICE

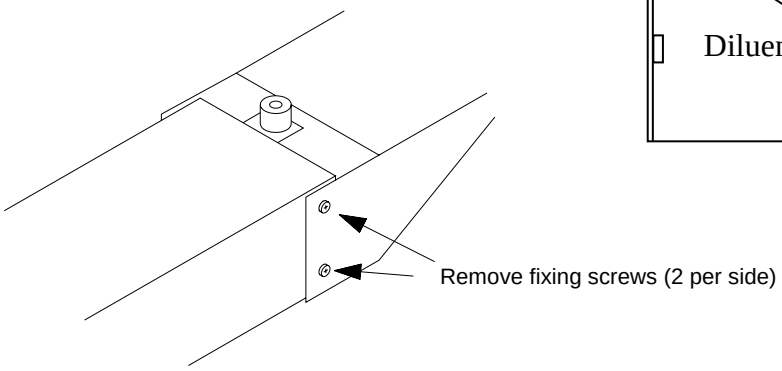
A Nafion tube connects the elbow underneath the centre of the arm to the Chamber head. It can be identified as the pipe enclosed by a protective spring. Please be very careful not to twist, stretch or strain the Nafion tube as it is extremely delicate. If bent too far it may become kinked and cannot be repaired. A damaged tube will affect the accuracy and performance of the ACE Station.

Do not pull on the pipes when removing them. When pipes are removed from push-on fittings there is a tendency for the pipe to stretch in length and reduce in diameter – causing it to grip tighter on the fitting. The best way to remove the pipes is by pushing them off from behind. Where this is not possible the pipe should be removed by gripping the pipe and wiggling it from side to side whilst gently pulling it.
It is best to remove the pipes in a warm environment as they will be more flexible and less prone to splitting under strain.

Similarly when removing the Fan leads do not pull on the wires directly as this may damage the internal solder joints. Gently wiggle each crimp from side to side whilst pulling on it to unplug it.

It is helpful to have an assistant to support the chamber head once the four fixing screws have been removed.





Removing a Chamber Head

1. Turn off the ACE Station by pressing power off then arm open

2. Disconnect external power and turn the Battery switch to the OFF position.
3. If a UV reflective umbrella is fitted (applies to metal heads only) unscrew the three retaining screws until the umbrella can be lifted away from the head.

   Put the umbrella assembly to one side.
4. Gently unplug the two fan power leads (red and black) from the two terminals under the arm. Gently wiggle each crimp from side to side whilst pulling on it to unplug it.
5. Unscrew the white plastic lock ring at the end of the Nafion tube. The lock ring should only be finger tight and so use of pliers should be unnecessary.

Note: On small chamber heads the lock ring is easier to access after the next stage.

6. Whilst supporting the Chamber Head undo the four M3 Crosshead screws and washers holding the head assembly to the ACE Station's arm.

   Do not allow the head to drop as it or its seal may become damaged.
   See Warnings and advice on previous page.
7. If fitted remove the diluent tube (It is approximately 8mm in diameter) from the 90° elbow at the end of the arm. See figure on previous page.
8. Remove the cell input pipe (approximately 4.5mm diameter) by pulling it gently from the brass elbow in the end of the arm. Be careful not to stretch the pipe if the head has been fitted for some time as the pipe may be quite well attached.
9. Providing all the connections have been undone as above the Head can now be drawn easily from the arm.

Fitting a Chamber Head

Refitting is essentially the reverse of the removal process:-

1. Fit the 1 or 2 push-on pipes first (Cell Input and Diluent)

Note: If the Station is being reconfigured from an Open to a Closed system it is advisable to cap off the Diluent bulkhead with a rubber cap to prevent dirt gaining entry. See Appendix 11 – Spares and Accessories for details of the cap.

2. Reattach the Nafion tube to the screw-on connector. (Small Chamber heads only)
3. Refit the Chamber Head to the arm using the 4 off M3 cross-head screws and washers.
4. Reattach the Nafion tube to the screw-on connector. (Large Chamber heads only)
5. Reconnect the Fan power cables ensuring that they are the correct polarity (Red wire to red terminal and black to black)

   If applicable do not fit the umbrella assembly yet as the Chamber Head position now requires setting.

Setting the Chamber Head position

This is important otherwise the head may not seal on to the collar assembly.

1. Reconnect the external power and/or turn the Battery switch to the ON position.

2. With the four fixing screws slightly slackened, close the arm using the power off and arm closed commands.

3. Adjust the head so that the seal is slightly compressed all round and tighten up the four screws.

4. Alternatively use the power off arm-open and arm closed commands to open and close the Chamber and check that the head is sealing properly.

Do not force the arm backwards and forwards always use the menu commands.

Note: The head should swing over the soil ring before lowering on to it. If it touches the ring during closing it may not seal properly.
If necessary have an assistant support the ACE Station with the “Head” end of the instrument hanging over the edge of a desk or bench and look from underneath to check that no light is visible when the arm is closed.

If the Chamber Head seal is not compressed the instrument will not give accurate measurements. It is advisable to test the instrument a few times by opening and closing the arm before redeploying it and starting an assay.

Finally when you are satisfied that the head is correctly aligned make sure that the four screws are tight then refit the umbrella assembly if required.

APPENDIX 11. SPARES AND ACCESSORIES

Part Number	Description
057-700	Plug for user-supplied sensor
022-456	2A fuse glass time delay
197-200	Compact flash card
192-353	Lead acid battery, 12V 2.8Ah
407-855	Cap EPDM masking 4.8mm I.D. x 12.7mm
630-963	Hydrophobic filter, disposable
630-980	Air inlet dust filter
650-652	O ring, 6.07IDx1.78mm
651-551	O ring, 28.30IDx1.78mm
706-157	PVC tube 6.4mm bore
708-656	PVC tube 3mm bore
802-656	Soda lime (indicating 8-14 mesh)
809-151	Silicone grease
867-056	Trimming tool
ACE-012	Source assembly with lead and plug
ACE-020/LM	Large metal head assembly
ACE-020/SM	Small metal head assembly
ACE-020/LC	Large clear head assembly
ACE-020/SC	Small clear head assembly
ACE-022	Transit case
ACE-040	Soil temp thermistor assembly
ACE-043	Moisture sensor SM300 assembly
ACE-045	Moisture sensor ML2X assembly
ACE-061	Pump with lead and plug
ACE-072	CF card extractor
ACE-080	10m interconnection lead
ACE-081	100m interconnection lead
ACE-084	10m power lead with crocodile clips & plugs
ACE-085	100m power lead with croc clips & plugs
ACE-093	RS232 serial lead to connect to PC
ACE-201	Soil collar (8cm)
ACE-200	Soil collar (28cm)
ACE-206	Soil chamber foot
ACE-222	Control box lid gasket
ACE-231	Weather shield
ACE-263	Spike short
LCM-025	Power supply & plug assembly