Delta-T Devices

AP4 Porometer

The AP4 Porometer measures stomatal aperture in terms of leaf conductance to water vapour.

This is a major determinant of water loss from plant leaves and of CO_2 uptake in photosynthesis.

- Direct readout of conductance or resistance
- Simple and rapid calibration in the field
- Minimises leaf stress during measurement
- Outstanding value, ease of use and durability - 5 year warranty

Applications

Loss of water vapour through plant leaf stomata is one of the critical factors linking transpiration with ambient temperature, pressure, humidity and wind speed. The stomata are sensitive to light, relative humidity (RH), carbon dioxide (CO_2), water stress, pathogens and pollutants. The AP4 Porometer makes accurate, repeatable and convenient field measurements of stomatal conductance using the cycling diffusion principle. When combined with leaf area and leaf temperature measurement, the instrument enables water loss from a whole plant or crop canopy to be estimated.

The AP4 is therefore an invaluable tool for quantifying the effect of various influences on stomatal behaviour. It also has an important role to play in comparing the performance of different crop varieties in response to environmental variations and stresses.

Practical experience The theory behind the cycling porometer is well understood (ref. 1), and is backed by Delta-T's considerable manufacturing experience of this type of instrument through four evolutionary stages. Over 1000 Delta-T Devices porometers have been used worldwide since the first was devised by Dr. J. L. Monteith in 1974 (ref. 2).

Easy and convenient use

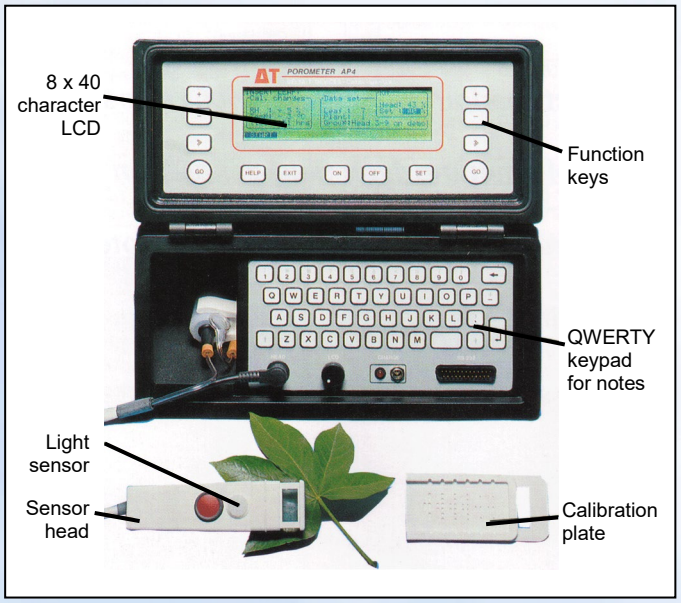
The innovative design of the AP4 provides users with logical, convenient operation and a comprehensive range of features and functions. In particular, the AP4 offers an automated, rapid cycle that gives temperature-compensated readings, and straightforward calibration.

New users can quickly make effective use of the AP4, without a deep knowledge of all the options available to the more experienced user.

In use, the AP4 is carried on a shoulder strap in its own protective carrying case, with the keyboard, control buttons and display at a convenient working level. The sensor head, on a flexible cable, is simply clipped on to the leaf to be measured. Once the instrument has been initialised, a READ button on the head allows single-handed operation. Successive readings can be taken, evaluated and stored just by pressing this one button. Stable readings are audibly indicated by a 'double beep'.

Step-by-step procedures from menus displayed on the LCD screen guide the user through the processes of calibration, taking readings, and the review and output of stored data. A SET button conveniently recalls operating settings stored previously.

AP4 Porometer



Direct calibration

The direct calibration technique used in the AP4 gives much greater confidence in the absolute accuracy of its readings than is possible in practice with other systems.

The AP4 is supplied with a moulded polypropylene calibration plate with six groups of holes; the rate of diffusion of water vapour through these holes has been carefully verified. Water vapour is provided by backing the plate with dampened paper. The sensor head is clipped onto the calibration plate, and readings are stored from each of the six standard calibration positions.

Calibration is a simple process, and easily undertaken in the field. It should be carried out at the start of a measurement session, and when necessitated by a change in temperature, or by moving to a new RH cycling level, or by changing to the alternative cup on the sensor head.

Dynamic diffusion and steady state porometers compared

Porometry

Porometry is the study of gas diffusion through pores, particularly through leaf stomata. Since plant transpiration is mainly controlled by the opening and closing of stomata, the use of porometers is vital to many areas of plant research.

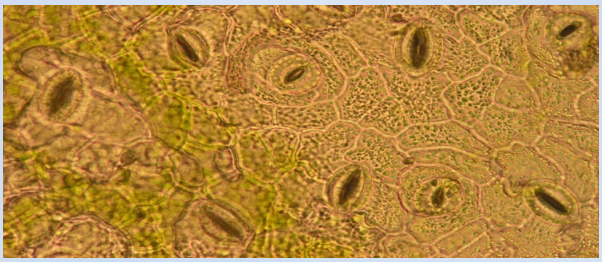
Most field measurements are currently made by diffusion porometers, using either the dynamic or steady state measurement principle. Dynamic diffusion porometers, such as the Delta-T AP4, are characterised by simplicity, unstirred leaf chambers, and the need for frequent but easy recalibration using plates with known diffusion resistances. Steady state porometers are comparatively complex, they require a vigorously stirred leaf chamber and their recalibration, while infrequent, can be difficult.

Relative strengths

Accuracy: Under laboratory conditions, the two systems are comparable, though the steady state can be significantly more accurate at very high diffusion conductances when carefully calibrated.

Under field conditions, the situation changes. The accuracy of the Delta-T system can be maintained by simply recalibrating in the field whenever appropriate. In the steady state system, accuracy depends on the absolute accuracy of the RH measurement: an error of more than ±18% in the diffusion reading can be caused by a ±3% RH error (refs. 3, 4).

When taking measurements in the field on leaves, the possibility of contamination will usually limit confidence in the absolute RH measurement to ±4%, even with careful and frequent laboratory recalibration.



Conditions within a porometer chamber can occasionally cause the stomata to close before a reading is taken. These are more likely to be present in a chamber where the leaf is stressed by the increased water loss associated with vigorously stirred steady state systems.

Resolution: Dynamic and steady state porometry systems offer similar resolution: approximately 0.5 $mmol.m^{-2}.s^{-1}$.

Speed: Both systems enable a reading to be taken within about 15 seconds for a highly conductive leaf, and within about 60 seconds for a highly resistive leaf.

Convenience: Both systems provide direct readout of stomatal conductance units, but the AP4 also features a simple comprehensive graphic display of all relevant reading information. The moulded plastic AP4 sensor head weighs only 130 g – less than 1/3 the weight of many steady state porometers.

Sampling area: Because the chamber in a dynamic system is unstirred, it is not practical to use large sampling areas in conjunction with a small RH sensor. However, users' experience suggests that this is a very minor inconvenience, occasionally requiring more samples to be taken.

Price: Generally, dynamic porometers are less expensive because they do not require such elaborate leaf chambers or expensive gas flow meters.

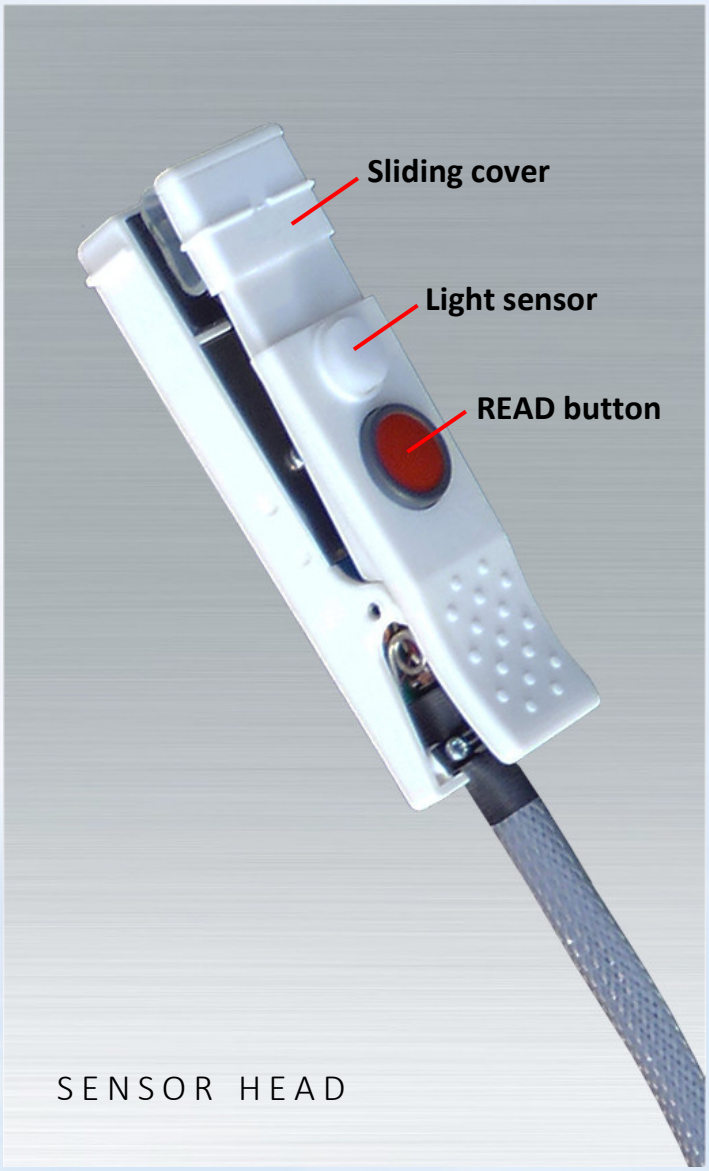
Ease of use, reliability and economy without compromising on accuracy continue to make dynamic diffusion porometers the first choice for scientists worldwide.

Compact sensor head

The lightweight, compact AP4 sensor head enables reliable and quick measurements, even in small or dense canopies, with minimum stress on the leaf. The red READ button allows single-handed taking of readings.

Made from low water absorption polypropylene, the head contains two cups (cuvettes), one slotted, the other circular, to suit different leaf shapes. A sliding cover lets the user check leaf alignment. A silicone rubber seal presses gently onto the leaf surface, defining the sample area.

The head contains fast response sensors to measure cup and leaf temperatures, allowing automatic temperature compensation to be applied (ref 3). White insulating materials reduce cup heating by bright sunlight, while a PAR photodiode sensor (Photosynthetically Active Radiation) measures light incident on the leaf.



Measurement units

The AP4 lets you choose whether to work in terms of stomatal conductance or resistance, and in "velocity" or mole units. Mole units offer comparability with biochemical units in photosynthesis, for example the moles of biomass created, or the flux density of PAR quanta. They have the advantage of being independent of pressure, and only weakly dependent on temperature, whereas velocity units depend on both. The AP4 refers all readings to the ambient temperature and pressure setting.

Changes in barometric pressure between a calibration and actual measurement will affect resistance readings: a change of 1 kPa can cause a 1% error in measured resistance. An extreme change in the weather could have this effect, but altitude is normally a greater factor, the rate of change being 1 kPa per 100 m. The Wristwatch Barometer type PBR1, is suitable for monitoring local pressure (see Ordering Information).

Data handling

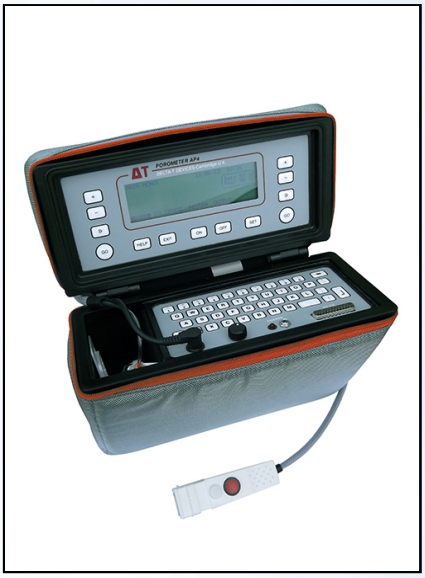
Onboard memory provides a storage capacity of up to 1500 readings, with a notes facility. Data is exported to a computer, printer or pocket terminal through the RS232 link. Data formats are suitable for direct entry to standard analysis software including Excel.

A complete set of data comprises the reading, reading labels, time, light level, temperature and relative humidity. Up to 30 characters of notes for each reading can be added using the keypad.

3	GROUP 6:	Pinot	Date :	10/07/2004	Set RH:	50%	Units:	mmol/m^2/s	
4							Press:	1000	hPa
5									
6	Time	Plant	Leaf	Conduct.	Cup T	Cup-Leaf	Light	Notes	
7	15:52	1	1	17.7	23.8	0.1	810	upper - centre of plot	
8	15:53	1	2	216.0	24.0	0.2	320	lower	
9	15:53	1	3	21.2	24.2	0.3	570	upper	
10	15:54	2	1	435.0	24.4	0.4	340	lower	
11	15:55	2	2	15.6	24.5	0.3	660	upper - edge of plot	
12	15:55	2	3	131.0	24.5	0.6	480	lower	

Porometer type AP4 Specifications

Parameter	Reading range	Resolution [1]	Accuracy [2]	Test conditions Reading range
Conductance	5.0 -1200 mmol m^{-2} s^{-1}	0.1 - 10	± 10 %	5 - 800 mmol m^{-2} s^{-1}
			± 20 %	800 - 1200 mmol m^{-2} s^{-1}
Conductance	0.25 - 30.0 mm s^{-1}	0.01 - 0.1	± 10%	0.25 - 20 mm s^{-1}
			± 20 %	20 - 30 mm s^{-1}
Resistance	0.2 - 40 s cm^{-1}	0.01 - 0.1	± 10 %	0.5 - 40 s cm^{-1}
			± 0.2 s cm^{-1}	0.2 - 0.5 s cm^{-1}
RH	0 - 100%	0.1	± 4%	
Cup temp	-5 - +55°C	0.1	± 0.7°C	0 - 50°C
Cup-leaf temp	-5 - +5°C	0.1	± 0.2°C	0 - 50°C
PAR flux [3]	0 - 2500 µmol m^{-2} s^{-1}	10	± 15%	
Pressure [4]	600 - 1200 hPa, settable in steps of 5 hPa			
RH cycle level	20 - 80 %RH, settable in steps of 5%			



Notes:

[1] 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.
[2] The stated accuracy applies over the range of the calibration plate and for optimum cup conditions, i.e. from +10 to -5°C difference between actual cup temp. and that existing at calibration, and for +2.5 to -2.5°C difference between leaf and cup temperatures.
[3] Spectral and cosine responses are approximate only.
[4] Ambient pressure may be read from a Wristwatch Barometer type PBR1.
[5] Cycling at extreme combinations of temperature, conductance and RH level may not always be possible.

Measuring units

Conductance: mmol m^{-2} s^{-1}, mm s^{-1}, cm s^{-1}
Resistance: s cm^{-1}, s m^{-1}, m^2 s mol^{-1}

Calibration plate values at 20°C, 1000 hPa

Plate position	Conductance (mmol m^{-2} s^{-1})	Resistance (s cm^{-1})
1	15	27.3
2	25	16.5
3	55	7.4
4	132	3.1
5	257	1.6
6	513	0.8

Sensor head

Cups: (a) slot, 2.5 x 17.5 mm, rounded ends
(b) circle, 6 mm diameter
RH sensor: IST P14 Rapid
Temp. sensors: high precision 100K thermistors
Light sensor: unfiltered GaAsP photodiode
Cable length: 1.2 m
Size/weight: 110 x 30 x 27 mm, 130 g incl. cable

Data handling

Reading memory: up to 1500 readings with full annotation (see sample printout)
Data interface: RS232 serial, up to 9600 baud, supplied with connector and adaptor for direct connection to PCs
Software: for Windows, saves data to a comma-separated ASCII data file (.CSV)

Control unit

Display: 8 lines x 40 character LCD
Keys: 13 function keys, plus full QWERTY keypad
Carrying case: padded, with shoulder and waist straps
Size/weight: 300 x 220 x 140 mm, 3 kg

Power supply

Battery: internal rechargeable, 20 hour duration
Charger: AP4 battery charger

References

1. Monteith, J. L., Campbell, G. S. & Potter, E. A., 'Theory and performance of a dynamic diffusion porometer'. Agric. For. Meteorol. 44,27-38, 1988.
2. Stiles, W., Monteith, J. L. & Bull, T. A., 'A diffusive resistance porometer for field use'. J. Appl. Ecol.7,617-638,1970
3. Campbell, G. S., 'Steady-state diffusion porometers'. Research Bulletin 809, Washington State University,20-23,1975.
4. McDermitt, D. K., 'Sources of error in the estimation of stomatal conductance and transpiration from porometer data'. HortScience,25(12),1538-1548,1990.

Ordering Information

Porometer type AP4 including: built-in rechargeable battery, sensor head type PSH1, calibration plate, carrying bag, manual, quick guide, RS232 cable, data collection software, consumables kit type PCK1 (paper pads, tape, 500 g silica gel, silica gel tube, 2 cup seals, cup gasket), battery charger (operates with 110V, 220V and 230V mains), USB to RS232 adapter cable.

Optional items:

Wristwatch Barometer type PBR1, reads atmospheric pressure.

AP4 consumables kit type PCK1, complete set as included with instrument.

AP4 spares kit type PSK2, includes spare manual. Detailed list available on request.

Spare AP4 sensor head type PSH1

Spare rechargeable battery type PSB2

Spare battery charger type AP-CHG

Spare calibration plate type AP-CP