
User Manual for the *AP4 Porometer*



Version 4.0



Delta-T Devices

Copyright

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User Manual version 4

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|---------------------|---|
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Introduction

The AP4 cycling porometer is used for measuring the stomatal resistance of plant leaves. This is a measure of the resistance to loss of water vapour through the stomata and is an indicator of the physiological state of the plant. Stomata are sensitive to light, carbon dioxide, pollutants, water stress and pathogens.

The AP4 provides an important tool for unravelling and understanding the intricate web of mechanisms that control stomatal behaviour. It is also used to compare the performance of different varieties and breeds of crops in phenotyping trials and in response to environmental variation and stresses.

It measures how long it takes for a leaf to release enough water vapour to change the relative humidity in a small chamber by a fixed amount. This is compared with a calibration plate of known resistance to derive the stomatal resistance or conductance.

The method is well established. It is supported by a good theoretical understanding of a cycling porometer (Monteith, Campbell & Potter, 1988), backed up by our considerable manufacturing experience of this type of instrument, and has been in world-wide use for over thirty years.

The AP4 corrects for changes in temperature. Readings are automatically converted into units of resistance or conductance, and can be annotated, displayed, saved and output to a computer or printer. Menu driven software, a 40 character by 8-line liquid crystal display and dedicated function buttons make the use of the instrument as intuitive and simple as possible.

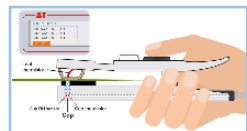
A single button on the porometer head permits one-handed use. Consecutive readings can be taken, evaluated and stored just by pressing this button. Stable readings are denoted by the sound of a double "beep". Two porometer cup shapes are provided for different leaf shapes. The head and case are relatively light, and a padded shoulder bag with a waist-strap is provided.

Beginners can be up and running quickly and experienced users have easy access to the default settings via the use of a context sensitive SET button. A HELP button displays context-sensitive help messages.

A Quick Guide is provided.

See the video at <https://youtu.be/ka7yS8JJsLE>

Download the AP4 Technical Manual from www.delta-t.co.uk



Warnings

HEAD UNIT

DO NOT USE ORGANIC SOLVENTS ON OR NEAR THE RH SENSOR.

PROTECT THE RH SENSOR FROM SMOKE.

PROTECT THE RH SENSOR FROM SHOCK

AVOID TOUCHING THE RH SENSOR

AVOID CONTAMINATING THE CALIBRATION PLATE

AVOID WARMING THE HEAD OR CALIBRATION PLATE BY EXCESSIVE HANDLING OR EXPOSURE TO THERMAL RADIATION

DO NOT LEAVE A LEAF OR THE CALIBRATION PLATE IN THE HEAD WHEN THE AP4 IS NOT CYCLING

WHOLE INSTRUMENT

AVOID STORAGE OR USE ABOVE 80% RH

PROTECT THE AP4 FROM WATER

AVOID DEEP DISCHARGE OF BATTERY

See "How to Service: Battery" on page 11 of the AP4 Technical Manual

DO NOT CONNECT BATTERY CHARGER TO THE WRONG MAINS VOLTAGE

YOUR ENVIRONMENT

DISPOSE OF THE LEAD ACID BATTERY SAFELY - both lead and the acid gel are toxic.

Unpacking

YOU SHOULD HAVE

- An AP4 including one head unit inside the case.
(You may have also ordered a spare head)
- A padded carrying bag with waist and shoulder straps.
- This AP4 User Manual.
- A Quick Guide (can be tucked in between the padded bag and the case).
- Two RS232 cables (one 25 to 9-way and one 9-way to USB).
- An AP4 Battery Charger.
- A Consumables Kit: - paper pads, tape, 500 g silica gel desiccant, silica gel tube, cup seal, cup gasket, cup insert, two screws.

OPTIONAL ACCESSORIES

- AP4 Spares Kit, type PSK2.
- Extra AP4 Consumables Kit, type PCK1.
- Barometer, wristwatch type PBR1.
- Spare sensor head, type PSH1.
- Spare AP4 re-chargeable battery, type PSB1.

} See also page 10 of the
AP4 Technical Manual

YOU WILL ALSO NEED

- Internet access to <https://www.delta-t.co.uk/software/ap4-retrieve-1-1/> for a copy of **AP4 Retrieve Release Notes**, the **AP4 Retrieve** software and the **AP4 Technical Manual.pdf**.
Please read **AP4 Retrieve Release Notes** to establish what Windows operating systems are supported by the current version of AP4 Retrieve.
(At 2019, AP4 Retrieve v1.1 works on Windows XP, Vista, Windows 7, Windows 8 and Windows 10)
- Access to a PC for AP4 Retrieve and to a PC or other device for browsing and/or printing the AP4 Technical Manual.pdf.
- Scissors.
- White paper towel or tissue.
- Access to distilled water and a bottle for it.

How to Use the AP4

SETTING UP AND SHUTTING DOWN

SETTING UP

- Renew the desiccant if depleted (see page 46)
- Plug the head unit into the chassis
- Press ON
- Turn the black LCD knob to optimise the screen contrast
- Check the display for battery low warning.
Recharge if necessary
(see Battery Recharging on page 11 of the AP4 Technical Manual)
- Check the displayed available memory.
If memory is low, someone was using it and has left readings in it.
To free memory, output readings to a computer (see page 36) then delete readings (via OUTPUT,DISCARD).

Shutting down for less than two weeks

- Press OFF button twice.
- Place head and cable in pocket provided.
- Zip up case.
- Protect from dust, humidity (greater than 80%), smoke and organic solvent fumes and other pollutants.

Shutting down long term

- Charge battery.
Recharge battery every year or more frequently if storing above 20°C.
See Battery Care and Service: page 11 of the AP4 Technical Manual.
- Protect from dust, humidity greater than 80%, smoke organic solvent fumes and sulphurous pollutants.

A TYPICAL MEASUREMENT SESSION

Press **ON** Check memory, battery and desiccant

Press **SET** to reset clock and calendar and to change format

Select **CALIBRATE**

- Measure ambient %RH
- Prepare Calibration Plate
- Insert Calibration Plate at first position
- Wait for a steady reading
- If steady, accept it and measure next position
- Do all six positions
- Fit curve
- Install calibration data if curve errors are less than 10%

Select **READ** Put leaf in head

Select **START** The AP4 starts taking readings.

- Wait for steady readings or “double beep” sound

ACCEPT the stomatal conductance reading

- Remove the head from the leaf and angle the head so that the PAR sensor is level with the leaf.

Select **STORE** to keep the reading or **DISCARD** to start again

EXIT to return to the main menu.

REVIEW the data

OUTPUT the data to a PC running AP4 Retrieve

See also

Calibration: page 12

Measurements with one hand: page 11

How to Read: Page 25

Planning your experiment: page 39

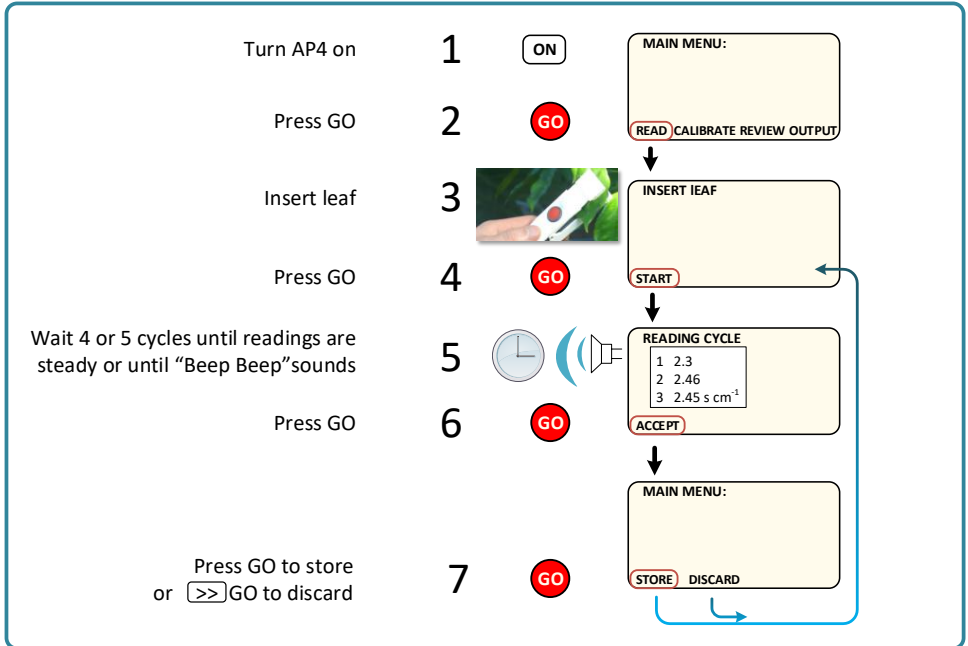
Hints and Tips: page 42

MEASUREMENTS WITH ONE HAND

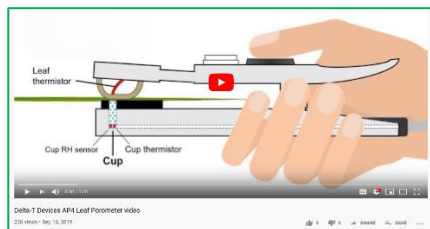
The AP4 permits one-handed operation.

Be sure to start each measurement session with a calibration.

TO TAKE A READING *with one hand*



See also <https://youtu.be/kA7yS8JJsLE>



CALIBRATION

PREPARATION

You need a Calibration Kit with:-

- Calibration Plate in plastic envelope
- Pack of filter pads
- Tape

You also need:-

- Scissors
- Distilled water - 250 ml should be more than adequate (only a small amount is needed - to wet a filter pad takes 5 ml)
- Tissue paper or blotting paper

You may wish to use a barometer, such as the wristwatch-style one which we can supply as an accessory. Without it a 100 hPa (mbar) pressure change, or a 1000 m change in altitude will cause a 10 % error in measured resistance.

If the pressure does not change significantly between calibration and measurement, then you can get away without a barometer.

See Pressure on page 31.

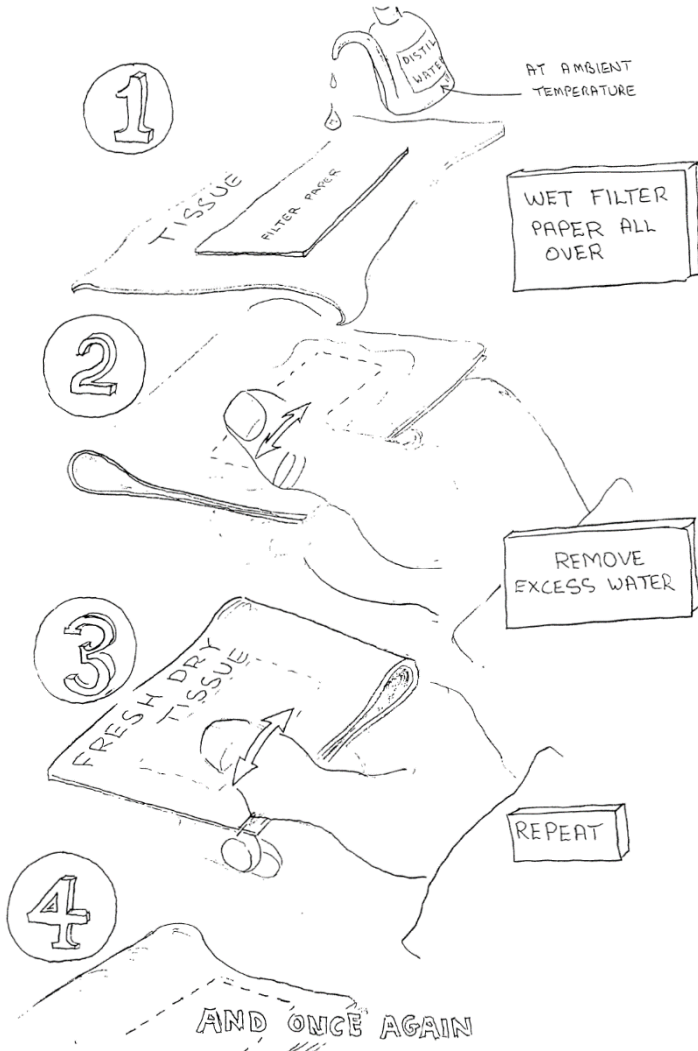
See page 8 in the AP4 Technical Manual (download at www.delta-t.co.uk)



WETTING THE FILTER PAD

Wet the paper all over with distilled water.

Remove the excess water with blotting paper or absorbent tissue paper. Repeat two more times with fresh dry absorbent paper.



CALIBRATION

STICK DOWN THE PAD

Place the damp filter paper on the back of the calibration plate to cover all the calibration holes.

Seal down with sticky tape.

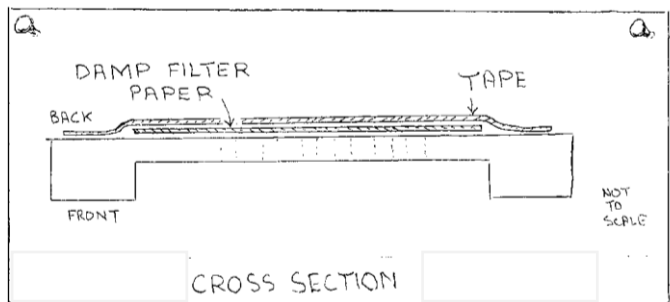
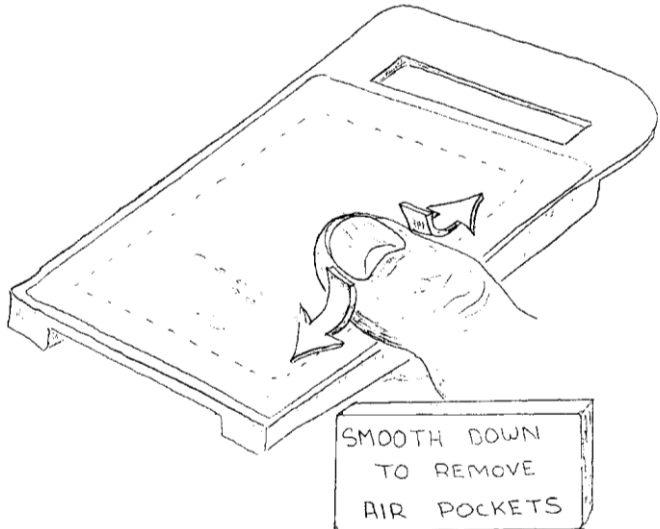
Trim loose tape from the edges. Smooth down the tape to remove any air pockets.

Return the calibration plate to its plastic zipper-lock bag until needed. This will slow down the rate at which it dries out, and also keeps it clean. *In our experience, in the U.K., it has stayed damp for three days if kept in its bag.*

Smooth down the tap

Protect the plate from

Leave for about 1 hour
calibrating.



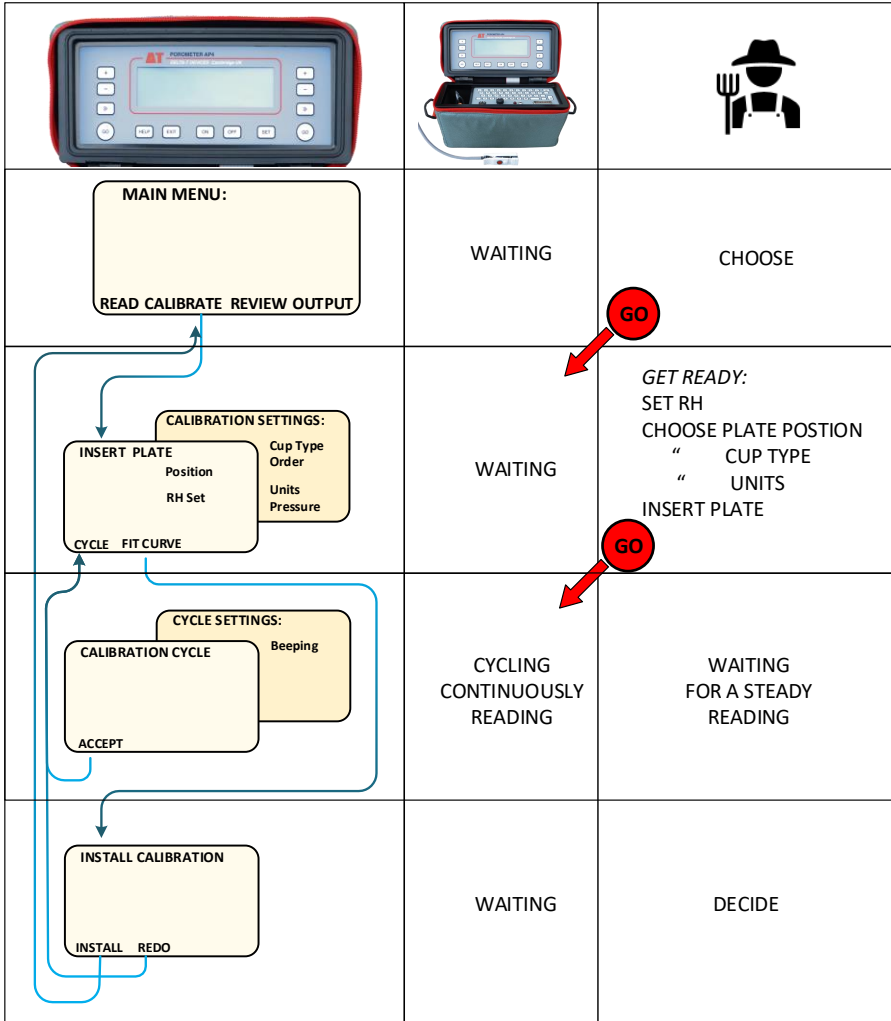
CALIBRATION LOOP

There are three stages: Insert Plate, Calibration cycle and Install.

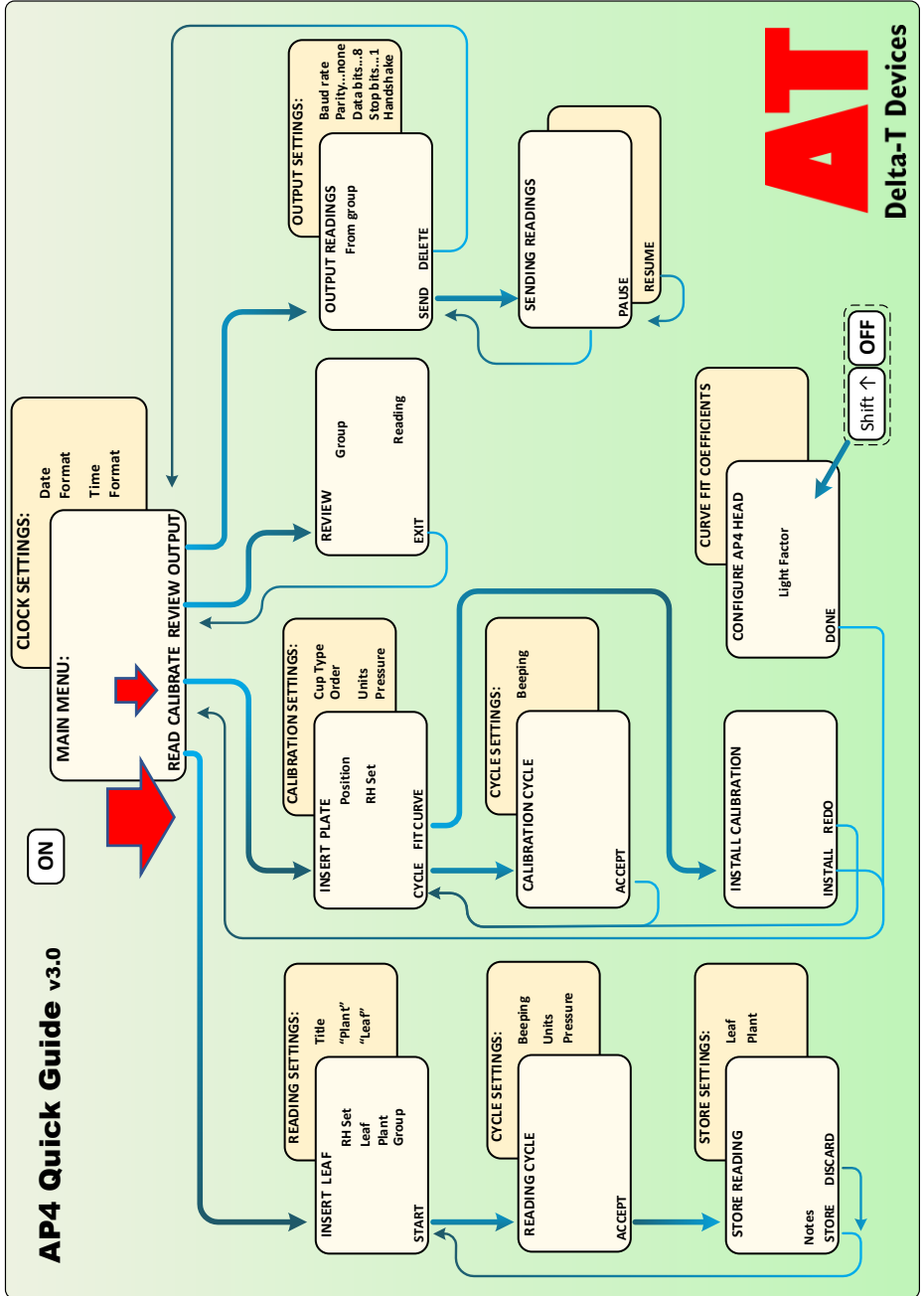
The program will lead you through the measurement of all six positions before asking you whether to install the new calibration.

It automatically keeps track of where you are.

Calibration Flow Chart



CALIBRATION



INSERT PLATE SCREEN

This is the title of the first action screen display which appears when you select CALIBRATION from the main menu.

The righthand column shows the calibration plate's true (theoretical) values adjusted to the current cup temperature and the default or set atmospheric pressure. Next to it is an empty column for readings.

Position: 1 indicates that the calibration plate should be positioned so that first row of holes is measured. The row numbers are moulded on the sides of the plate. Ensure that the plate is sitting snugly against the cup seal. The position indicated can be changed with the + or - key, but you do not need to do this unless you want to repeat a reading.

RH Head: indicates the actual relative humidity in the cup.

RH Set: indicates the fixed value that the porometer will cycle about.

1. Select Set RH and press + or - to temporarily disable the pump.
2. Open the head and wave it about.
3. Read the Head RH to determine the ambient RH.
4. Adjust the Set RH value with the + or - key to be close to, and just below, the ambient RH. (example: if ambient is 43%, set to 40%)
5. Press SET to call up and change any of the default values on the settings screen.
6. Press GO or EXIT to return to the INSERT PLATE screen.
7. Insert the plate at the position indicated.
8. Press GO to START cycling and reading.

See Hints and Tips on page 42

CALIBRATE SETTINGS SCREEN

Cup type : Slotted or circular cups can be chosen.

*See Cup: How to Change it – page 17 in AP4 Technical Manual **

Order: Choose whether to go from calibration plate position 1 to 6 or from 6 to 1

| | | | |
|---------------|---------------------|---|-------------|
| Units: | $s.m^{-1}$ | } | resistance |
| | $s.cm^{-1}$ | | |
| | $m^2s.mo1^{-1}$ | } | conductance |
| | $mm.s^{-1}$ | | |
| | $cm.s^{-1}$ | } | conductance |
| | $mmol.m^{-2}s^{-1}$ | | |

Results can be in units of resistance, or its reciprocal, conductance.

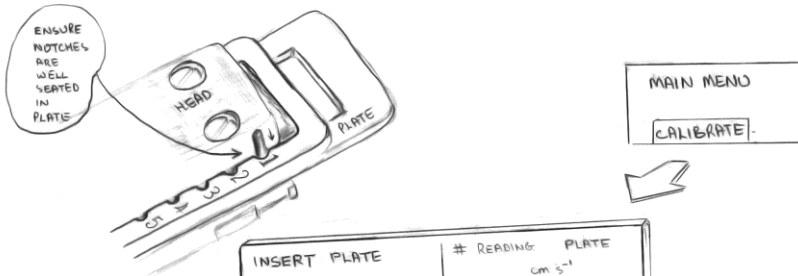
*See: Resistance and Conductance Units – page 6 in the AP4 Technical Manual**

Pressure: Enter the ambient pressure if you have a barometer, or see page 31

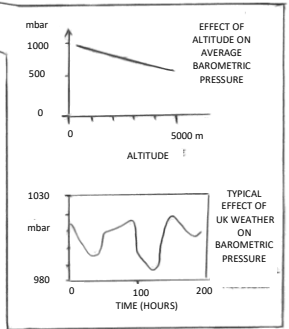
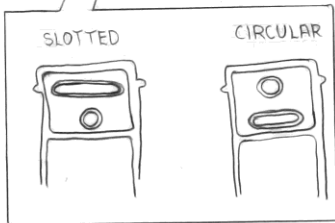
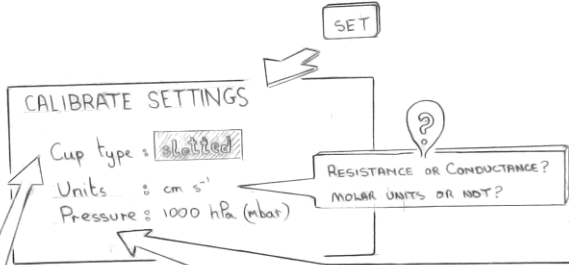
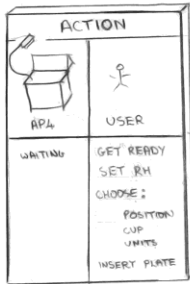
*See also: Barometric Pressure -page 8 in the AP4 Technical Manual**

CALIBRATION

* Download the AP4 Technical Manual at www.delta-t.co.uk



| INSERT PLATE | # | READING | PLATE |
|---|---|---------|--------------------|
| | | | cm s ⁻¹ |
| Position: <input checked="" type="checkbox"/> | 1 | ... | 0.038 |
| Head RH: 43% | 2 | ... | 0.064 |
| Set RH: 45% | 3 | ... | 0.14 |
| | 4 | ... | 0.33 |
| | 5 | ... | 0.62 |
| | 6 | ... | 1.25 |



CALIBRATION CYCLE

The porometer is automatically cycling and taking measurements of the transit time.

This is the time it takes the calibration plate to release enough moisture to raise the cup RH by a fixed amount.

Dry air is then pumped through the chamber until the RH is a few percent below the set point.

The cycle repeats until you press GO to ACCEPT the last reading.

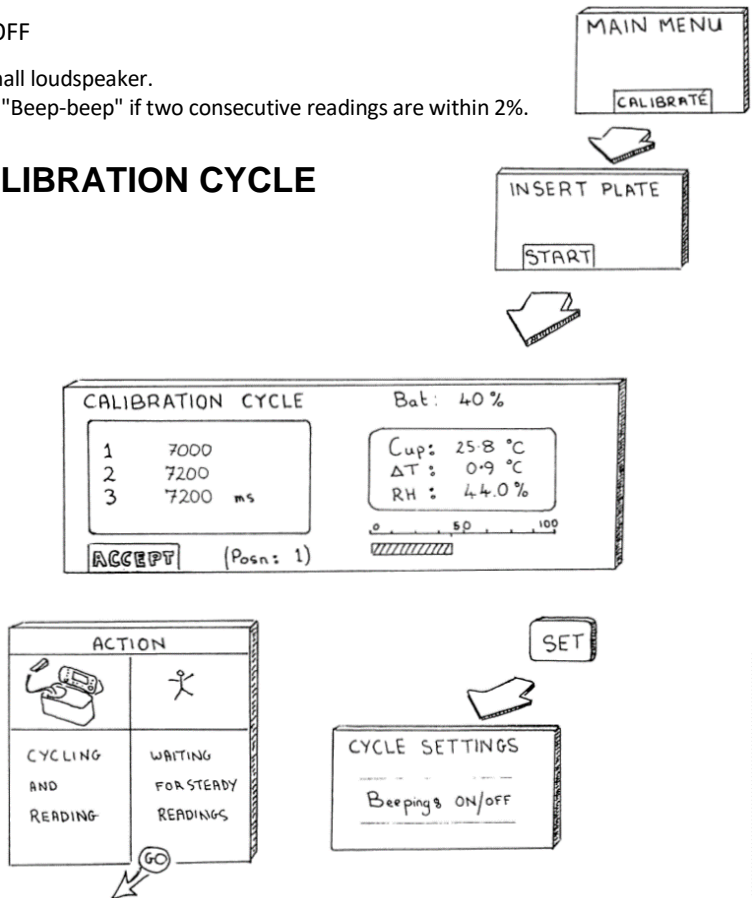
CYCLE SETTINGS

Beeping : ON or OFF

This refers to a small loudspeaker.

When ON, it goes "Beep-beep" if two consecutive readings are within 2%.

CALIBRATION CYCLE



CALIBRATION

INSERT PLATE (for subsequent plate positions)

After choosing ACCEPT in the first calibration cycle run you automatically return to the INSERT PLATE screen.

The reading you have just accepted is displayed in the results column.

It will have been automatically converted from time to resistance or conductance units.

You may also notice the corresponding true calibration plate value updated in the righthand column. It displays the theoretical value true at the cup temperature at which the reading was taken.

The left-hand, results column, is a measured value based on the previous calibration.

This may have been done some time ago - which may be the reason you are recalibrating.

Do not worry about the logic of this right now, it will get sorted out as we go along.

It does not matter, at this stage, if these two readings are wildly different.

Wait until you have worked through, or at least attempted to work through, all 6 plate positions, and then accepted the curve-fit option (which will appear later).

After that the results will be recalculated using the current measured transit times and theoretical plate values as data. The two sets of readings should then match quite closely.

Wait until then before deciding whether you need to redo any calibration reading.

So for now, re-insert the calibration plate, at the next position, and retake the reading as before.

Repeat this until all six positions are done.

After four consecutive positions the FIT CURVE will appear. Ignore this option until you have done all 6 positions, then accept it. Beginners should always go for all 6 readings. Only accept less if you are forced by circumstances - for instance if a reading is far too slow.

Experts may curve-fit on less than six positions in special situations.

This is discussed in greater detail in Hints and Tips on page 42.

Move to next plate position

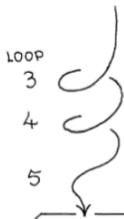
Last reading at last plate position calculated at
 T_{cup} , P_{set} (atmospheric pressure set) & adjusted to $\Delta T = 0$

| INSERT PLATE : | | # | READING | PLATE |
|----------------|---|---|--------------|-------|
| | | | $s\ cm^{-1}$ | |
| Position | 2 | 1 | 25.7 | 24.2 |
| | | 2 | | 15.0 |
| | | 3 | | 6.75 |
| | | 4 | | 2.89 |
| | | 5 | | 1.54 |
| CYCLE | | 6 | | 0.77 |

Updated to latest cup temperature (T_{cup})

Loops back to cycle at next plate position

Next position : You can change this. But always try to do all 6 positions first before going back to redo a reading



This column always has measured values

This column always has known (i.e. theoretical) values

| INSERT PLATE : | | # | READING | PLATE |
|----------------|---|---|--------------|-------|
| | | | $s\ cm^{-1}$ | |
| Position | 5 | 1 | 25.7 | 24.2 |
| | | 2 | 15.0 | 15.1 |
| | | 3 | 8.5 | 6.8 |
| | | 4 | 3.85 | 2.92 |
| | | 5 | | 1.54 |
| CYCLE | | 6 | | 0.77 |

← Last position done
 ← Not done yet
 ← Keep going!

Appears after 4 positions done. But repeat **CYCLE** for all 6 positions (except for special situations) Then select **FIT CURVE** to calculate the new calibration parameters

CALIBRATION

INSTALL CALIBRATION

After you select FIT CURVE the AP4 accepts the last reading at the last plate position, and with the readings from all the other positions, it calculates the new calibration constants for the cup. The new calibration is then used to recalculate the measured values in the left-hand results column.

Compare the measured and true values in the left and right columns. Look for glaring discrepancies which might indicate a possible experimental error on one of the plate positions.

To help you decide whether you like the quality of the new calibration data, the porometer calculates a statistical estimate of the average error over all the readings. It is defined as follows:

$$\sigma = \left[\frac{\sum_{m=1}^{m=N} \{(r_m - r_t)/r_t\}^2}{(N - 3)} \right]^{1/2} \times 100 \%$$

where

- r_t = true or theoretical plate resistance
- r_m = measured plate resistance
- N = number of positions used.

On the porometer screen this is called the curve error. A fuller description is the standard deviation of the residual errors.

This figure is useful when calibrating to check that the calibration ran OK. If the error is less than 10% then go ahead and INSTALL it. If between 10 to 15% then redo the worst reading in the results column. The porometer is accurate to $\pm 20\%$ once it is accurately calibrated. The spread on your readings should be better than this.

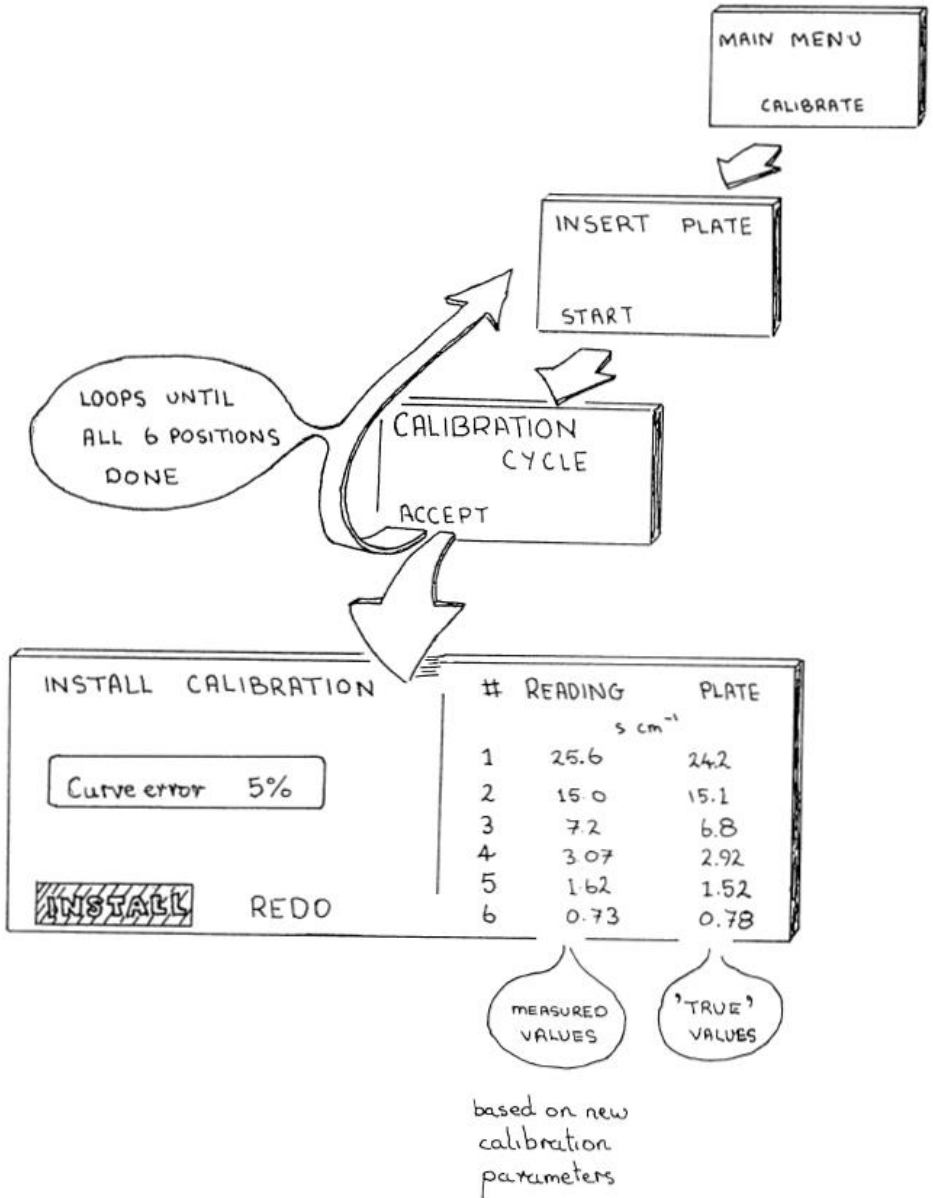
If the error is greater than 10 % the cursor will (suggestively) surround the REDO option. Otherwise it will suggest you accept the INSTALL option. When you do this, it saves the new calibration settings.

Things to do if the curve fitting error is unacceptably large :

- Redo calibration on the worst plate position.
- Ensure calibration plate is properly seated against the cup and protect it from the wind.
- Check the cup seal is OK.
- Check the calibration plate is clean, moist and has had about 1 hour to stabilise since it was last moistened.
- Check for thermistor damage. (Is the δT erratic or greater than 0.5°C on the shift-OFF screen when the cup is in thermal equilibrium?)

See also Hints and Tips on page 42 and How Results are Calculated on page 32 of the AP4 Technical Manual.

INSTALL CALIBRATION FLOW CHART



CALIBRATION

CALIBRATION SUMMARY

- Prepare calibration plate ahead of time.
- Leave it to stabilize, in its plastic envelope, for about 1 hour.
- Set RH close to ambient.
- Check other settings: -
Cup type: slotted or circular
Units: resistance or conductance
Pressure: actual barometric pressure
or average barometric pressure at your altitude or leave it at 1000 hPa (mbar)
- Insert damp calibration plate at position 1.
Ensure it fits snugly.
- Press GO to start the reading
- Wait until readings are stable, then press GO to ACCEPT it.
- Move plate to next position and repeat until all 6 positions are read.
- Select CURVE FIT.
The porometer then fits a calibration curve to the data, recalculates the results and estimates the error.
- INSTALL if the error is less than 10%
Otherwise DISCARD and redo the worst result, or redo the whole calibration.
- Recalibrate when the temperature changes by more than 5°C.
- Recalibrate when changing RH set point.

HOW TO READ

This section describes how to take readings by driving the porometer around the READ loop, and what settings can be changed.

WARNINGS

- Keep cup relative humidity (RH) below 80% if possible.
- Avoid exposing the cup to organic solvents and smoke.
- Keep calibration plate clean, avoid finger grease.
- Remove excess water from paper pad before taping it to the calibration plate.
- Recalibrate whenever the temperature changes by more than 5°C.
- Recalibrate when changing RH set point.
- Do not allow battery to remain discharged.
- Prepare and plan your experiments: see Planning Your Experiment on page 39 and Hints and Tips on page 42.

THE READING LOOP

Readings can be taken one handed. Just press the GO button on the head.

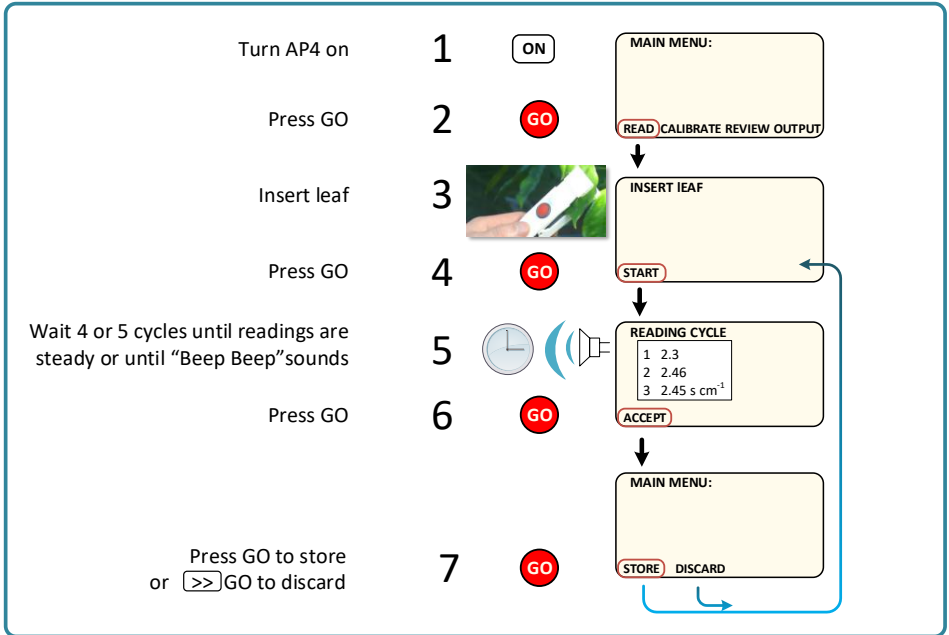
| YOUR ACTION | POROMETER ACTION | DISPLAY TITLE |
|--|---|---|
| Press ON | Porometer wakes up | MAIN MENU |
| Press GO | Selects READ loop | INSERT LEAF |
| Insert leaf | Waits... | |
| Press GO wait | Selects START option Starts cycling | READING CYCLE updated with every reading |
| Wait 4 or 5 cycles until readings are stable or until double beep sounds | | |
| Press GO | Stops cycling and ACCEPTS last reading | STORE READING |
| Press GO | STORES last reading and PAR* reading. Loops back to beginning of READ | returns to INSERT LEAF display |

*Notice that the PAR light sensor reading changes if you change the lighting. The only value which will be saved is the one existing at the instant when you press GO to select STORE. So position the head thoughtfully when you do this, level with the leaf if possible.

HOW TO READ

Readings Flow Chart

TO TAKE A READING *with one hand*



SETTINGS

There are checks and settings to think about if you want to be accurate. You also have choices, such as what units you want the results displayed in and what titles to use for groups of data. Setting the communications protocol with computer is a choice you must get right.

Up to now you have just used what we might call "action" screen displays. They always have at least one option displayed on the bottom line, representing an action activated by the GO button.

Some of the action screens have information displayed in **inverse video**. This can be changed using the + and - keys. Most action screens have a settings screen behind them. You can bring them forwards with the SET button. This is where you go to change most of the settings.

Use the >> key to highlight each option, and change them with the + and - keys in the normal way. Press HELP if you get stuck.

See also the laminated plastic Quick Guide.

SETTINGS OPTIONS

| PATH | ITEM | OPTIONS |
|------------------|--|---|
| MAIN MENU/SET | Date Date format Time Time Format | DAY 1-31 MONTH 1-12 YEAR 0-99 month/day/yr or day/month/year 0-24:0-60 12 hour 24 hour |
| READ/INSERT LEAF | Set RH Leaf Plant Group | 5 – 80 1 – 255 1 - 255 0 - 16 characters |

HOW TO READ

| PATH | ITEM | OPTIONS |
|--|--|---|
| READ/INSERT LEAF/SET | Output title "Plant" name "Leaf" name | 0 - 16 characters 0 - 5 characters 0 - 5 characters |
| READ/READINGS CYCLE/SET And also CALIBRATE /CALIBRATION CYCLE/SET | Beeping Units | On/Off cm.s-1 mm.s-1 m2.s.mol-1 s.cm-1 s.m-1 mmol.m-2 s-1 |
| CALIBRATE/ INSERT PLATE/SET | Pressure | 600 to 1200 hPa (mbar) |
| CALIBRATE/INSERT PLATE | Position Set RH | 1 to 6 5 to 80% |
| CALIBRATE/INSERT PLATE/SET | Cup type Order Units & Pressure | slotted or circular 1 to 6 or 6 to 1 as above |
| OUTPUT/OUTPUT READINGS | From group | 1 – 255 |
| OUTPUT/OUTPUT READINGS/SET | send as Parity Data bits Stop bits Handshake | CSV or text none 8 1 hardware or none |
| SHIFT KEY & OFF together, use when installing head | Light sensor Thermistor | 0.00 to 9.99 (0.65 typical) For setting zero offset |

INSERT LEAF SCREEN DISPLAY

The left-hand box on the display refers to what has changed since the AP4 was last recalibrated. When one or more of the items flash it is time to recalibrate.

"RH :" shows the difference between the current set point and that used at the last calibration.

%RH stands for relative humidity, the porometer cycles around the set point. The reading is displayed in **inverse**, denoting that this setting can be altered.

"Temp:" refers to the change in cup temperature since the last calibration. The AP4 automatically corrects for changes in temperature. When the difference is too big the porometer will keep on doing its best for you, but the display will flash a warning.

Open the head and wave it about to equilibrate. The "Head RH" reading indicates the ambient RH. Using this, change the RH "Set" value in the right-hand box.

Use the + and — keys to do this until close to ambient. This will cause the least disturbance to the stomata, and minimise any errors due to leakage between the cup seal and leaf.

If the pump comes on, press + or —. This disables the pump until you press GO.

Recalibrate when you change the RH Set point.

You may alter the leaf and plant number if you wish. This will never cause you to lose data. The AP4 will automatically increment the leaf number if you do nothing.

The AP4 stores readings in groups which you can name via the keyboard. Each group is also given a number which you cannot alter.

Example group names: - Treatment, Control.

The AP4 will create a new group number whenever you change one or more of the following: 'group' name, 'plant' name or 'leaf' name and also units or RH Set.

READINGS SETTINGS SCREEN DISPLAY

Press SET to access this.

If you wish you can change the names of the labels used to identify groups and subgroups of readings here. Their use can be appreciated by studying the sample printout of data, see the sample printout on page 38.

To begin with, do add an output title, but do not change the name "plant" or "leaf".

Later you might want to change these labels to match the way your samples are organised. Any name of up to 5 characters long is OK. Each reading is given a unique number by the porometer anyway. You can also add a short note after each reading. Do not worry. It will become clear later.

READING CYCLE

Readings are displayed on the left. A bar graph shows the percentage RH in the cup. A tick mark below the scale indicates the set point.

Inside the box on the right, the cup temperature, leaf-cup temperature difference - δT , and the RH are displayed.

Try to keep $\delta T < 1^\circ\text{C}$ if possible, by allowing the leaf and cup to thermally equilibrate. Wait for the reading to stabilise. The accuracy of results also depends on any changes in the cup temperature since it was last calibrated, so recalibrate frequently.

Automatic temperature correction is incorporated in this version (2) of the software. See also : How the Results are Calculated, in the AP4 Technical Manual

See Hints and Tips on page 42.

CYCLE SETTINGS SCREEN

Beeping : ON/OFF

This refers to a small loudspeaker.

When ON, it goes "Beep-beep" if two consecutive readings are within 2%.

Combined with the use of the GO button on the porometer head this allows you to take and store readings without needing to look at the screen at all.

Units

| | |
|---|-------------|
| s.m ⁻¹ s.cm ⁻¹ m ² .s.mol ⁻¹ | Resistance |
| mm.s ⁻¹ cm.s ⁻¹ mmol.m ⁻² .s ⁻¹ | Conductance |

See also Resistance and Conductance Units in the AP4 Technical Manual

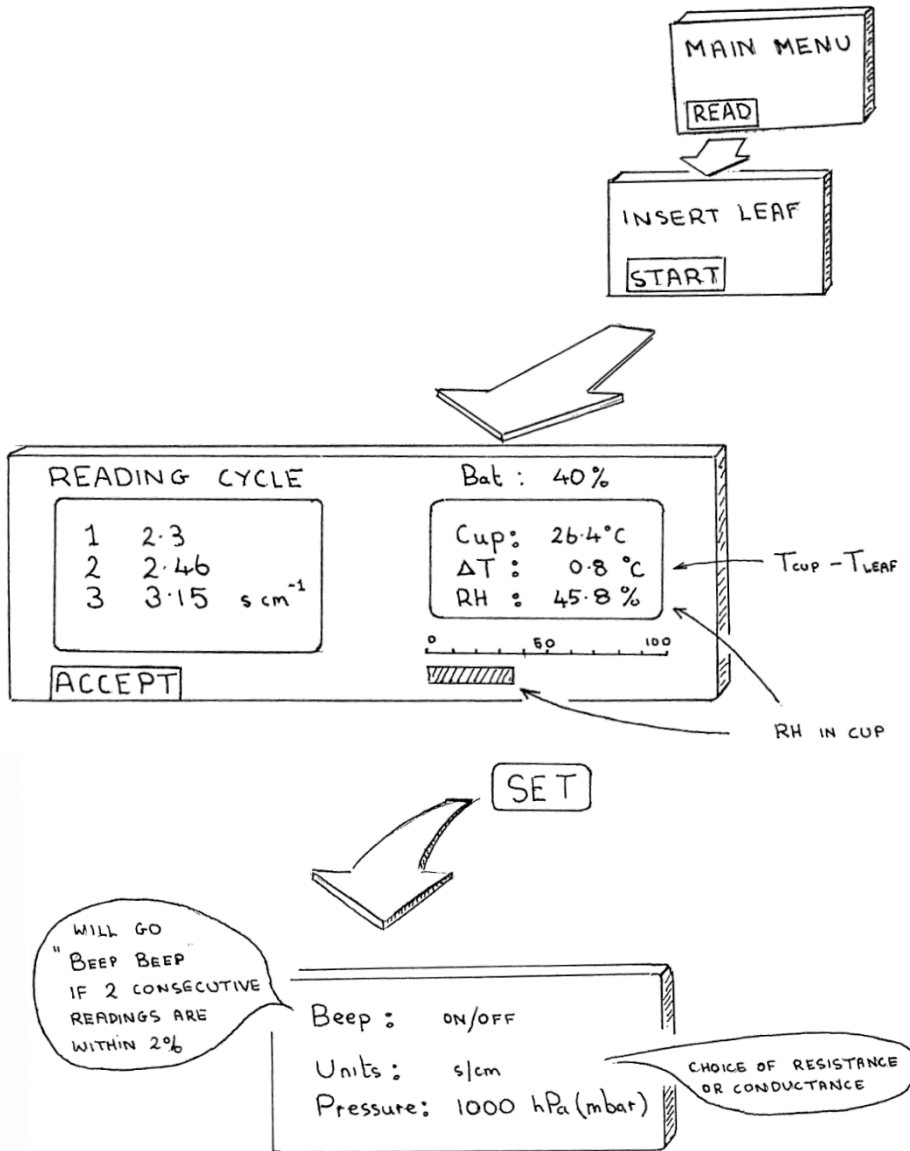
Pressure : hPa (mbar)

If you have a barometer, enter the actual pressure.

If not, put in the standard pressure at your altitude above sea level. Use 1000 hPa (mbar) at sea level. Reduce this by 100 hPa for every 1000 m. The results will be referenced to the pressure you have entered. Recalibrate if you change altitude by 1000 m or more, or if there is an extreme change of weather.

See also Barometric Pressure on page 8 of the AP4 Technical Manual and How Results are Calculated, page 32 of the AP4 Technical Manual.

READINGS CYCLE FLOW CHART



STORE READINGS

The box shows what information will be saved with the reading.

Add a note of up to 30 characters to each reading if you wish. This costs you memory, but there is lots of it. Do not worry unless someone else left lots of readings in it.

See also : "How many readings to take" and "Memory usage" on page 40.

Notice that the light sensor reading changes if you change the lighting. The only value which will be saved is the one existing at the instant when you press GO to select STORE. So position the head thoughtfully when you do this, level with the leaf if possible.

STORE SETTINGS SCREEN

The leaf number automatically increments by 1 every time you store a reading. You can also change it manually if you wish, with the + and -keys, in the normal way.

Increment the plant number with the + button when you change to another plant.

If you want to you can label your plants with these numbers.

You can label and read your plants in any order you like.

Your AP4 just prints the number along with the rest of the data for that leaf.

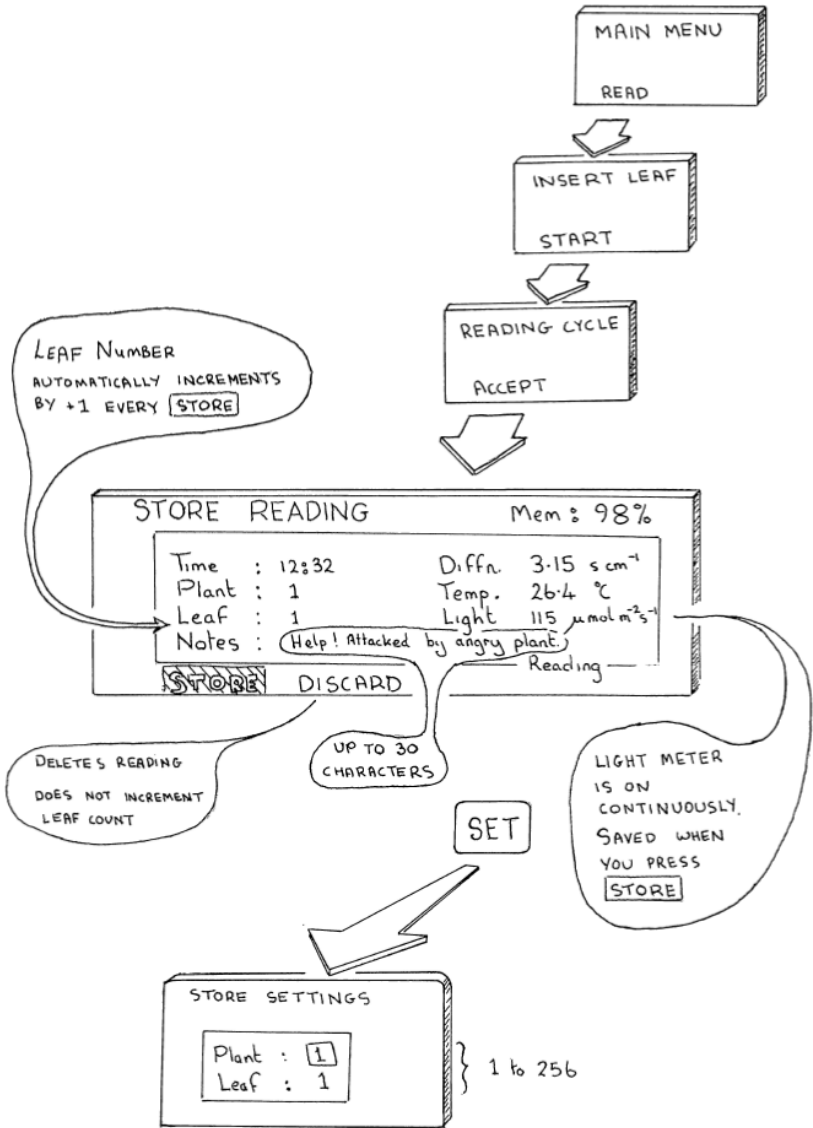
You do not have to start at number 1.

Advanced Users

Provision has been made for you to change the name "plant" and "leaf" on the set screen called "Readings Settings" at the beginning of the READ loop.

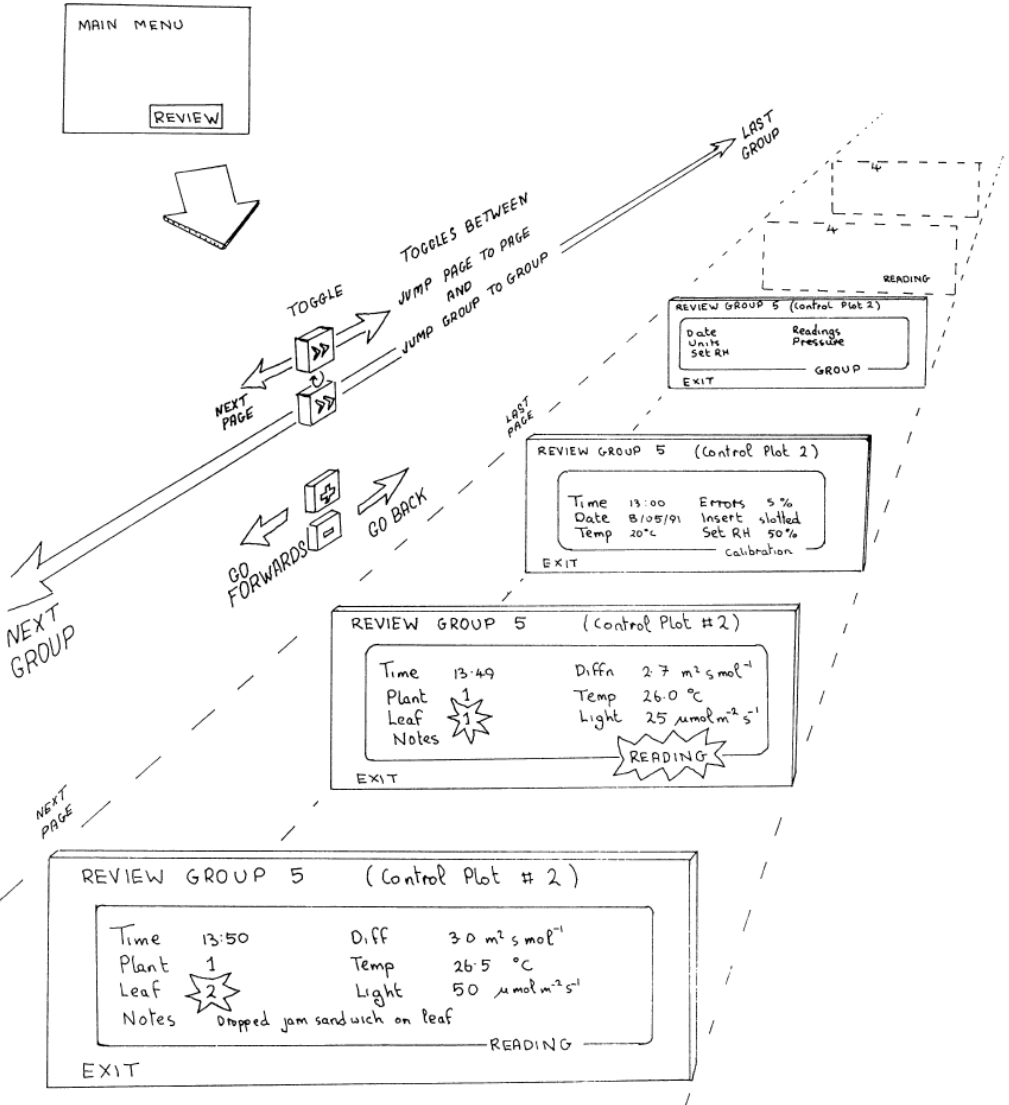
You may use the word "plot" or some other.

STORE READINGS FLOW CHART



REVIEW

No editing can be done, and no settings changed within REVIEW.



OUTPUT TO COMPUTER

This section describes how to output data to a PC.
You can also delete data using the OUTPUT, DISCARD option

REQUIREMENTS

The PC program **AP4 Retrieve** is used to download data to a PC .
Before installing it on you PC please check latest installation requirements in the document **AP4 Retrieve Release Notes** at <https://www.delta-t.co.uk/software/ap4-retrieve-1-1/>

The following instructions apply (at 2019) for use with **AP4 Retrieve v 1.1**:
To install and use AP4 Retrieve you will need:

- A PC running Windows XP, Vista, Windows 7, Windows 8 or Windows 10.
- One free USB port.
- An AP4 RS232 cable and a USB adapter cable (both supplied with the AP4).

Run AP4 Retrieve on your PC

You need local administrator rights to install AP4 Retrieve 1.1. Please contact your system administrator for further information.

Download **AP4 Retrieve** from www.delta-t.co.uk

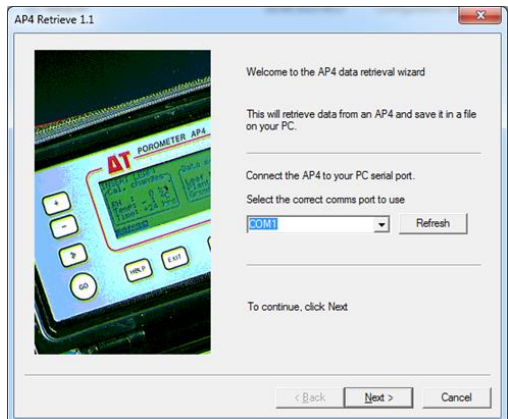
When the download completes, right click on AP4Retrieve.exe and select **Run as Administrator**.

The installation program creates a copy of **AP4 Retrieve** on the desktop .

Run the AP4 Retrieve software and follow the onscreen instructions

Figure 1 AP4 Retrieve

- Click **Refresh** to refresh the list of available COM ports.
- Remove and reinsert the USB cable to identify the correct COM port.
- Highlight this COM port and
- Click **Next**
- Select **Browse** to choose where to save results.
- Follow the on-screen instructions.



OUTPUT TO COMPUTER

AP4 Retrieve 1.1

Prepare the AP4 to send data

1 2

From AP4 main menu select OUTPUT and press GO.

3 Press SET and check the AP4 OUTPUT SETTINGS are :-

| | |
|-------------|-----------------------------|
| Baud rate : | 9600 |
| Parity : | none |
| Databits : | 8 |
| Stopbit : | 1 |
| Handshake : | hardware |
| Format : | CSV or Text, as you prefer. |

AP4s are shipped with valid RS232 parameters set. These RS232 parameters should also work OK

3 Press SET again.

On OUTPUT READINGS menu, specify the group number to start from.

6 Press GO on the AP4 to start data retrieval.

5

1344 bytes have been transferred to file C:\Users\Nick\Documents\My AP4 D...

< Back Next > Cancel

AP4 Retrieve 1.1

You have completed the AP4 data retrieval wizard.

1344 data bytes have been retrieved from the AP4 and copied into the file :-

C:\Users\Nick\Documents\My AP4 Data\AP4Data.CSV

To close this wizard, click Finish

< Back Finish > Cancel

The data is now copied to your PC

OUTPUT TO COMPUTER

TYPICAL PRINT OUT OF DATA

TITLE: Garden plants Output : 21/05/17 12:19 pm

GROUP 4: 2.19 exercises Date : 21/05/17 Set RH: 45% Units: mmol/m²/s
Press: 1000 hPa

| CALIBRATION: | Time | ms | Cup T | Cup-Leaf |
|--------------|------------------|-------|-------|----------|
| | 10:49 am | Posn. | | |
| | Date : 21/05/91 | | | |
| | Set RH : 45% | 1 | 11315 | 23.4 |
| | Insert : slotted | 2 | 6804 | 23.5 |
| | Errors : 5.0% | 3 | 2127 | 23.3 |
| | | 4 | 777 | 23.3 |
| | | 5 | 437 | 23.2 |
| | | 6 | 297 | 23.7 |

| Time | Plant | Leaf | Conduct. | Cup T | Cup-Leaf | Light | Notes |
|----------|-------|------|----------|-------|----------|-------|-------------|
| 10:52 am | 1 | 1 | 1300 | 23.1 | 0.1 | 475 | |
| 10:53 am | 1 | 2 | 81.0 | 22.8 | 0.6 | 40 | top of leaf |
| 10:55 am | 1 | 3 | 325 | 23.3 | -0.4 | 294 | |
| 10:56 am | 1 | 4 | 740 | 22.7 | 0.8 | 292 | nettle |
| 10:58 am | 1 | 5 | 51.0 | 22.1 | 1.0 | 208 | daffodil |
| 10:58 am | 1 | 6 | 17.4 | 22.4 | -0.9 | 1670 | grass |

GROUP 5: 2.19 plants(res)Date : 21/05/17 Set RH: 45% Units: s/cm
Press: 1000 hPa

| Time | Plant | Leaf | Resist. | Cup T | Cup-Leaf | Light | Notes |
|----------|-------|------|---------|-------|----------|-------|-------------|
| 11:32 am | 1 | 1 | 0.51 | 24.4 | 1.3 | 1050 | |
| 11:32 am | 1 | 2 | 1.13 | 24.0 | 1.5 | 350 | |
| 11:33 am | 1 | 3 | 0.91 | 23.8 | 1.7 | 244 | |
| 11:34 am | 1 | 4 | 0.88 | 23.6 | 1.7 | 252 | grey leaves |
| 11:35 am | 2 | 1 | 0.61 | 22.8 | 1.4 | 212 | |
| 11:35 am | 2 | 2 | 0.81 | 22.7 | 1.2 | 108 | |
| 11:36 am | 2 | 3 | 0.90 | 22.5 | 1.1 | 182 | |
| 11:36 am | 2 | 4 | 0.92 | 22.3 | 1.1 | 87 | nettle |
| 11:37 am | 3 | 1 | 0.36 | 22.1 | 0.6 | 390 | grass |
| 11:38 am | 3 | 2 | 0.36 | 22.1 | 0.3 | 405 | |
| 11:40 am | 3 | 3 | 0.39 | 21.8 | 0.2 | 262 | |
| 11:41 am | 4 | 1 | 0.66 | 22.1 | -0.5 | 1550 | rabbit food |
| 11:41 am | 4 | 2 | 0.74 | 22.4 | -1.9 | 1530 | |
| 11:42 am | 4 | 3 | 11.3 | 22.7 | -1.4 | 1230 | top surface |

GROUP 6: 2.19 hse plants Date : 21/05/17 Set RH: 45% Units: s/cm
Press: 1000 hPa

| Time | Plant | Leaf | Resist. | Cup T | Cup-Leaf | Light | Notes |
|----------|-------|------|---------|-------|----------|-------|---------------------------|
| 11:45 am | 1 | 1 | 79.0 | 23.3 | -0.7 | 29 | vargtd leaf dummy reading |
| 11:46 am | 1 | 2 | 12.6 | 23.5 | -1.0 | 18 | heptalureum |
| 11:48 am | 2 | 1 | 4.30 | 24.0 | -1.1 | 85 | |
| 11:48 am | 2 | 2 | 8.50 | 24.5 | -1.2 | 29 | |
| 11:49 am | 2 | 3 | 7.70 | 24.6 | -1.1 | 69 | marant |

Planning Your Experiment

CHECKS

Is the porometer ready?

| WHAT | WHERE | TEST | ACTION | See also: |
|-----------------|----------------|---|---|-------------------------------------|
| Battery life | Turn on | 100% = 20 hours | Recharge if low | Tech. Manual page 11* |
| Memory | Turn on | 100% = 632 to 1597 readings (depends on note size) | Delete or Output if low | Page 40, 41 |
| Desiccant | Pocket in case | Check colour e.g. Blue/pink type: Orange/green | Replace if exhausted - Replace if pink - Replace if green | Page 46 Technical Manual page 19 |
| Calibration Kit | Anywhere! | Do you have...? Calibration plate Filter pad Tape Blotting paper or tissue Scissors Distilled water | Refresh calibration plate with damp filter paper. | Page 12 |
| Cup shape | Sensor | Slotted or round | Select | Tech. Manual page 17* |

* In the AP4 Technical Manual

Are you ready?

Check that you know the following:

- How to calibrate, and when.
- How to record and output the data.
- What you are going to measure and why.
- What names you will use for the experiment and the groups of data.
- How many plants and leaves per plant you will measure?
- How long it will take? Do you have time?

Is the experiment ready?

- It may take a growing season to get ready.

HOW MANY READINGS TO TAKE

- Contact a statistician, or get a good statistics book, for advice on how to ensure your results are statistically significant.

HOW MANY READINGS TO TAKE

You can take nearly 1600 readings with no annotations added.

This reduces to 632 if you add a 30-character note to each.

Most users will take readings for 2-3 days before filling memory.

MEMORY USAGE

The memory size is 32,000 bytes.

Each reading uses 20 bytes, with an optional 0 to 30 bytes overhead for any annotation you add (1 keyboard character = 1 byte).

Readings are kept in groups, each with its own optional name of up to 16 characters.

There is a fixed overhead of 44 bytes per group.

The main title can also be up to 16 characters long.

Each group is identified by a number, as is each plant and each leaf.

EXAMPLE PLAN

Title: My first attempt

Number of groups = 4

Group names will be: Treatment 1, Treatment 2, Treatment 3, Treatment 4

Number of plants in each group = 5

Number of leaves per plant = 5

So, total number of readings = $4 \times 5 \times 5 = 100$

At one reading per minute expect to take about 2 hours.

Battery life = 20% (say) [100% \approx 20 hours]

[This is a bit low - better recharge battery]

Free memory = 20% (say)

[Should be OK for 126 readings at least, more if I keep down the annotation to a reasonable level. Someone must have left in a lot of data from last time. Do they want it or can I delete it now?]

Check desiccant.

Check Calibration Kit - see *CHECKS* above.

Is the calibration plate fresh, i.e. recently made up with damp filter paper?

Are the plants ready?

OK? ACTION! LET'S GO AND DO SOME SCIENCE!

HOW TO CALCULATE AVAILABLE MEMORY

1 reading uses 20 bytes

Each note uses 0 - 30 characters = 0 - 30 bytes.

Each group of readings uses an additional 44 bytes (independent of the length of the group name).

Memory size = 32000 bytes

$$\text{Number of readings} = \frac{\left(\frac{a \times 3200}{100}\right) - (b \times 44)}{20 + c}$$

where a = % memory left

b = number of groups of data

= number of experimental plots, for instance

c = average length of annotation (to 30 characters)

Example (1)

Given: No notes, 1 group

$$\begin{aligned} \text{Maximum number of readings} &= \frac{(32000 - 44)}{20} \\ &= 1597 \text{ readings} \\ - & \\ &= 1 \text{ reading every 18 seconds for 8 hours} \\ - & \end{aligned}$$

Example (2)

Given: 30 characters of notes per reading. 16 groups of readings

$$\begin{aligned} \text{Maximum number of readings} &= \frac{(32000 - (16 \times 44))}{20 + 30} \\ &= 625 \text{ readings} \\ &= 1 \text{ reading every 46 seconds for 8 hours} \end{aligned}$$

In normal use the AP4 should be able to cope with 1 days' data with no problem.

Hints and Tips

IN TRANSIT

Avoid shocks and keep the lid shut. The padded carrying case will give the AP4 some measure of protection when travelling to and from the field.

It is not bomb-proof however and will not necessarily save the AP4 if you drop it! Keep the zip fasteners done up. They hold the AP4's lid shut and help to reduce the ingress of dirt and dust.

Avoid high temperatures. Leaving the AP4 in a closed vehicle in the sun can easily expose it to >50°C. Likewise avoid the opposite extreme, where falling temperatures could lead to dew or condensation forming on the instrument. Bringing a cold porometer into a warm greenhouse may also cause condensation. Give it time to equilibrate.

THE FIRST RUN OF THE DAY

Make up the calibration plate well ahead of time. Leave it in its plastic wallet, stored in the head pocket in the AP4 case. A freshly made up plate needs about 1 hour to stabilise. If you do not do this the measured resistance (after calibrating) may be in error by 15%.

At 20°C and 50 % RH we found that the calibration plate will stay fresh, with its measured resistance within $\pm 5\%$, for several days in its wallet, and up to 18 hours out of the wallet. It will be shorter at higher temperatures and lower RH's.

Make up the plate the day before. This may also be a convenient time to make sure the correct cup shape is installed in the sensor head.

When starting up the AP4, first use it to measure the ambient RH. Select the cycling level nearest to this RH, then leave the instrument to cycle on one of the calibration plate positions for maybe 10 or 15 minutes. This gives the cup time to acclimatise to the current RH. During storage it may have been quite different, resulting in different equilibrium concentrations of moisture in the cup walls.

The calibration run can now be done with the expectation that a stable reading will be obtained within a few cycles of changing to each new plate position. It's a matter of personal preference whether you work through the calibration plate from position 1 to 6, or in the reverse order - it doesn't affect the final result. The "6 to 1" lobby say the high resistance end, position 1, takes longest to equilibrate, so do it last. The "1 to 6"

lobby say do the slowest reading first, in case it takes forever.

At extreme conditions, for example 5°C and 80 %RH ambient this may be a problem.

It really does not matter which one you choose. Just wait for the readings to stabilise.

The same considerations apply when the ambient RH changes. Allow 5 or 10 minutes for the moisture in the cup walls to reach its new equilibrium concentration when you reset the RH Set point. You will know this when the calibration plate readings are stable.

When calibrating you have the option of curve-fitting after you have only measured four positions, but we strongly recommend you always do all 6. Only in special situations should you accept less - for instance if you find a plate position which is impossibly slow, or if you are certain that the range you are working in is very small and will not exceed the shorter calibration range.

Avoid leaving the calibration plate (or a leaf) in the head when it is not cycling (e.g. when the Main Menu is displayed). The cup RH will rise to a high level, and it will take a further few minutes to stabilise when cycling is resumed.

CHOICE OF CUP

This depends on the shape, size and texture of leaf surfaces you are trying to measure. The leaf must cover the whole of the cup aperture -you can view the cup through the rubber pad to check this. In general, the slotted cup is preferable because it covers a larger area. Leaf stomata can be very unevenly distributed.

The other consideration is contact between the leaf and the rubber seal around the cup rim. The circular cup shape might be better for working between the veins of some leaves.

LEAF HANDLING

With the prospect of making hundreds of stomatal measurements in a session, it is worthwhile to optimise your technique so that you take readings as quickly as possible.

It is generally better to accept a reading after four or five cycles even though some drift is still apparent, rather than hang on for a possibly more accurate reading. The double beep gives you an indication of <2% change, but you may prefer to override this as you gain experience - or if you can't stand the noise! It also frees you from watching the display continuously.

The only caution to this procedure is when the new leaf temperature is substantially different from the previous one. You will probably see the cup-leaf δT moving, and you should wait until it stabilises. The AP4 automatically compensates for non-isothermal conditions, but the correction will be inaccurate if the measured δT is lagging behind the true value.

Hints and Tips

SENSITIVE STOMATA

The stomata of a few species start to close rapidly as soon as the light level is reduced by attaching the sensor head. If successive cycles give higher and higher resistance readings, this may be happening. Accepting a reading after the second or third cycle is your only option.

THE CUP-LEAF SEAL

Leakage between the cup seal and the leaf will lead to errors if the ambient RH differs much from the cycling RH level. Variability in successive cycles is the usual symptom of this. A quick test is to breathe over the sensor head. The next reading will show a considerably lower resistance if there is significant leakage. Reposition the sensor head to improve the seal.

TEMPERATURE MANAGEMENT

One of the more demanding aspects of field measurements (and in glasshouses) is keeping the sensor head near isothermal conditions (i.e. a cup-leaf temperature difference δT of 0°C) when in strong sunlight.

If exposed to direct solar radiation, the sensor head will heat up significantly above air temperature. Excessive handling will also warm it up. Leaves may be either hotter or cooler than air temperature, depending on their stomatal aperture, water stress and a number of other factors.

As far as possible therefore, keep the sensor head shaded and the shutter over the leaf-pad closed. If the δT can be kept $<1^{\circ}\text{C}$, you are doing well. The AP4 software will be applying its automatic correction anyway, and can cope with up to $\pm 2.5^{\circ}\text{C}$. You may occasionally have to tolerate a higher δT though. The dangers are twofold: the correction itself becomes less good as δT increases; and if the temperatures are not stable, the indicated δT may lag the true δT and introduce further error.

LEAF TEMPERATURE

What the AP4 calls leaf temperature (as in the cup-leaf δT) is the temperature of the leaf after it has been clipped into the sensor head and has equilibrated (more or less) with the cup. This may be a few degrees different from the actual temperature of the undisturbed leaf. If you need the actual leaf temperature, you should measure it by some independent means. The AP4 readings are always related to the cup temperature to avoid confusion.

See How Results are Calculated in the AP4 Technical Manual, page 32.

CUP TEMPERATURE

The AP4 automatically corrects for deviations of the cup temperature from the temperature of the calibration run. Above a 5°C shift the AP4 will start to flag a warning by flashing. The correction is good, i.e. remains within specification, to +10°C and - 5°C.

Beyond this, the correction is likely to become successively less accurate. You should run one or two calibration plate positions to check their resistances. If these are unacceptable, you will have to do a full calibration run at the new temperature.

COPING WITH VERY HIGH RESISTANCES

Problems can arise if the resistance is so high that the AP4 cannot complete even a single cycle. This could be the case for instance if you wanted to record the resistance of the top surface of a hypostomatous leaf along with the (much lower) under surface resistances. Terminate the reading by opening the head and breathing on it. Either discard the reading or add a note as a reminder.

THE LIGHT SENSOR

This is a simple sensor intended for comparative estimates of leaf irradiance. The spectral and cosine response approximate to that of a PAR quantum sensor, but no levelling device is provided. After a resistance reading has been accepted and the sensor head unclipped from the leaf, the light sensor should be oriented in the plane of the leaf. The irradiance reading will be "frozen" at the moment of storing the data. An irradiance value will get stored for every reading whether you want it or not - so note which are the valid readings.

CLEANING THE SENSOR HEAD

Deposits of dirt and plant substances, pollens and resins may accumulate on the rubber cup seal and even inside the walls of the cup.

Unplug the sensor head lead from the AP4.

Remove the cup seal and cup insert from the sensor head as shown on page 21 of the AP4 Technical Manual and clean them, by washing with distilled water. Then leave them to dry out thoroughly for a day or so. Avoid the use of any solvents, which may damage or be absorbed by the silicone rubber. Spares are included in the consumables kit.

If the RH sensor itself appears dirty, use only a very soft brush to dislodge the dirt. Scratching the sensor may change its calibration.

Whilst you have the sensor head in pieces you can wipe the RH sensor with distilled water. Use a cotton bud - or a twist of cotton wool around a matchstick. Be gentle. The sensor substrate is brittle, like glass. It is glued down on a finger-like extension of the

Hints and Tips

head printed circuit board. Try not to get rest of the circuit board wet. The electronics do not like water. Leave it for a full day to dry out. Some chemicals are known to produce permanent damage or a calibration shift in the RH sensor. Avoid all organic solvents and their vapours, cigarette smoke, Sulphur dioxide and other sulphurous pollutants.

DESICCANT

Check the colour of the desiccant in the drying tube about once a week.

Recent AP4s are supplied with desiccant which is orange when dry and green when wet. Note: Earlier AP4s had desiccant which changed from blue to pink when wet.

Please note that the current advice from the desiccant manufacturer is **not** to attempt to regenerate the desiccant by heating, but to replace it. They also say desiccant is damaged above 120°C

A 500 g pot of 2-5 mm beads of orange to green self-indicating silica gel is currently supplied with each AP4. The amount used in the AP4 silica gel tube is about 16 g so the pot may supply about 30 refills, if you store the pot in a dry place and close the lid immediately after use.

In tropical high humidity environments, if you are changing the desiccant weekly, the 500 gm pot might last 6 months. But if you expose this to the high humidity, even for a short period, the lifetime will be reduced.

In contrast, at Delta-T in the UK, our technical support people have a pot of desiccant, used for occasional AP4 repairs, which is two years old and still good.

Layout and Control

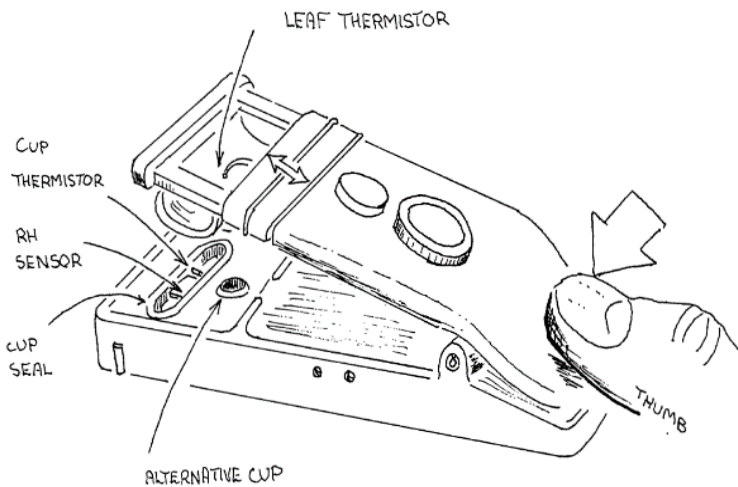
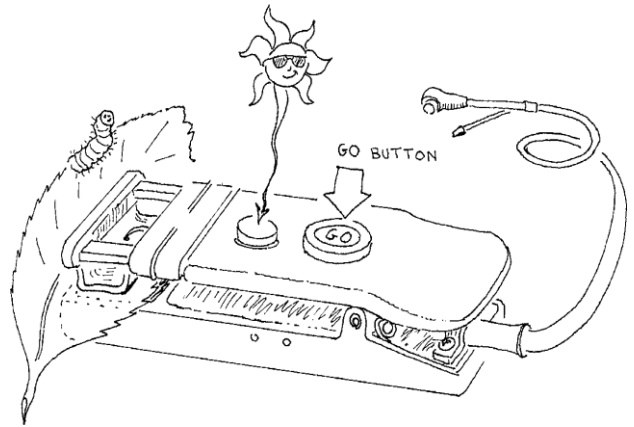
Examine the head unit. It is like a large clothes peg, for clipping onto leaves. Identify the shiny mirrored surface of the RH sensor inside the cup. It is quite fragile and is also easily damaged by organic solvents. Next to it is a microchip thermistor, no bigger than a pin head. Opposite the cup a second microchip thermistor is buried in the translucent flexible silicon rubber pad. These measure the cup and leaf temperatures respectively.

One control button is mounted next to the light sensor.

The cable attached to the head contains a tube for air as well as signal wires.

The tubing plugs into a container of self-indicating desiccant, located in the pocket to the left of the keyboard. Check the desiccant is dry – see page 46.

The cable plugs into the head socket on the left of the keyboard.



Layout and Control

The rest of the control keys are push buttons clustered around the display panel on the lid. The most frequently used keys are duplicated around both sides of the lid, to help both left and right-handed people.

The most important and useful button, GO, is also found on the porometer head. It does not matter which one you use.

The main menu is displayed across the bottom of the screen when the porometer is on.

Options are selected and activated using the » and GO keys described below.

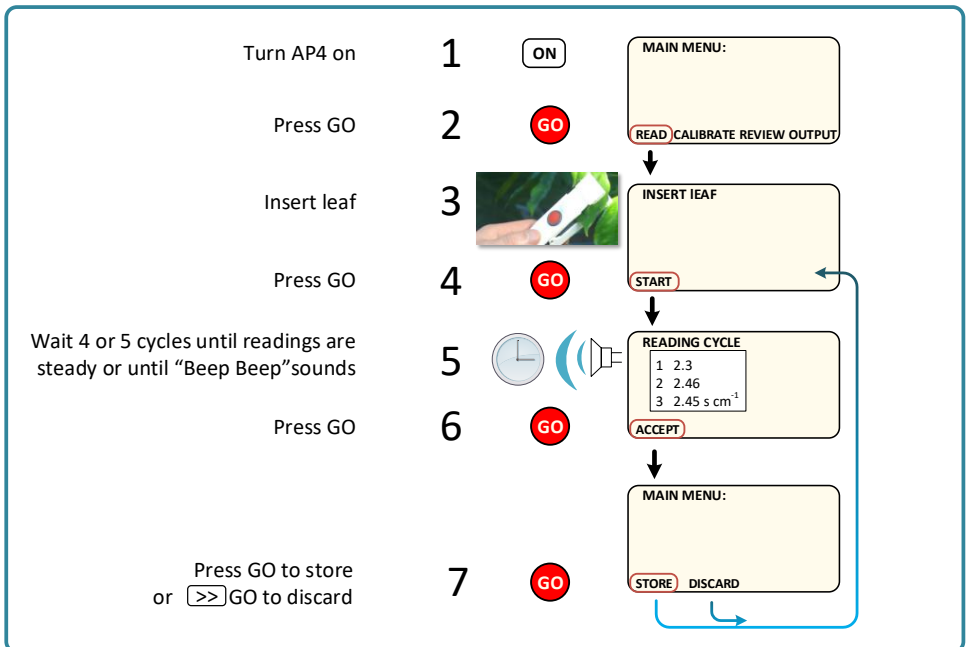
To adjust the contrast use the LCD knob.

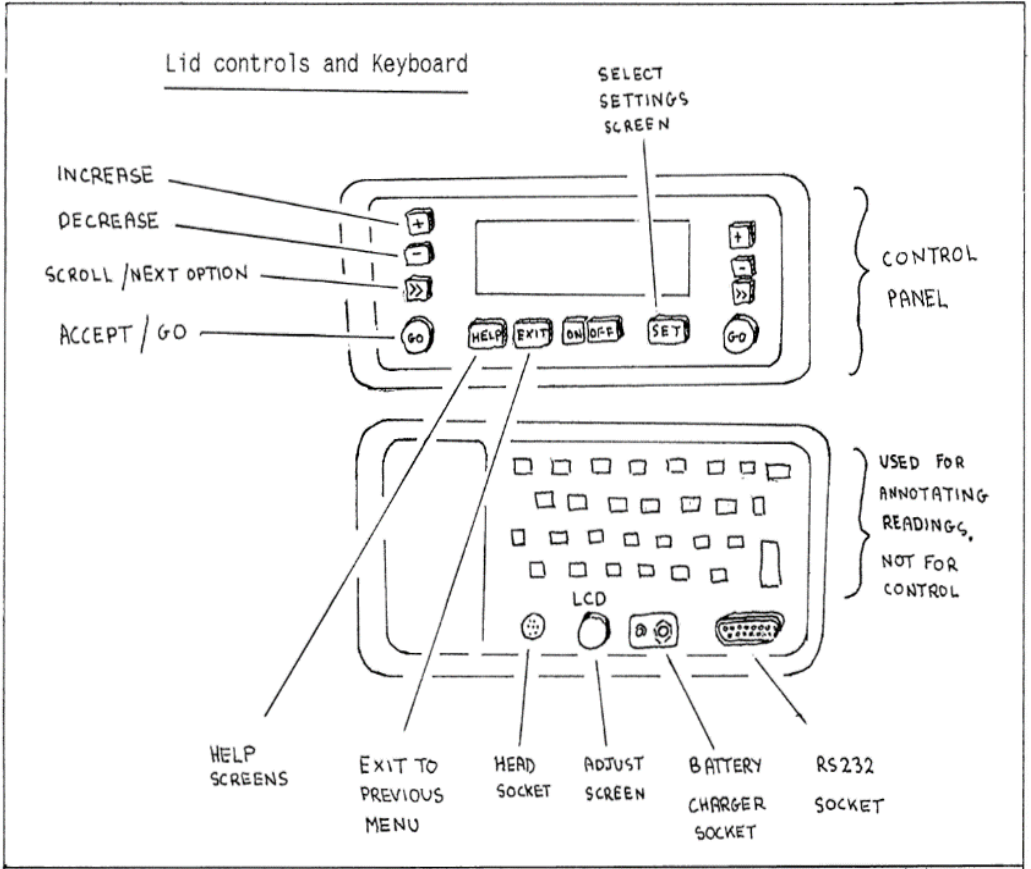
The standard QWERTY keyboard on the case of the porometer does not control the porometer. It is just used for adding optional notes to readings, and for entering the titles of groups of readings.

Below the keyboard, from left to right, are located

- the socket for the head lead,
- a knob to adjust the screen contrast,
- an input socket with a red light for the battery charger,
- and an RS232C serial interface socket for sending data to a printer or computer.

TO TAKE A READING *with one hand*





CONTROL KEYS



The **ON** and **OFF** key turn the instrument on and off.
Press **OFF twice** to turn off.

See also :

Warnings:

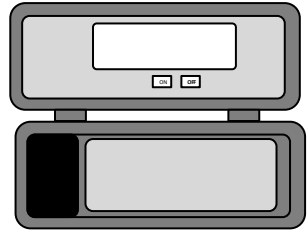
Setting up and shutting down :

Battery care and recharging :

Page 7

Page 9

Page 11 in the AP4 Technical Manual

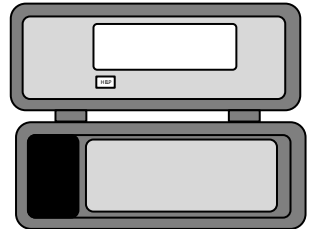


The **HELP** key provides context-sensitive information on what to do next.

Up to 7 screens of help may be provided.

Press **HELP** again to read the next screen.

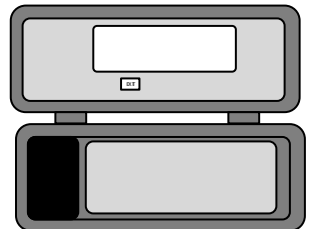
Press any other key to return to the program.

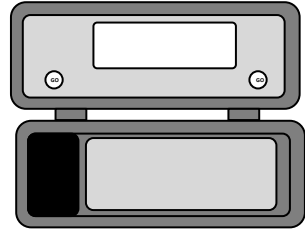
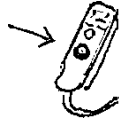


The **EXIT** key is used to leave a menu without selecting any option.

The program returns to the next higher menu level.

Use it to go back.





The **GO** key is duplicated, for left and right-handed people, on both sides of the lid.
The larger button on the porometer head is also a **GO** key.

It is an action key, causing the execution of the selected or default menu option.

- Examples :*
- ACCEPT a menu option
 - DO a suggested command
 - START a reading
 - STORE a reading

The meaning of the GO key is context sensitive.

During readings, the options on the display will cycle sequentially.

| USER | POROMETER | |
|-------------|------------------|---------------|
| ACTION | ACTION | DISPLAY |
| - | - | OFF |
| Press ON | Wake up | MAIN MENU |
| Press GO | Select READ loop | INSERT LEAF |
| Insert leaf | Waiting | INSERT LEAF |
| Press GO | START reading | READING CYCLE |
| Wait | Continues | READING CYCLE |
| Press GO | ACCEPTS reading | STORE READING |
| Press GO | STORES result | INSERT LEAF |

THIS PERMITS ONE-HANDED OPERATION OF THE POROMETER

At any stage other options can be selected via the >> key
or the previous menu can be selected via the **EXIT** key

Display Flashing

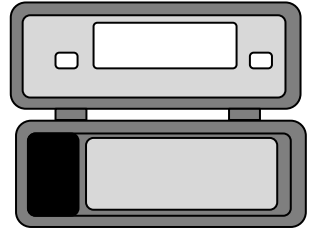
The display will flash when it is time to recalibrate. This can occur after a long interval since the last calibration, after a large shift in the cup temperature or if the relative humidity cycling set point is altered.

You can choose to ignore it if you wish, but the accuracy may suffer.

Layout and Control

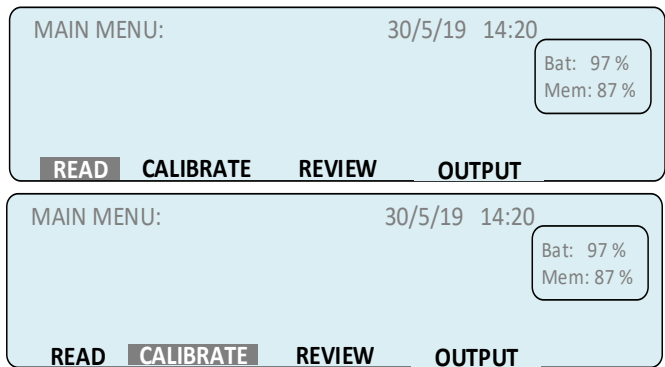


SCROLL KEY



The scroll key >> can be used to step through all the available options on the screen.

PRESS



*Next option
identified*



SHIFT OFF (together)

Beginners can ignore this.

Use this when replacing the AP4 head.

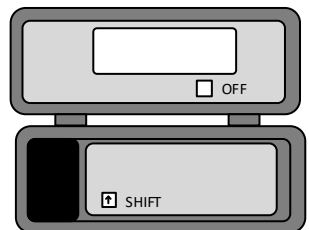
It gives access to the “Configure AP4 Head Screen”

Use it to install the appropriate calibration for a new light sensor and to zero the electronics circuit which measures the cup-leaf temperature difference,

See also :

Light sensor calibration: Page 23 in the AP4 Technical Manual

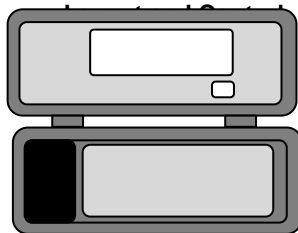
Thermistor calibration: Page 26 in the AP4 Technical Manual



Accessing the SET SCREEN will display three head calibration coefficients, used to characterise water absorption in the cup. These are automatically used to calculate the results. Only theoreticians and other experts will be interested in this.



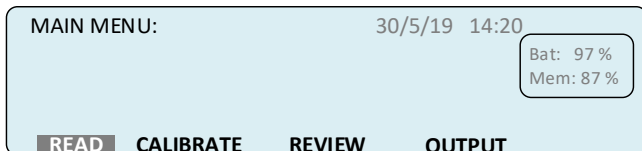
SET KEY



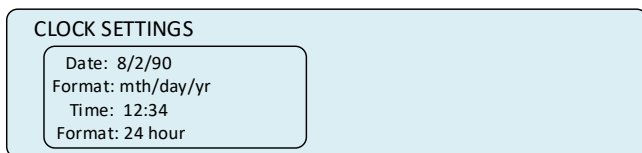
The SET key is used to set or change **default values**.
It is context-sensitive and depends on which menu is active.

See also:

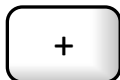
Example:
Before



After



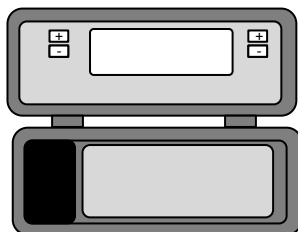
Menu flowchart: AP4 Quick Start
Settings options: page 27



PLUS KEY

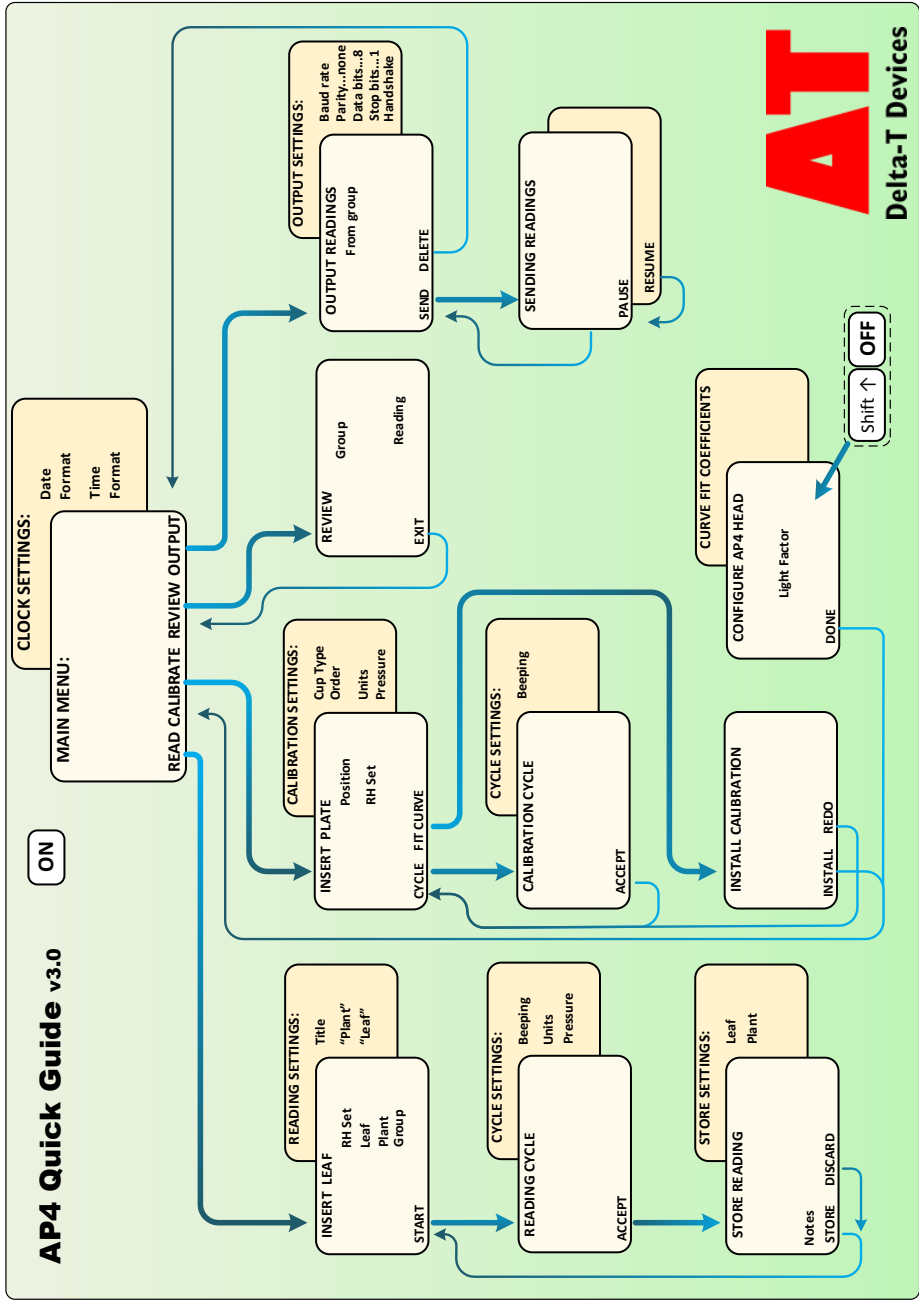


MINUS KEY



The plus and minus key are used to change default settings. *Example* : To change the date

| USER ACTION | POROMETER | |
|------------------|---------------------------------------|---|
| | ACTION | DISPLAY |
| - | Asleep | OFF |
| Press ON | Wakes | MAIN MENU |
| Press SET | Day of month | CLOCK SETTINGS shown in inverse video |
| Press + | Day of month increments | |
| Press GO | Accepts change - returns to MAIN MENU | |



Specifications

SENSOR HEAD

| | |
|----------------------|--|
| Size: | 110 x 30 x 27 mm |
| Weight : | 130 g (including cable) |
| Cup apertures: | 2.5 x 17.5 mm (slot with rounded ends) 6.0 mm dia (circular) |
| Cable length: | 1.1 m |
| RH sensor | IST P14 Rapid |
| Temperature sensors: | Betatherm 100K (curve 6) microchip thermistors |
| Accuracy | $\pm 0.1^{\circ}\text{C}$ at 25°C $\pm 0.3^{\circ}\text{C}$ at 0 and 50°C |
| Light sensor: | Unfiltered GaAsP photodiode |

CONTROL UNIT

| | |
|---|--|
| Interface | Control panel with 8 lines x 40 character LCD display |
| | QWERTY keypad for annotation |
| | RS232 interface |
| | Pocket for sensor head, desiccant and calibration plate |
| PROM Software Version 2 Functions: | |
| Functions | read, calibrate, review and output. |
| | automatic calibration curve fitting |
| | automatic temperature correction |
| Choice of units: | Resistance: s.cm^{-1} , s.m^{-1} , $\text{m}^2\text{s.mol}^{-1}$ |
| | Conductance: cm.s^{-1} , mm.s^{-1} , $\text{mmol.m}^{-2}\text{s}^{-1}$ |

Specifications

| | |
|------------------|---|
| Battery : | Duration: 20 h |
| | Life expectancy: 200 to 2000 recharge cycles |
| | Charging: 12 to 15 V dc, 0.5 A |
| | Recharge time: approx. 14 hours |
| Memory | 32 Kbytes, approx. 630 to 1600 readings depending on the extent of added notes. |

CABLES

| | |
|----------------------|--|
| RS232 cable | 25 way female to 9 way female D connectors |
| USB to RS232 adapter | |

DATA COLLECTION SOFTWARE

| | |
|-----------------------|---|
| Filename: | AP4 Retrieve |
| Function: | Collects data from AP4 and saves to a file on a PC. |
| File format: | Comma separated values (CSV) and ASCII text |
| Computer: | A PC running Windows XP, Vista, Windows 7, Windows 8 or Windows 10. One free USB port and an internet connection |
| AP4 Retrieve software | Download from www.delta-t.co.uk |

OPERATING LIMITS

| | |
|--------------|-------------------------------|
| Temperature: | 0 to 50°C |
| Humidity: | 10 to 90 %RH (non-condensing) |

CALIBRATION PLATE VALUES

At 20°C, 1000 hPa

| Plate position | Resistance | | | Conductance | | |
|----------------|------------|------|----------|-------------|-------|------------------------|
| | s/cm | s/m | m2.s/mol | cm/s | mm/s | mmol/m ² .s |
| 1 | 27.3 | 2730 | 66.51 | 0.04 | 0.37 | 15 |
| 2 | 16.5 | 1650 | 40.02 | 0.06 | 0.61 | 25 |
| 3 | 7.4 | 740 | 18.03 | 0.14 | 1.35 | 55 |
| 4 | 3.1 | 310 | 7.55 | 0.32 | 3.23 | 132 |
| 5 | 1.6 | 160 | 3.90 | 0.63 | 6.25 | 257 |
| 6 | 0.8 | 80 | 1.95 | 1.25 | 12.50 | 513 |

Specifications

PERFORMANCE SPECIFICATIONS (cont'd)

| Parameter | Reading range | Resolution note [1] | Accuracy note [2] | Test Conditions |
|----------------|--|---------------------|-----------------------------------|--|
| | | | | Reading Range [5] |
| Conductance | 5.0 -1200 mmol m ⁻² s ⁻¹ | 0.1 - 10 | >90 % >80 % | 5- 800 mmol m ⁻² s ⁻¹ 800 - 1200 mmol m ⁻² s ⁻¹ |
| Conductance | 0.25 - 30.0 mm s ⁻¹ | 0.01 - 0.1 | >90 % >80 % | 0.25 - 20 mm s ⁻¹ 20 - 30 mm s ⁻¹ |
| Resistance | 0.2 - 40 s cm ⁻¹ | 0.01 - 0.1 | >90 % + 0.2 s.cm ⁻¹ | 0.5 - 40s cm ⁻¹ 0.2 - 0.5 s cm ⁻¹ |
| RH | 0 - 100% | 0.1 | 96% | |
| Cup temp. | -5 - +55 °C | 0.1 | ± 0.7 °C | 0 - 50 °C |
| Cup-leaf temp. | -5 to +5 °C | 0.1 | ± 0.2 °C | 0 - 50 °C |
| PAR flux [3] | 0 - 2500 μmol m ⁻² s ⁻¹ | 10 | >85% | |
| Pressure | 600 -1200 hPa (mb), settable in steps of 5 hPa | | | |
| RH cycle level | 20 - 80 %RH, settable in steps of 5% [4] | | | |

Notes:

- Resolution varies with the magnitude of the value obtained. The range shown corresponds to the reading range. In relative terms, the resolution is better than 2%, but at least the smallest amount shown.
- Accuracy is the extent with which the measurement agrees with the true value (100% is perfect), as verified by comparing plate readings with the reference value (for a specific temperature and pressure).
The stated accuracy applies within +10 to -5°C of the calibration temperature, and < ±2.5°C temperature difference between cup and leaf.
- Spectral and cosine responses are approximate only.
- Cycling at extreme combinations of temperature, conductance and RH level may not always be possible.
- For Ambient RH 10 — 90%.

CE CONFORMITY

The Porometer type AP4 conforms to EC regulations regarding electromagnetic emissions and susceptibility when used according to the instructions contained within this user manual, and is CE marked by Delta-T Devices Ltd.

Warranty, Service, Technical Support

Terms and Conditions of Sale

Our Conditions of Sale (ref: COND: 1/07) set out Delta-T's legal obligations on these matters. The following paragraphs summarise Delta T's position but reference should always be made to the exact terms of our Conditions of Sale, which will prevail over the following explanation.

Delta-T warrants that the goods will be free from defects arising out of the materials used or poor workmanship for a period of two years from the date of delivery.

Delta-T shall be under no liability in respect of any defect arising from fair wear and tear, and the warranty does not cover damage through misuse or inexpert servicing, or other circumstances beyond their control.

If the buyer experiences problems with the goods they shall notify Delta-T (or Delta-T's local distributor) as soon as they become aware of such problem.

Delta-T may rectify the problem by replacing faulty parts free of charge, or by repairing the goods free of charge at Delta-T's premises in the UK during the warranty period.

If Delta-T requires that goods under warranty be returned to them from overseas for repair, Delta-T shall not be liable for the cost of carriage or for customs clearance in respect of such goods. However, Delta-T requires that such returns are discussed with them in advance and may at their discretion waive these charges.

Delta-T shall not be liable to supply products free of charge or repair any goods where the products or goods in question have been discontinued or have become obsolete, although Delta-T will endeavour to remedy the buyer's problem.

Delta-T shall not be liable to the buyer for any consequential loss, damage or compensation whatsoever (whether caused by the negligence of the Delta-T, their employees or distributors or otherwise) which arise from the supply of the goods and/or services, or their use or resale by the buyer.

Delta-T shall not be liable to the buyer by reason of any delay or failure to perform their obligations in relation to the goods and/or services if the delay or failure was due to any cause beyond the Delta-T's reasonable control.

Service, Repairs and Spares

Users in countries that have a Delta-T distributor or technical representative should contact them in the first instance.

Spare parts for our own instruments can be supplied and can normally be despatched within a few working days of receiving an order.

Spare parts and accessories for products not manufactured by Delta-T may have to be obtained from our supplier, and a certain amount of additional delay is inevitable.

No goods or equipment should be returned to Delta-T without first obtaining the return authorisation from Delta-T or our distributor.

On receipt of the goods at Delta-T you will be given a reference number. Always refer to this reference number in any subsequent correspondence. The goods will be inspected and you will be informed of the likely cost and delay.

We normally expect to complete repairs within one or two weeks of receiving the equipment. However, if the equipment has to be forwarded to our original supplier for specialist repairs or recalibration, additional delays of a few weeks may be expected. For contact details see below.

Technical Support

Users in countries that have a Delta-T distributor or technical representative should contact them in the first instance.

Technical Support is available on Delta-T products and systems. Your initial enquiry will be acknowledged immediately with a reference number. Make sure to quote the reference number subsequently so that we can easily trace any earlier correspondence.

In your enquiry, always quote instrument serial numbers, software version numbers, and the approximate date and source of purchase where these are relevant.

Contact details:

Tech Support Team
Delta-T Devices Ltd
130 Low Road, Burwell, Cambridge CB25 0EJ, UK
email: tech.support@delta-t.co.uk
email: repairs@delta-t.co.uk
web: www.delta-t.co.uk
Tel: +44 (0)1638 742922
Fax: +44 (0)1638 743155

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