

ACE
Automated CO₂ Exchange Station
INSTRUCTION MANUAL



L.MAN-ACE Station

Issue 20-102 May 2019. Software PRD-1074 issue 1.06

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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 CO₂ 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)

Secure digital 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 CO₂ Exchange System (ACE) is used to measure CO₂ exchange in soil (soil respiration).

Each ACE Station consists of a control box and an arm assembly, both mounted on a rigid baseplate. The control box contains a 240 x 64 pixel LCD display, a five-button keypad and a microprocessor control system (the control box may also contain a fixed or programmable Air Supply Unit (ASU) depending on the hardware configuration). The arm assembly consists of a motorised moveable arm containing an infra-red gas analyser (IRGA) to measure CO₂, 4 different types of head assembly can be mounted on the end of the arm. The head assemblies consist of either a 1Litre measurement chamber or a 2.6 Litre measurement chamber and can be made from either metal or clear material.

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, and the head encloses the area of soil being measured. The recorded measurements consist of the soil Net Carbon Dioxide Exchange Rate (NCER), ambient CO₂, 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 30 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 Secure digital (SD) card after the measurement sequence.

There are 2 basic modes of CO₂ measurement, each of which can have a zero function added for the measurement of ambient CO₂.

To obtain a Net CO₂ Exchange Rate (NCER) reading the lid is closed and a measurement is made of either

- 1) The difference of the CO₂ concentration of the gas in the chamber between the start and the end of the assay (open mode).

or

- 2) The rate of change of CO₂ concentration of the gas in the chamber during the assay (closed mode).

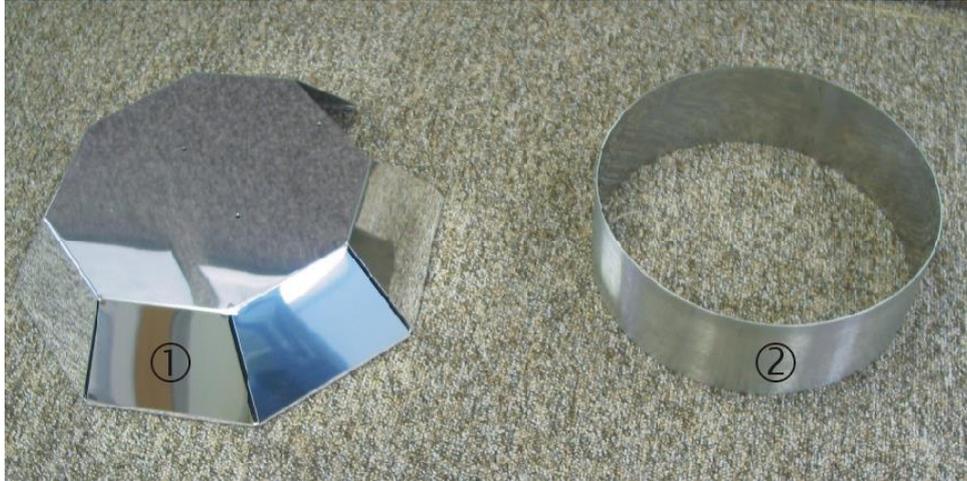


ACE Station layout and external functions

- | | |
|---|--|
| 1. Head assembly | The example shown is a small (Open mode) metal chamber. |
| 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. The arm assembly houses the integral CO ₂ infrared gas analyser (IRGA). |
| 6. PAR sensor | Fixed to ACE Station arm. Remove the yellow dust cover before use. |
| 7. Station arm casing and jacket | Robust, flexible, weatherproof protective cover for ACE Station pivoting mechanism. A retractable carrying handle is fitted to the arm casing on newer ACE stations. |
| 8. Positioning feet | Adjustable and reversible ACE Station feet with spikes or disks 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. Control console lid strap | Used with a padlock to lock the console lid closed. |
| 12. Control console lid | Keep closed for field security and durability. |
| 13. Soda lime | The soda lime column is fixed under the cover. |

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. This is not usually fitted for clear heads.
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 by positioning the pumped fresh air inlet at a higher level. To re-position the inlet, connect one end of a 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 CO₂ 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. Newer ACE stations are fitted with a retractable handle on the station arm casing.

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.

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.

Insert the Secure digital card into the drive slot ([see figure on page 8](#)).

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 12V battery charged by a solar panel or wind turbine. Ensure that the arm will not touch the battery when it opens. 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

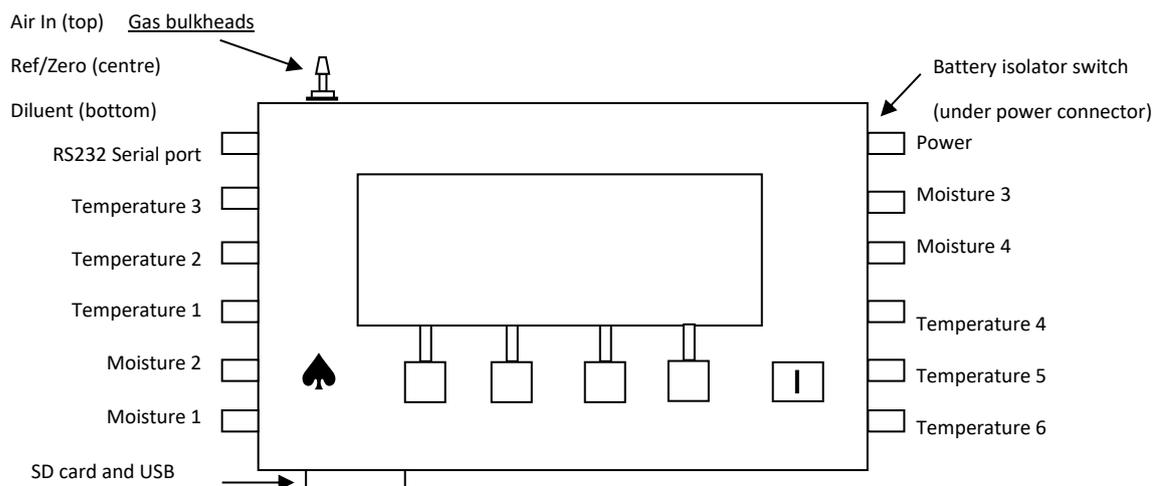
If you so wish an external 6mm bore pipe may be connected to the input of the cartridge filter in order to obtain air from a stable source away from the Station.

Checking the Chemicals

The CO₂ zero column for ambient CO₂ reading, is 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 white when fresh and violet when exhausted.

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).

³ See Hutchinson & Livingston reference in Appendix 3 – Calculations & References



1.4 Switching on

1. Switch the ACE Station on using the Power/Page button on the console.
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 SD memory card” message may also briefly appear on the status line at the top of the display.

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

To open the chamber: press the power off softkey, then open. When the screen goes blank press the page/I key to switch on again.

The ACE station is supplied with a thin blue plastic film covering the display and keypad, this is to protect the display during manufacture and can be removed when the ACE station is delivered to make the display easier to read. Another blue plastic film covers the paintwork on the top of the arm pivot assembly, again, this can be removed when the ACE station is delivered.

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 to reach the settings page. Press the **diagnose** key, then **time+date** and then press the **select** key to select each component of the date & time in turn, using the **change+** & **change-** keys to change each value in turn. Note that the seconds go to zero when changed. Press the page/I key to exit.

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 usually 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. The PAR sensor can be unclipped from its holder for cleaning. Remove the yellow dust cap before use.

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 strap 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 SD card slot or USB socket.

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/I is held down for two seconds the Station will automatically power off 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 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 internal battery 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 (real time clock) will continue to run, maintained by a small PCB mounted battery. 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 dependent on the hardware. Both of these modes are fitted with a zero (Z) mode, (to provide ambient CO₂ measurements):

These are closed with zero (CZ) and Open with zero (OZ).

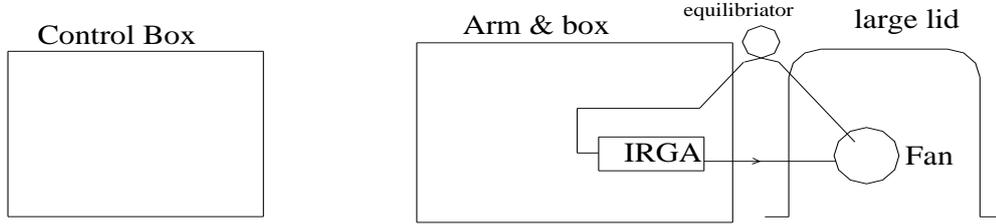
In both modes, a ΔCO_2 value is given. The ambient concentration at the start is known as the 'reference' CO₂ and that at the end is 'measured' CO₂.

In the CZ mode, a sealed lid is used so that the CO₂ increases in the measurement chamber due to the activity of the soil. At 10 second intervals the CO₂ is measured and the rate of increase determined. The user sets the assay end point by specifying a rise in CO₂ (ΔCO_2) and a time limit. The final measurement occurs at the first of these two events.

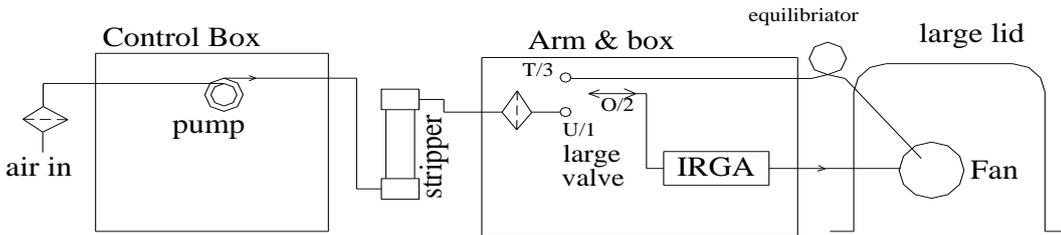
In the OZ mode, the lid is fitted with a vent to stop any rise in chamber pressure. Fresh air is pumped into the chamber at a controlled, set flow. This mixes with the CO₂ from the soil and, after a period, equilibrium is reached. The assay end point is determined by the user specifying a rate of change in the form of ΔCO_2 between successive readings, and a time limit. During the assay the rate of change slowly reduces until it meets the rate of change criteria, or the time limit is reached.

The Station 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.

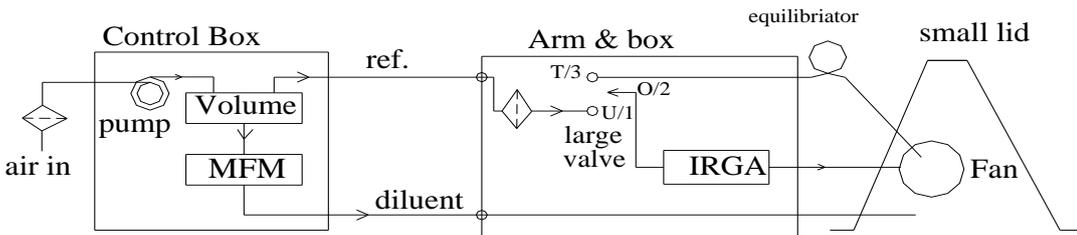
Basic closed (CO2 ramp) configuration



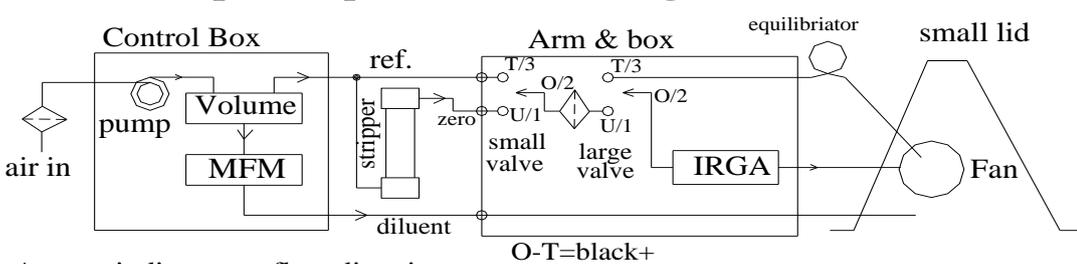
Closed configuration with zero



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 assay length is determined by the value set for either ΔC set or LimT, whichever comes first. These two values can be set from the configuration menu. During an assay, readings are taken every 10 seconds and stored. The ambient CO₂ level is assumed to be 16mmol m⁻³ (358ppm at STP) but may be adjusted for other values by the user: `config more Camb`. This value is also used to calculate an approximate, live CO₂ reading which is displayed during an assay.

Mode CZ CLOSED MODE with ZERO option

Firstly the fan is turned on to purge the cell. The fan is then turned off and the measurement chamber is closed. A CO₂ measurement (C0) is then made. The fan is then turned on and CO₂ measurements made every 10 seconds and stored until the first of either delta CO₂ or the time limit is reached. From the CO₂ measurements, the rate of increase is determined and converted into an NCER reading ([see Appendix 3 – Calculations & References](#)). The interim measurements are saved should the user wish to determine the NCER by another method. The measurement chamber is then opened and CO₂ free air is passed through the infra-red gas analyser. The zero measurement is used to recalculate ambient CO₂ and position the stored values on the linearization curve so that a new delta CO₂ and hence a NCER value can be calculated.

Mode C CLOSED MODE without ZERO option

Only the increase in CO₂ in the measurement chamber from soil activity is measured. As there is no measurement of absolute CO₂, the assumed ambient CO₂ value, as above, is used. Operation is as mode CZ, except that a zero measurement is not made at the end of the assay.

Note: This mode is not normally used, but is retained should zero chemical (soda lime) not be available.

Mode OZ OPEN MODE with ZERO option

Firstly, the cell is purged with ambient gas to remove any soil gas remaining in the measurement chamber from the preceding assay and to provide an initial reference reading. The pump also passes ambient air into the lid at the set flow rate. The measurement chamber is then shut and the fan turned on to both mix and pump gas into the cell. The CO₂ concentration in the chamber will rise until gradually settling. The settling value is dependent on the flux of CO₂ from the soil and the set flow of the pump (U), but independent of the chamber volume.

Measurements are made at 10 second intervals (assuming that the first CO₂ 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 or the time limit is reached. Next, the solenoid valve is changed to ambient and a reference measurement made after enough time has passed for the gas analyser to be purged. The CO₂ and ambient CO₂ readings are temporarily stored and a zero measurement performed at the end of the assay. The zero is used to recalculate new ambient CO₂, values, the curve is replotted and new values of delta CO₂ and NCER are obtained.

Mode O OPEN MODE without ZERO option

The operation is as Mode OZ above except a zero measurement is not performed at the end of the assay and measurements are not re calculated. **Note** that this mode would not normally be used as the open with zero option is preferable, but is retained should zero chemical (soda lime) not be available.

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.

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

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, 4 of which are allocated as soft keys whilst the fifth is a power on /page key marked 'I'. The fifth button also acts as an 'enter' (↵) key. The functions of the 4 soft keys are different in each menu, the display above each key shows the keys current function in inverse video (white text on a black background).

There are three main pages that the user can switch between using the page key.

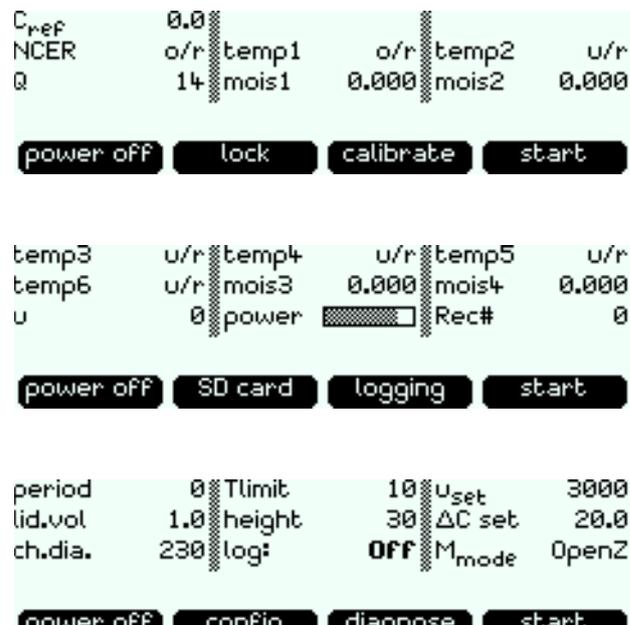
These are measurements1, measurements2, and settings.

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 changes to parameters and configurations can be made ([see appendix 9 - menu tree](#)).

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 only pressed to save changes and exit the page.

Only the currently underlined parameter can be changed, e.g. a numerical value. The parameter to be changed is selected by using the select soft key until it is underlined. Press the + or – soft keys to change the parameter, then OK or page to save and exit the menu, or select to move to the next parameter on the same page.

3.2 Page descriptions



3.3 Parameter Descriptions

1. Switch the ACE Station on using the power on/PAGE button (marked I).
2. The ACE Station will boot up whilst displaying the software version number and instrument serial number. An “accessing SD memory card” message may also briefly appear.
3. You are now on the **measurements 1 page**:

Cref:	Ambient CO ₂ concentration (in mmol m ⁻³).
NCER:	Net Carbon Dioxide Exchange Rate. This will be displayed after an assay has been performed.
Soil temp 1 & 2:	Displayed as a temperature in °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 mmol m ⁻³)
Delta (Δ) 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 the current experiment.

4. By pressing the ON/PAGE button again you access the **measurements 2 page**:

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. This is not updated until the ACE has finished reading from the SD card.

5. To access the **settings page** press PAGE 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:

- 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 1 hour. E.g. 30 is 30 minutes, 1200 is 12 hours. If period is set to 0 the ACE will not perform any automatic assays. If the ACE station is being used with an ACE master, Period is usually set to 0 on the ACE stations, as the ACE master is responsible for starting assays.
- Period should be set to zero when the ACE is being transported, to stop it immediately performing an assay next time it is switched on.
The **Period** should not be set lower than **Lim T** (see below), unless set to zero. If this does happen then assays will run one after the other without giving the operator a chance to stop or change any settings.
- To cancel an assay: Press the right-most soft key at the start of an assay. The soft key name may be covered by an 'assay in progress' message but it will still work. 'Are you sure?' will be displayed. Press the left soft key for 'yes', even if it is covered by an 'assay in progress' message at the bottom of the screen. It is now possible to change either period or **Lim.T** to prevent the problem re-occurring.
- Lim T:** Maximum time that a single measurement assay can run. A single measurement assay by an ACE Station is normally terminated by the $\Delta Cset$ 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:** Applicable to OZ mode only. Sets flow rate of ambient air into chamber ($\mu\text{mol sec}^{-1}$). The flow rate set is dependent on the soil activity. Range: 200 to 3720 $\mu\text{mol sec}^{-1}$ in 10 μmol increments.
- lid. vol:** Volume, in litres, of the soil chamber being used.
Open chamber: 1.0L. Closed chamber: 2.6L.
Range: 0.50 to 5.00 litres in 0.01L increments.
- height:** The distance from the soil to the top of the collar (in mm).
Used to determine the total volume, when added to the volume of the chamber.
Range: 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.
Range: 100 to 600 mm, in 1mm increments
- Log:** Name of data file currently selected to store data.
- Mmode:** Selects measurement mode e.g. Open with zero (OZ).
- $\Delta Cset$:** The point at which the measurement assay terminates. The value for $\Delta Cset$ is in $\mu\text{mol m}^{-3}$ or mmol m^{-3} (see below) and 10 is a reasonable starting value. The setting of this value will depend on the soil activity.
- In Closed (CZ) mode: **$\Delta Cset$** is displayed in mmol m^{-3} and refers to the difference between the CO_2 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 Open (OZ) mode: ΔC_{set} is displayed in $\mu\text{mol m}^{-3}$ and is the average of delta (Δ) CO_2 between successive readings ($\Delta C/\Delta T$).

If ΔC_{set} is set too large, the assay will terminate early, before the CO_2 concentration in the chamber has reached stability. This will cause a low calculated NCER value.

If ΔC_{set} is set too small, rapid, small changes in CO_2 caused 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, so the ΔC_{set} value will be a compromise. The compromised value can be investigated by comparing the effects of different ΔC_{set} values in a spreadsheet.

6. Press **config** then **more** to access:

- Camb:** Set to a default value of 16 mmol m^{-3} .
Range: 12.0 to 20.0 mmol m^{-3} in 0.1 increments.
- cmt:** The comment field which is recorded to the SD 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 SD card was present. The old comment is deleted immediately that a new assay is started. See Section 4.1 for the meaning of the characters in the comment field.
- name:** The name of the station. This can be edited by the user, read and stored by the Master in a networked system.
- a lock:** This is a software lock to prevent tampering of settings. When **a lock** is enabled, the screens can 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

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

- NCER:** Closed mode NCER calculation method ([see Appendix 3 – Calculations & References](#)).

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

A 'Euro' data format option is available for use in countries where a comma is used in place of a full stop to denote decimal values. For further details, please see [Appendix 1 - File format and Contents](#).

4.1 Logging and File manipulation

4.1.1 Formatting the Secure Digital (SD) card

The data on the SD card is stored in a DOS FAT16/32 compatible format.

New cards do not normally require formatting before use on the ACE Station. The ACE software does not have a format utility. The SD card may be formatted in a PC with a suitable SD card reader, or, the ACE can be connected to a PC via USB and formatted from the PC.

4.1.2 Reading the Secure Digital (SD) data storage card

When the ACE Station is first switched on, the processor will read the SD card. This process can take a few seconds, after which a pop up window displays the card size.

4.1.3 Data logging

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

Logging can be sent to the SD 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 ([Appendix 1 – File format & contents](#)) are sent as soon as RS232 logging is enabled ([Section 4.2 – Sending a Log File](#)).

Log files that have been sent to SD card may be reviewed on the display, one record at a time, or dragged and dropped to a PC when connected via USB.

At start up, the logging mode defaults to the last set mode. If the mode was set to send data to the SD card, 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 SD card.

4.1.4 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 +1 of the last saved file.

If you select an existing file, records will be added to it.

The filename can be changed 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.

4.1.5 Renaming a File

Files may be renamed as described above, but they cannot be called 'new' (as this is a reserved word).

4.1.6 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.

4.1.7 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 via **previous** takes longer to scroll 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.

4.1.8 Transferring Files to a PC

The ACE station is fitted with a USB port. When connected to a PC the ACE is recognised as a mass storage device. Files can be dragged and dropped as required. Files cannot be modified by the ACE station whilst it is connected via USB, so assays should not be carried out with a PC connected to the USB. Alternatively the SD card can be removed from the ACE when all measurements are completed, and transferred to a PC with a suitable card reader, the files can then be opened or saved to the PC.

Each log file results in 2 files being saved to the SD card, the file names will be that set by the user in the logging menu, but one file has a *.csv extension the other has a *.log extension.

4.1.9 Example of the *.csv file

ADC BioScientific ACE Station Serial No. 34355 Hd81861

Rec#	dt	tm	Cref	^CO2	NCER	Q	u	Vbatt	temp1	temp2	mois1	mois2	temp3	temp4	temp5	temp6	mois3	mois4	r.flgs	res
1	26-Jul-17	16:03:05	18.5	2.3	4.01	3	2953	12.5	u/r	u/r	0	0	u/r	u/r	u/r	u/r	0	0	OO_Z011D	0
2	26-Jul-17	16:32:00	18.4	2.2	3.77	3	2950	12.5	u/r	u/r	0	0	u/r	u/r	u/r	u/r	0	0	OO_Z013D	0
3	26-Jul-17	17:02:42	18.2	2.1	3.66	4	2947	12.5	u/r	u/r	0	0	u/r	u/r	u/r	u/r	0	0	OO_Z016D	0
4	26-Jul-17	17:32:45	17.9	2.2	3.79	3	2947	12.5	u/r	u/r	0	0	u/r	u/r	u/r	u/r	0	0	OO_Z015D	0
5	26-Jul-17	18:03:28	17.5	2.3	3.92	2	2947	12.5	u/r	u/r	0	0	u/r	u/r	u/r	u/r	0	0	OO_Z018D	0
6	26-Jul-17	18:35:21	17.2	2.4	4.11	1	2950	12.5	u/r	u/r	0	0	u/r	u/r	u/r	u/r	0	0	OO_Z028D	0
7	26-Jul-17	19:05:14	16.9	2.4	4.23	0	2959	12.5	u/r	u/r	0	0	u/r	u/r	u/r	u/r	0	0	OO_Z026D	0
8	26-Jul-17	19:39:26	16.5	2.9	4.98	4	2950	12.5	u/r	u/r	0	0	u/r	u/r	u/r	u/r	0	0	OO_Z050D	0

The file above is shown in 2 parts so that it fits on a page. Usually, each record is displayed on one line and when the file is viewed in a spreadsheet program it will be wider than a screen or page. This file shows the calculated results and sensor data.

The penultimate entry of each log record (r.flgs field) has an 8 character result flag 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
[P	]	in CLOSED, NCER etc calculated using Pederson's Method (see appendix 3)
[L	]	in CLOSED, NCER etc calculated using Linear Regression (see appendix 3)
[S	]	in CLOSED, NCER etc calculated using Simplex method (see appendix 3)
[ _	]	in CLOSED, NCER calculations not attempted (cancel or error)

3rd character in open mode indicates a 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.

4.1.10 Example of the *.log file

```
15:58:48 Log file opened: 26 Jul 2017
15:58:48 ADC BioScientific ACE Station Software PRD-1074 ver. 1.02
Current File Log Record: 1
15:58:48 Open measurement started
16:00:29 ,OO____C, 17.44
16:00:39 ,OO__001C, 18.23
16:00:49 ,OO__002C, 18.46
16:00:59 ,OO__003C, 18.56
16:01:09 ,OO__004C, 18.62
16:01:19 ,OO__005C, 18.69
16:01:29 ,OO__006C, 18.71
16:01:39 ,OO__007C, 18.7
16:01:49 ,OO__008C, 18.73
16:01:59 ,OO__009C, 18.74
16:02:09 ,OO__010D, 18.77
16:03:04 File closed: 26 Jul 2017

16:28:04 Log file opened: 26 Jul 2017
16:28:04 ADC BioScientific ACE Station Software PRD-1074 ver. 1.02
Current File Log Record: 2
16:28:04 Open measurement started
16:29:04 ,OO____C, 17.19
16:29:14 ,OO__001C, 17.87
16:29:24 ,OO__002C, 18.1
16:29:34 ,OO__003C, 18.2
16:29:44 ,OO__004C, 18.29
16:29:54 ,OO__005C, 18.36
16:30:04 ,OO__006C, 18.39
16:30:14 ,OO__007C, 18.44
16:30:24 ,OO__008C, 18.44
16:30:34 ,OO__009C, 18.46
16:30:44 ,OO__010C, 18.47
16:30:54 ,OO__011C, 18.5
16:31:04 ,OO__012D, 18.53
16:31:59 File closed: 26 Jul 2017
```

This shows only the first 2 assays for an open mode with zero ACE station. The complete *.log file shows results for all assays and is too large to print here.

The *.log file is a text file and can be opened with a text viewer or word processor program e.g. Microsoft notepad or word. This file shows the raw data and allows the user to plot the curve for each assay.

4.2 Data output and serial communication

4.2.1 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, 19200, 38400, 76800, 115200 and 230400

The default protocols are none (no handshake) and 115200 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.

4.2.2 Serial cable wiring

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)

Section 5. Setting Up/Performing an Assay

5.1 Operating in Closed mode with Zero (CZ)

5.1.1 Running a single Closed Mode with Zero experiment

1. Press **start** on any menu.

The measurement chamber will 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 around 45 seconds.

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

2. Ambient (reference) gas will now be measured by the ACE.
3. The chamber will close and cover the soil area. The first display screen will now appear together with the status message “Closed Mode Measurement in Progress”.
4. The gas in the chamber will now be measured by the ACE every few seconds. The first display screen will continue to be shown until the assay is completed due to either LIM.T or ΔC_{set} being reached. At this point the status message “performing calculations” appears.
5. The message “Performing Auto-zero” will appear as the ACE station uses air stripped of CO₂ via the soda lime column to recalculate ambient CO₂, ΔCO_2 and NCER. At the end of the assay, the message “waiting for reading to stabilise” is displayed as the ACE finalises the corrected measurements.
6. The chamber will open to uncover the soil area (the message “one moment please...operating arm” will appear).
7. Press **page** until the results for the assay, NCER and Ref CO₂ are displayed.

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.

To stop an assay which is already proceeding press **cancel**. This will terminate the measurement of CO₂ in the chamber but the measurements for ambient and zero CO₂ will proceed normally.

5.1.2 Programming a Closed Mode with Zero experiment

1. Press PAGE to select third display screen. Press **config**
2. Press **select** to move cursor to **Mmode**. Use **+** and **-** keys to select **ClosZ**
3. Press **select** to move cursor to **Period**. Use **+** and **-** keys to select time between measurement cycles in minutes. Times over 99 are in hours/100 e.g. 200 means 2 hours. For most applications this will be 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 maximum 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 5 is a reasonable starting point.
6. Press **select** to move cursor to **lid.vol**. Use keys as above to select 2.6 (volume of standard closed measurement chamber).
7. Press **select** to move cursor to **height**. Measure and enter distance in mm from the soil surface to the top of the soil 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 **carb**.
Unless known, enter value of around 16mmol m⁻³.
11. Press **select** to move cursor to autolock. Select using the **adj** keys. See section 3.1 6a/b. for a description of autolock.
12. Press **select** to move cursor to Name and change from the default if desired.

13. Press **select** to move cursor to NCER and select the desired NCER calculation method using the **adj** keys.
14. 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 into a dormant state and will conserve power).

Note: Operation as closed mode without zero is as above except that that m mode is set to Closed and the value of CO₂ reference is not corrected with an auto zero.

5.2 Operating in Open Mode with Zero (OZ)

5.2.1 Running a single Open Mode with Zero experiment

1. Press **start** from any main menu.

The measurement chamber 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 about 20 seconds.

2. The ambient gas (reference) is measured.

Note: Lim.T will commence as soon as the chamber shuts.

3. The chamber will close and cover the soil area. The measurements 1 page is displayed, together with the message “Open Mode Measurement in Progress”.

4. The gas in the chamber is measured every 10 seconds.

The measurement 1 page will continue to be shown until the assay is completed due to either Lim.T or ΔC_{set} being reached. At this point the status message “performing calculations” appears.

5. Ambient gas is measured again (CO₂ reference).

6. The message “Performing Auto-zero” will appear as the ACE station uses air stripped of CO₂ via the soda lime column to calculate a correction for the values of ambient CO₂, ΔCO_2 and NCER. The message ‘end of assay’ is displayed.

7. Upon completion of the assay, the chamber will open to uncover the soil area.

8. Press page until the results for the assay: NCER and Ref CO₂ are displayed.

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 with Zero experiment

1. Press PAGE to select the third display screen.
2. Press **config**
3. Press **select** to move cursor to **Mmode**. This should read **OpenZ** for 'Open Zero', the ambient reading option. Use **+** and **-** keys to change mode
4. Press **select** to move cursor to **period**. Use **+** and **-** keys to select time between measurement cycles in minutes. Times over 99 are in hours/100 e.g. 300 is 3 hours. For most applications, period will be set to 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. A shorter time avoids heating the soil or changing the CO₂ gradient above the soil (leading to reduced NCER values). A long time may give more accuracy in a shaded sample area.
6. Press **select** to move cursor to **uset** for flow rate in $\mu\text{mol sec}^{-1}$. Use **+** and **-** keys to 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 3000 $\mu\text{mol sec}^{-1}$ to test and then adjust to your sample area.
7. Press **select** to move cursor to **ch.dia**. Ensure this is set at 230.
8. Press **select** to move cursor to **lid.vol**. Use keys as above to select 1.0
9. Press **select** to move cursor to **Δ cset**. Use **+** and **-** keys to select at which differential CO₂ reading the measurement assay should terminate. A value of 20 is a reasonable starting point.
10. Press **select** to move cursor to **log**. Press **+** or **-** key to select the log file that you wish to record data to.
11. Press **set file** then use the arrow keys to select log file then press **set log** for an existing file. Alternatively, select **new file** **set log**. Now use **>**, **+** and **-** keys to name a new file. Press PAGE to create the new file.
12. Now use the **+** and **-** keys to name the new file. Press PAGE and a message will appear whilst your new log data file is created.

13. Press **more** to see an additional menu, then **select** to move cursor to **camp**. Unless known, a value of 16mmol m^{-3} is the factory default.
14. Press **select** to move cursor to autolock, if you want to lock the screen whilst the ACE is unattended during an assay. Select using the **adj** keys. On returning to the ACE, you will be prompted to enter a password to unlock. The factory default password is set to 'adcb'. Entering this password will unlock the buttons for use. See section 3.1 6a/b. for further details.
15. Press **start** before leaving the ACE to log data. There is a **start** button on every main menu screen. The first assay will occur period, (eg. 60 minutes) later. You can now 'power off' the ACE and it will remain dormant to conserve power until it takes the first measurement.

Note: operation as Open mode without zero (O) is the same as above except that m mode is set to Open and the value of CO₂ reference is not corrected with an auto zero.

5.3 The *.log File

Each data file has an associated *.log file. If data logging is set to 'file', data will be saved onto the SD card and can be loaded into a spreadsheet to examine the CO₂ values (see Section 4 for data file example). If data logging is set to 'serial', a file lastrun.log is saved to the SD card.

The *.log file contains every CO₂ reading taken during each assay, and in the case of a closed mode with zero assay, a second set of readings corrected with the zero value after the assay. This means that the *.log file will have the readings twice, with one offset from the other. The zero corrected values are used to calculate NCER.

The open mode with zero *.log file only stores the raw uncorrected values, zero correction is only applied to the NCER value.

At the end of an open mode assay, the values should have reached stability, indicating equilibrium. If values do not stabilise, adjust 'lim.T', flow rate and delta CO₂ accordingly.

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 lasts for too long, the soil will be covered for longer and not being exposed to natural atmospheric conditions.

5.4 Changing the assay length / How to test that ΔCO_2 set and T.LIM are correct.

For an OPEN MODE ASSAY:

Principle to follow: Balance the length of time when chamber is closed with the flow rate, to give a long enough measurement with enough accuracy for that particular soil.

Explanation of principle: The duration of an assay is set by both ΔCO_2 set and LIM.T – an assay stops when the first of these is reached. A higher flow rate (Uset) gives a faster response time if the soil is very active – a lower flow rate is best if the soil is less active.

The best way to determine your optimum settings is through having a ‘trial day’, whereby you alter these settings in the field and monitor the ACE and/or review the data files on a laptop in the field or laboratory if possible, until you find the optimum settings for your particular sample area. If your measurement cycle takes 60 minutes (most common), be aware that this is the length of time needed to gain one line of data from a trial.

Aim: You are looking for your test to be long enough to record ΔCO_2 at equilibrium, when values stop increasing and remain steady. You do not want the soil to be covered for longer than needed, or ambient conditions will be altered e.g. soil temperature increase. These changes will cause measurement errors. A ratio of cover time (with chamber closed) to period of **1:10 or less** is a recommended guideline (e.g. 6 minutes cover time every 60 minutes).

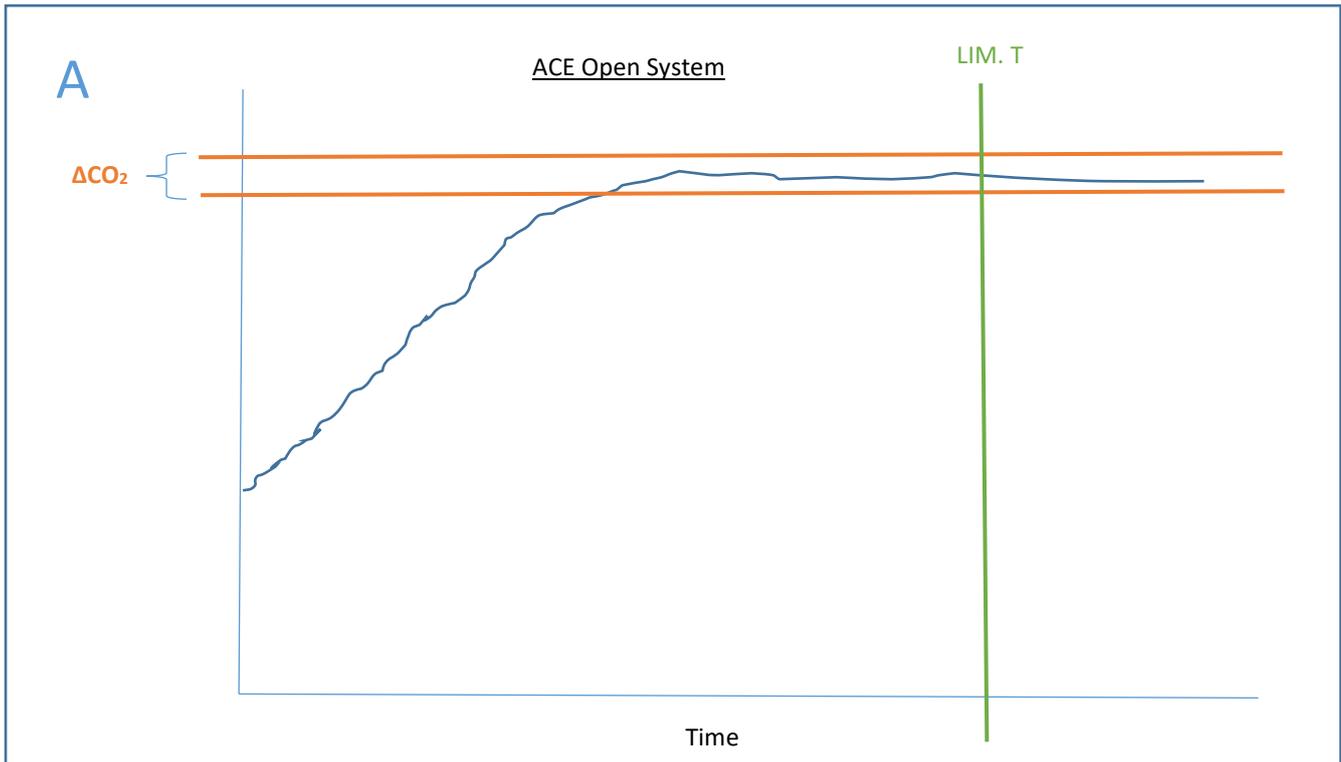
You can visually evaluate your settings, as follows:

If you have set the ACE to be closed over the soil for 10 minutes (LIM.T set to 10 minutes), but you see the ACE open after less than 10 minutes, the settings need adjusting to the soil activity. **Check how the assay has been terminated by the last character in the line of the data file.** The last character of a data file is either a T for ‘time limit’ (LIM.T) or D for ‘delta C’ (ΔC) termination.

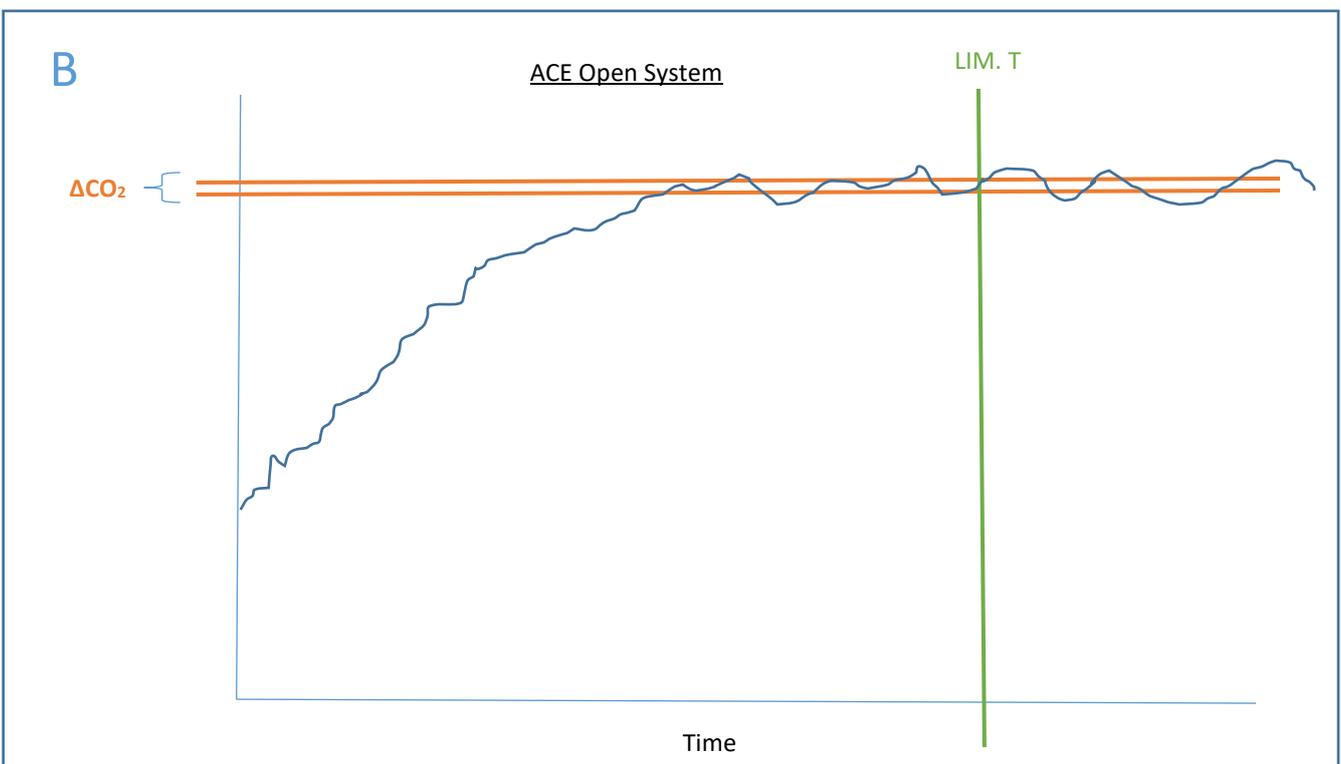
The two Figures on the next page illustrate and explain the two scenarios for assay termination.

If you cannot check the data file in the field at the time of your trial, we recommend monitoring the ACE in person and watching the ΔCO_2 values as (ideally) they start to increase up to a point and then remain relatively stable. *Your measurement should be set to stop as soon as stability or equilibrium is reached.* You will see a background level of variation in ΔCO_2 after equilibrium is reached, this is normal.

Important Note: When an ACE chamber is open, your breath and movements will strongly influence the CO_2 condition. For extra security, you can extend the air inlet with a 5m length of large bore tubing (as supplied) and place this away from the ACE whenever you need to watch the data on the ACE screen as a measurement takes place, but you should avoid doing this when the ACE chamber is open.



Example A will complete the assay based upon the ΔCO_2 because the gas readings have stabilised between the limits of ΔCO_2 specified in the software.



Example B will complete the assay based upon the LIM.T time because the CO_2 readings never stabilised between the limits set for ΔCO_2 . If we wanted the assay to finish earlier we could increase the ΔCO_2 value so that the plateau values fell within the ΔCO_2 limits set.

For a closed mode assay, the values will increase exponentially. The final NCER value will be more repeatable with a larger number of readings. We recommend a **minimum of 10 readings** and a **maximum of 40 readings** per assay (to avoid covering the soil for too long).

The NCER is calculated from the slope at the start of an assay, by one of three methods, dependent upon how the assay has been configured. When the data in the *.log file is plotted it should show an exponential which the methods try to fit. 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 used for calculations is the Cref value (default 16). 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.

As well as checking the shape, having the raw experiment data recorded in the *.log file allows the user to determine the NCER using any preferred method.

When the measurement chamber closes 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 achieve a good shape.

Section 6. Calibration

Important Note: The ACE Station is factory calibrated prior to despatch. Recalibration should not be necessary. Performing a Zero or Span gas calibration should 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:

CO₂-stripped gas (Zero gas) is passed through the infra-red gas analyser 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 **calibrate** page and highlighting “zero” using the **select** key. **yes** – Apply --- **yes** – Zero. A highlighted value will appear.

To access the zero potentiometer:

1. Remove the lid of the control box as described in section 5.
2. 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.
3. Adjust the potentiometer until the highlighted value reduces towards zero and “OK” appears (adjust the potentiometer clockwise if the arrow is pointing up).

Note: Due to electronic filtering of the infrared detector 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 infra-red gas analyser. If you have or can make some zero gas (eg. nitrogen) cylinder, or by pumping air through a soda lime column, connect this to the infra-red gas analyser. 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 perform an assay so that fresh air is collected. The NCER value will be meaningless, but it will leave fresh air in the infra-red gas analyser at the end of the assay. In the zero menu, set the count to around 4000, arrow down, with the zero pot. When leaving the calibration page, a message will say “calibration failed – reading too low”, but do not worry. If outside working is not possible, perform an ACE assay indoors, preferably with the window open. Select 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, e.g. downwind from volcanic activity or heavy industry.

Span:

Reference span gas is manually connected to the infra-red gas analyser at the same end as zero gas (above). The calibration gas is supplied from a regulated outlet at a maximum flow rate of 800ml min⁻¹ to avoid pressurising the infra-red gas analyser and causing a false calibration.

ACE Stations with zero fitted (now standard) will perform a zero automatically prior to a span, to prevent zero drift from upsetting the span. For (previous) systems where no zero was fitted, a zero must be manually performed immediately 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 gas circuit. We recommend that the filter is regularly checked and a new one fitted if necessary, up to once a month if the local environment is dusty. There are 2 spare filters in the Spares pack.

Hydrophobic filter:

There is also an internal hydrophobic filter inside the Arm. This filter will become blocked if water enters the system and will allow water into the system when saturated. 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 darker than a new one, it should be changed. There are 2 spare hydrophobic filters in the spares pack.

Soda Lime:

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 white when fresh and turns to a violet 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 equilibrator:

The equilibrator tube is a delicate item and can be easily damaged. If removing it (e.g. when 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 formatted in one of two ways: 'UK mode' or 'EU mode'.

The type of format currently in use can be readily determined by examining the displayed parameters. In UK mode, the decimal point will be shown as a full stop. 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.

EU mode 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 'EU mode' format log files (since the extension is different). Also the instrument cannot correctly display .txt log files.

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

For the *.log files the extension remains the same although the delimiter does change as above.

Changing the File Format

1. Connect the ACE Station serial port to a COM port on a PC (Personal Computer) and running the HYPERTERMINAL™ program to reprogram the ACE Station mode.
2. Refer to [Appendix 7 "Setting Up HyperTerminal"](#) and follow the instructions in paragraphs 1,2,4 & 5.
3. Type ^ (Shift+6) to enter FORTH CLI mode (FORTH Command Line Interpreter)
HYPERTEMINAL™ will display the ACE Station's details then await commands.
4. Type "SET-EURO-DATA" to switch from UK (default) mode to Euro mode.
5. Type "SET-UK-DATA" to switch from Euro mode to UK mode.

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, beneath a header listing the parameter names. The order is the same whether logging to the local SD 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
- Result flags
- Variance

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) mode)	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	°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 (open mode)	Uset	200	5000	μmol sec ⁻¹

- * The relationship between molar and volumetric measurements is dependent on the ambient temperature and pressure (see Appendix 3 – Calculations & References)

Note that CO₂ ref (volume) only appears in the CO₂ span calibration page.

ACE Configurations (default settings)

(O) = Open ; (C) = Closed; Flow only available in “open” 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
NCER	closed mode calculation method		
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 CO₂ Exchange Rate (Open)

symbol: **NCER** ($\mu\text{mol m}^{-2} \text{s}^{-1}$)

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

where **u** volumetric flow of air, $\text{m}^3 \text{s}^{-1}$
 Δc difference in CO₂ concentration through soil chamber mmolm^{-3}
a Area, m^2

Δc is that at equilibrium. To check this the .log file should be viewed in a spreadsheet and the data from an assay reviewed to check that the level has flattened out. If the experiment ends on the **Δc set**, indicated by a D in the final character of the experiment flags then the assay is likely to have stopped at the correct point. If however it finished on limit T then either the assay has finished prematurely or the **Δc set** is too low and has not been reached due to noise. Adjust the time and **Δc set** appropriately as observed in the .log file.

The assay length should be kept to a minimum to have the least impact on the soil but make sure that the **Δc** achieved is not too low to get consistent results, we suggest 2 mmolm^{-3} as a minimum. If the soil is not very active giving a low **Δc** then decrease the diluent flow.

Net CO₂ Exchange Rate (Closed)

The NCER is determined from the slope at the beginning of the CO₂ response curve

symbol: **NCER** ($\mu\text{mol m}^{-2} \text{s}^{-1}$)

$$NCER = \frac{V}{a} (Sc)^3$$

where **V** Chamber volume, m^3
Sc Rate of CO₂ change at $t=0$, $\mu\text{mol m}^{-3}\text{s}^{-1}$
a Area, m^2

The determination of the slope is made from one of three methods explained below, according to the settings for a closed assay.

If any of the methods below are not what the user requires the raw data of each assay is saved in the corresponding *.log file so the NCER can be determined with any method desired. Note that the second set of data of each assay should be used which has been zero corrected.

Pederson

This determines the slope from a stochastic diffusion model as explained in the paper referenced below and has been used for the estimation of NCER by ACE stations to date. This method claims to better fit the exponential curve produced in a closed assay than a straight line.

Linear Regression

Following feedback from customers there are those that prefer to use a straight line estimate produced with linear regression. This does have the advantage that any uncertainty of time 0 has little effect on the results.

Simplex

The exact time of **t0** is uncertain in a closed assay as the closing of the chamber is not instant, so the question arises as to when to make t0. In the ACE a point is chosen at calibration that gives the best looking exponential curve. However some uncertainty remains. The simplex algorithm developed by ADC uses a minimisation technique to best fit an exponential of the form $y = a + b.e^{-cx}$ to the data, ignoring the first couple of points where there may be uncertainty. The slope of the resultant equation is then determined at the reference CO₂ concentration which can be reasonably assumed to correspond to t0.

Converting molar to volumetric CO₂ 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 (°C)

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)

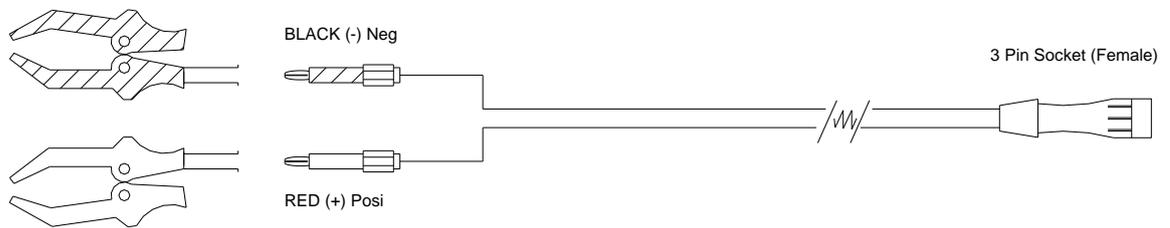
Appendix 4 Power Connection

Power leads supplied by ADC Bioscientific Ltd.

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.

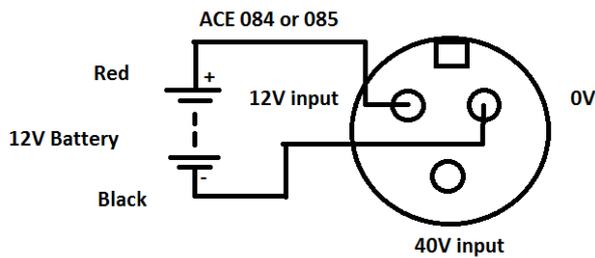
Methods of supplying power to the ACE Station

Independent Station powered from a Battery

Never connect the ACE station to a source of AC voltage or mains supply (110V or 230V), without a suitable DC power supply or battery charger. To do so will cause damage to the ACE station and risks injury to the user.

Be sure that when the arm opens or closes, it cannot touch the external battery. The ACE station metalwork is connected to the external battery negative terminal through the power lead. If the metalwork or arm assembly touches the external battery + terminal, it will cause a short circuit. This will damage the ACE Station and risks injury to the user.

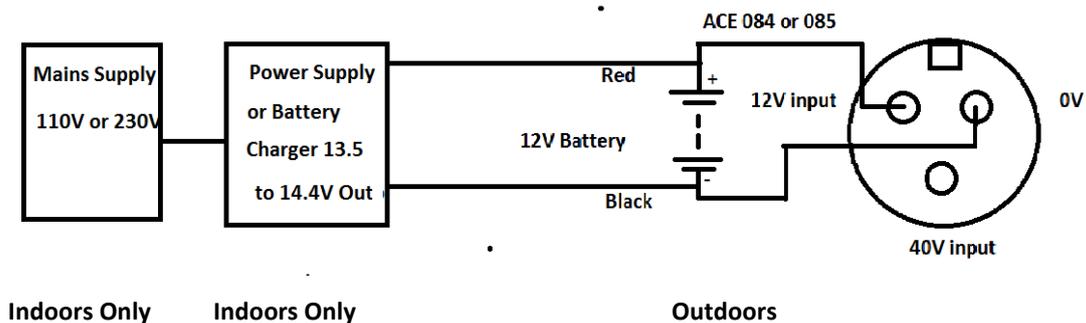
When an ACE Station is used independently, the internal battery is omitted. Power can be supplied from an external 12V lead acid battery. It is also possible to power the Station from any DC supply giving between 12 and 14.8V and capable of 1.0 Amps.

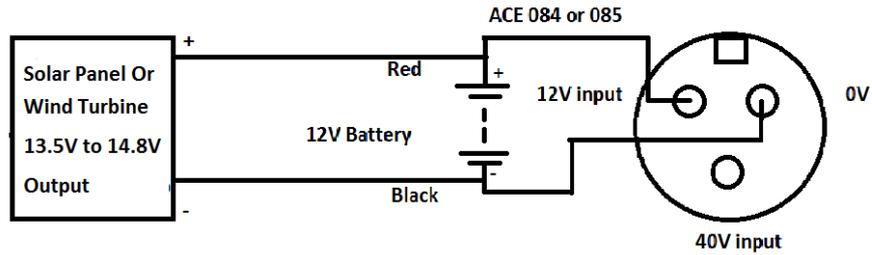


The Power connector is a 3 pin male circular type mounted on the side of the control box (view shown is from outside the control box, looking at the pins). The power cables ACE-084 and ACE-085 have a 3 pin female connector.

Supplying Power from a Mains power supply, Solar panel or Wind Turbine

The external 12V battery may be charged by a battery charger giving a voltage between 13.5V and 14.8V D.C. This can be from a mains power supply, a solar panel or a wind turbine with a suitable D.C. output voltage. Alternatively, it can be swapped with a charged battery as needed.





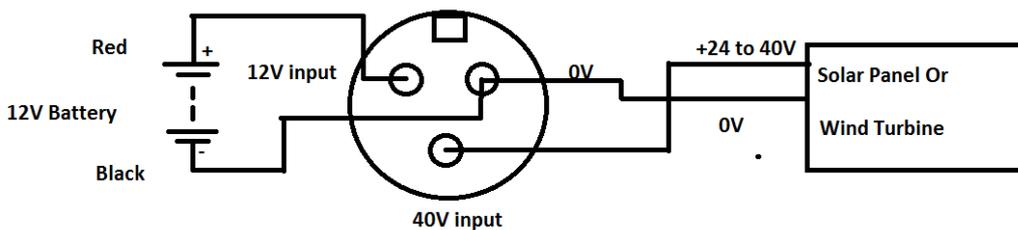
ADC BioScientific can supply a 13.5V D.C. 2A 110/230V 50/60Hz charger that can be used to float charge the external battery.

Note that this charger is not waterproof and is not intended for outdoor operation.

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.

An alternative way of powering the ACE station is to use the 40V input (24V to 40V D.C). This uses a different connection, so a special cable is needed. Please contact ADC Bioscientific for advice. If a solar panel or wind turbine with an output voltage of between 24V and 40V DC is connected to the 40V input, an external 12V lead acid battery can be connected to the 12V input at the same time. The ACE station will provide a regulated 13.6V on the 12V input, to charge the battery. If the 40V input is lost (at night or low wind), the ACE station will run from the battery.



Networked Station(s)

When using the ACE Station in a network controlled by an ACE Master, leads are available from ADC BioScientific (Parts: ACE-080 for 10m and ACE-081 for 100m) to connect between individual stations and the master. Each ACE station should be fitted with a network conversion kit ACE-023. This is fitted inside the ACE station during manufacture, if the ACE Station is ordered with a master controller. The battery isolator switch on the side of the control box should be ON when the ACE station is in use and OFF when the ACE station is being transported or stored.

The Master Controller supplies each station with around 40 Volts DC and low current in order to minimise losses along the cables. Each ACE Station takes the power from the Master, reduces and regulates it with a low loss converter, and uses it to float charge the internal lead acid battery. The internal battery supplies relatively high current to operate the motor and pumps during an assay and is recharged at a low current between assays while the ACE station is idle.

The 40V 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 should contact ADC Bioscientific 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 $\mu\text{mols m}^{-2} \text{sec}^{-1}$ 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. Remove the yellow plastic cover when the ACE Station is in use.

The value (Q) is shown on the first page of the display. (Units = $\mu\text{mols m}^{-2} \text{sec}^{-1}$)

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 ($^{\circ}\text{C}$)

The sensors are of the thermistor type and have to be supplied by ADC BioScientific as they require a suitable linearizer 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 ACE Station is configured 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 4-way DIP switches:

- 1) Disconnect power from the ACE Station and set the battery isolator switch to the off position.
- 2) IMPORTANT: Remove the Soda lime column cover first.
- 3) Remove the 6 screws which retain the display panel.
- 4) CAREFULLY lift the display panel, so that no connectors are pulled off.
- 5) When lifted, the two PCA-303 interface boards are exposed.
- 6) IMPORTANT: When refitting the control box display panel, be sure that the ribbon cable rests in its slot before tightening the screws, otherwise the cable may be damaged.

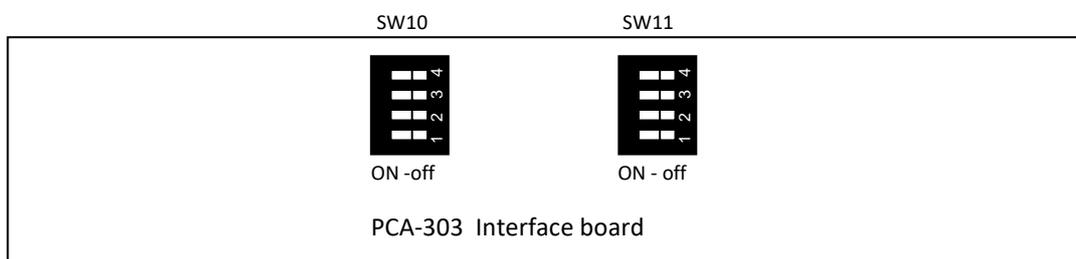
Each interface board controls either sensors 1 & 2 or 3 & 4 depending at which end of the control box it is mounted (see figure on page 8).

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		Board selection	
	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 fairly soon after initialisation and remains on. The only exception being that if the assay was started by the timer from the OFF state, the power would be removed after reading the sensors at the start of the assay.

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 were 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, assuming 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 more modern Windows systems which do not have Hyperterminal and non-Windows systems, you will need to use an alternative 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) 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)

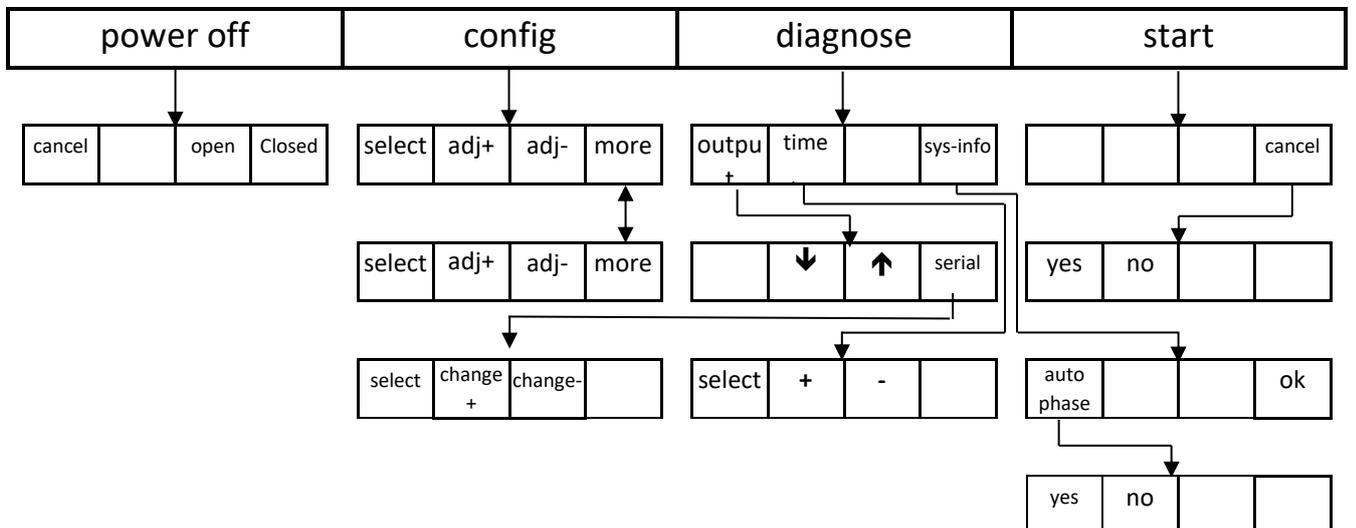
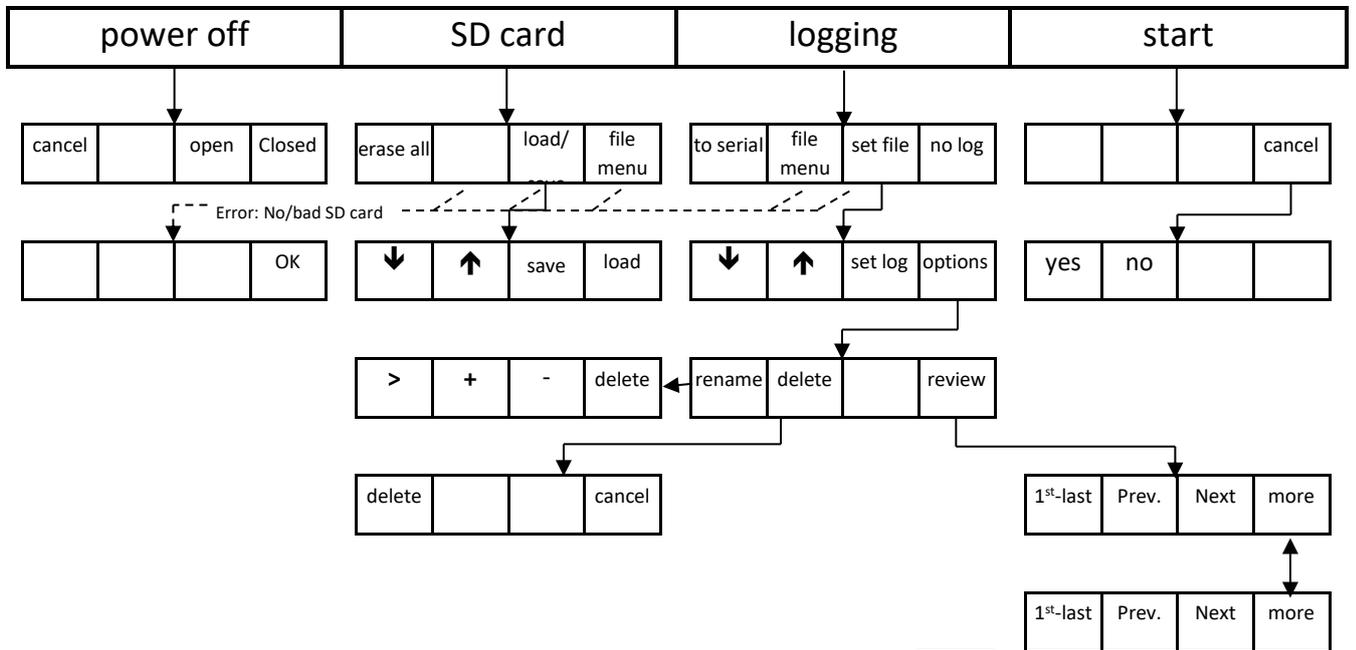
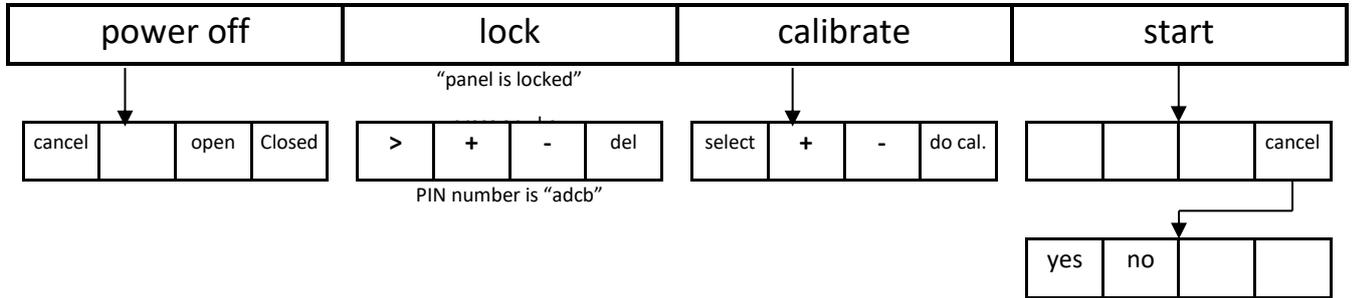
5. Click on "OK"
Ensure the settings match those on your ACE Station before transmitting data ([see Section 4.2](#)).

Appendix 8. Technical Specifications

Measurement of CO ₂ :	Standard range: (Molar) approx. 40.0mmol m ⁻³ . (Equivalent to 896ppm at standard temperature and pressure) 0.1mmol 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:	0-3000µmol 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:	200 -5000 ml min ⁻¹ (137-3425 µmol sec ⁻¹)
Flow control accuracy:	± 3% of f.s.d.
Display:	240 x 64 dot matrix LCD.
Programming:	User-friendly interface driven by only 5 keys.
Recorded data:	Removable Secure Digital (SD) cards.
Real time clock battery:	Maintains time and date when power is removed or during battery changes, PCB mounted and fully automatic charging. Not accessible by the user.
Internal battery:	12V 1.0Ah lead acid battery mounted inside the control box, for networked Stations only.
Power supply:	External source battery, optional solar panel, or wind turbine. One 40Ah 12V car battery provides power for approximately 28 days of continuous use.
RS232 output:	User selectable rates from 300 to 230400 baud. Handshakes CTS (hardware), X on/X off or none.
Electrical connections:	Robust, waterproof 3 pin & 5 pin "binder" connectors.
Station Weight/Dimensions:	7.5Kg (<i>Closed with zero</i>) / 82 x 33 x 13 cm
Chamber volume:	Closed type 2.6 Litre / Open type 1.0 Litre
Soil collar diameter:	230 mm
Packed Weight & Dimensions:	17 kg 95 x 40 x 40 cm

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

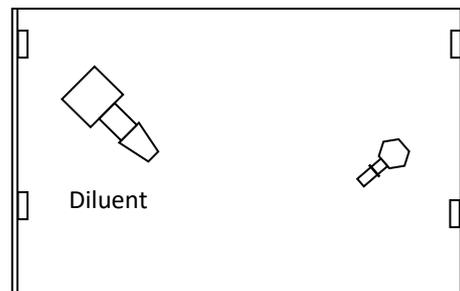
A Nafion tube connects the elbow underneath the centre of the arm to the Chamber head. It can be identified as the pipe enclosed by a protective spring. Please be very careful not to twist, stretch or strain the Nafion tube as it is extremely delicate. If bent too far it may become kinked and cannot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

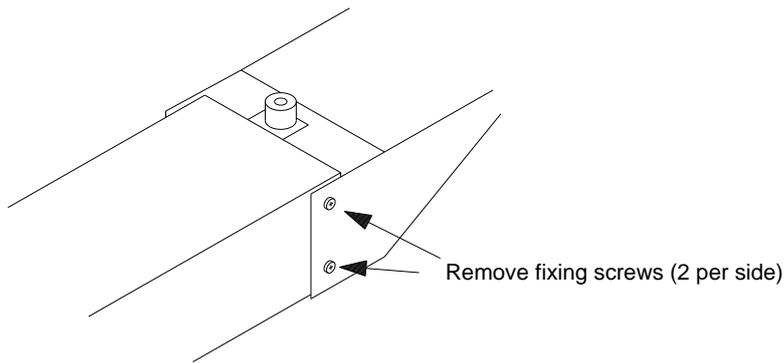
Do not pull on the pipes when removing them. When pipes are removed from push-on fittings there is a tendency for the pipe to stretch in length and reduce in diameter – causing it to grip tighter on the fitting. The best way to remove the pipes is by pushing them off from behind. Where this is not possible 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 isolator switch to the OFF position.
3. If a radiation parasol is fitted (applies to metal heads only) unscrew the three retaining screws until the radiation parasol can be lifted away from the head.
Put the radiation parasol assembly to one side.
4. Gently unplug the two fan power leads (red and black) from the two terminals under the arm. Gently move 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 (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

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 radiation parasol 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 isolator switch to the ON position if a network kit is installed.
2. With the 4 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 4 screws.
4. To check that the head is adjusted properly 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 the head 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 re-deploying the Station and starting an assay.

Finally when you are satisfied that the head is correctly aligned, make sure that the 4 screws are tight then refit the radiation parasol assembly, if required.

Appendix 11. Spares and accessories

<u>Part Number</u>	<u>Description</u>
057-700	Plug for user-supplied sensor
022-456	2A fuse glass time delay
197-710	Secure Digital card
192-353	Lead acid battery, 12V 2.8Ah
407-855	Cap EPDM masking 4.8mm I.D. x 12.7mm
630-967	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
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-023	Network conversion kit (fitted inside ACE station).
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-080	10m interconnection lead, ACE station to ACE master, for networked ACE stations only.
ACE-081	100m interconnection lead. ACE station to ACE master, for networked ACE stations only.
ACE-084	10m power lead with clips & plugs, ACE station to battery
ACE-085	100m power lead with clips & plugs, ACE station to battery
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
LCM-068	Soda Lime, white to violet indicating, 500g

APPENDIX 12 Frequently Asked Questions

1. The display has a blue plastic film covering it and is difficult to read, what should I do?

The film is to protect the display during manufacture. When the ACE station is delivered the film should be removed. Blue plastic film is also used to cover the arm pivot box paintwork, this film should also be removed.

2. Can the ACE station be powered from a mains supply 110v or 230V?

Do not apply mains power directly to the ACE station. Use a battery or power supply, see Appendix 4 for more details.

3. What does the Delta CO₂ value mean? What is Delta CO₂ set?

The **Delta CO₂** is the difference between reference CO₂ (environmental, or ambient air) and that measured at the end of the assay (from analysis CO₂ in the chamber). This is saved in the data file and applies to both closed and open methods/modes.

Delta CO₂ set in the 'config.' menu defines when the assay ends (along with limit T). How they work differs between closed and open.

In the closed mode, **Delta CO₂** is simply the difference between the reference and the measured CO₂. This value continues to rise in the closed mode, until you set the assay end point.

In the open mode the definition is different. In an open assay, the CO₂ delta rises until it reaches an equilibrium. To determine when to stop the assay, the average of the differences between the last 6 readings is continually calculated and displayed during the assay under **Delta ave CO₂**. When this falls below the value in **Delta CO₂ set**, the assay stops. Please also note that the ave. is shown in mmol on screen, whilst the setting is μmol .

4. How do I set the assay end point?

In the open mode, if the Delta ave CO₂ < Delta CO₂ set, the assay stops.

5. I would like to know how to set the parameters: **delta CO₂**, **limit T** and **U set**. What is the relationship between them? Why do I sometimes see the comment 'Time out'?

The 'Delta CO₂' at the end of the experiment should be greater than 3mmol to get a good measurement. Adjusting the flow (U) will effect this. Decreasing the flow increases the 'Delta CO₂'.

Some experimentation will be required to set the parameters optimally for your application.

6. Is NCER a good assay to use with an open mode without zero system?

The **NCER** on an open instrument is valid when it has reached equilibrium.

The **set Delta CO₂** is a setting of how flat the response is, for detecting when equilibrium is reached. The average of the difference of the last 6 measurements are compared with it. We would recommend setting Delta CO₂ between 10 & 20. If set below 10, the assay will not end on the Delta.

Limit T sets the maximum assay length. The assay will either finish on the Delta CO₂ or limit T, depending upon which occurs first. Ideally, the assay should finish on Delta CO₂. Limit T is a safety net preventing the assay from lasting indefinitely if for some reason set Delta CO₂ is not reached.

7. How do I interpret the penultimate field (result flags) of a data file?

See section 4.1 for details of what the individual result flags mean.

8. Can I leave ACE Stations on the sample plot when it is raining outside?

When it is raining, if your sample ground is not prone to flooding, you can leave all ACE stations and the master unit outside. This is fine.

Top Tips:

1. Avoid placing ACE stations in a local area of low topography, which may be prone to flooding.
2. Please make sure only that the metal covers are all down over the unit screens/panels.
3. To be extra safe, you can use an extra piece of tubing to extend the tubing which connects to the air filter inlet (this is found under the little metal cover, loosened by the black screw). Attach an extra piece of tubing here and make it into a U bend shape, facing downwards, so that the tubing faces away from the rain. See application note on this.

Using the ACE Master Controller (ACM) Frequently Asked Questions

1. Should I power on the ACM before connecting the ACE stations?

The ACM can be powered from 12V batteries and/or a mains supply [100V to 240V]. Connect power to the ACM first, then connect the ACE stations one at a time (matching up the cable and output port numbers on the ACM). Switch the battery switch on the side of the ACE stations to 'on', to avoid a surge of power from the batteries inside the ACE stations.

2. What would happen if I connect all ACEs to the master controller and switch the entire system on at once?

The ACM will not be damaged, but it may not work properly for a few minutes until the batteries inside the ACE stations are charged. The charging is automatic.

3. Could I change parameters on the ACE station, instead of on the ACM?

The ACE station parameters can be changed from the ACE master, yes. Please see the ACM manual, section 5.2.

4. How can I set the measuring period interval on my ACM, for example if I want measurements to be taken once per hour, through the ACM?

You can set the measuring period to 1 hour through the Master unit.

This is by actually removing the compact flash card from the Master unit and setting a '.seq' file (a sequence file), which will then operate the units when it is inserted into the master.

5. How can I edit sequence files (.seq)?

Sequence files can be edited directly on the ACM.

Note that the times in the sequence file are 24 hour clock. The first assay should be set to 0:00 or later and the last, less than 24:00. If 24:00 is used as a time, the assay will run for a day then stop at midnight, no measurements will be made after midnight. If the file is correct, the assay will continue indefinitely. The assays will be performed at the same times every day until the user stops the test.

To change the number of measurements to be performed each day:

Copy or delete lines to make the required number, then edit the times in the 1st field. The times must be in increasing in sequence but you can set differing time intervals between each line/step in the assay.

To load the project select [project] on the ACE Master then [choose] use the arrow keys to select the required project, then [run] to start.

Select [configure] from the main menu to automatically detect any ACE stations (this takes a few minutes).

The period on the ACE station should normally be set to 0, whereby the ACE station will not perform any assays until it is commanded by the ACE master.

6. Will my data be safe?

You can lock the screens on all ACE stations from the AMC, or individually on each ACE station, you can also lock the screen of the AMC screen itself. Unlock by entering the code: **adcb**

7. Can I set a sequence file using the compact flash card in my PC?

The sequence file must have the extension .seq otherwise the Ace Master will not recognise it. The easiest way to create a sequence file for the ACE master controller is to edit an existing file using notepad. Unfortunately Microsoft Windows 7 does not allow the user to change the extension type to .seq.

The way to work around this problem is to make a copy of the existing file (to the desktop is convenient) then edit the copy and use the save function (not save as). Next rename the copy on the desktop without changing the extension.

Next copy the new file from the desktop to a CF card and insert the card in the ACE master. Note that if 'save as' is used to save the file from notepad, the extension is automatically set to .txt and the ACE master will not recognise the file.

