OPTI-SCIENCES

Presents -

ADC BioScientific Ltd.

LCi - The *truly portable ambient differential photosynthesis gas exchange system* for precision measurement

World Class Precision

40 years of experience and reliability

U.S. warrantee and service center

Console Weight	5.3 lbs
Hand Held Leaf Chamber Weight	1.3 lbs
Total Weight	6.6 lbs

Battery life -10 hours

IRGA in leaf chamber head

Unlimited storage

The *LCi* - *The perfect portable compliment to "transportable" gas exchange systems*

Lightweight - High Precision - 10 hour Battery Life - Easiest to Use

Photosynthesis Measuring Parameters

A - Net assimilation rate of CO_2

Area - Leaf area

C_i - Intercellular CO_2 concentration.

c_{ref} - O_2 reference

c'_{an} - CO_2 analysis value corrected for dilution

$\triangle c$ - Delta CO_2

E - Transpiration

e_{ref} - Reference partial pressure H_2O

e'_{ad} - Dilution corrected H_2O analysis measurement

$\triangle e$ - Delta H_2O

g_s - Stomatal conductance

T_{ch} - Chamber temperature

T_l - Leaf surface temperature

P - Barometric pressure

Q - PAR light at window

Q_{leaf} - PAR at leaf

r_s - Stomatal resistance to H_2O

r_b - Boundary resistance to H_2O

U - ASU measured mass flow

W_{flux} - Net H_2O exchange rate

Soil Respiration Parameters

Ce - Soil respiration

NCER - Net CO_2 Exchange Rate

Other Parameters and Variables

(cab)a - Infrared absorption due to CO_2 analysis

(cab)r - Infrared absorption due to the reference CO_2 measurement.

(c)z - Raw CO_2 zero reading

Dt - Date

H_{fac} - Energy conversion factor

Log - Name of measuring file

Phase - CO_2 rectifier phase shift

$r_b$set - Boundary resistance at full flow

Tm - Time

Trw - Chamber window transmission factor

U_a - Last value of flow from flow check

u_s - Flow per unit leaf area

u_{set} - Desired molar air flow rate

V_a - Measured analyzer flow rate

V_{aux} - Auxiliary input, scaled as Volts

V_{batt} - Battery Voltage

W_{ref} - H_2O reference as a % of relative humidity

w'_{an} - H_2O analysis measurement corrected as a % of relative humidity

w'_{ad} - H_2O analysis measurement dilution corrected

$\triangle w$ - Delta H_2O as a % of relative humidity

(w)a - Raw H_2O analysis reading

(w)r - Raw H_2O reference reading

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ADC BioScientific Ltd.
located in
Great Amwell, Herforshire
England.

Opti-Sciences, a manufacturer of precision Chlorophyll Fluorometers, is now the exclusive US distributor for ADC BioScientific products.

Opti-Sciences also operates the US customer service and repair center at it's headquarters in Hudson NH.

ADC- a history of innovation, precision and portability.

- **In 1970 ADC introduces the *first* "Differential" Infrared Gas Analyzer (IRGA) system available anywhere for plant science.**
- **ADC champions the first "Open" plant IRGA system in 1970. Open IRGA systems are now the standard in photosynthesis investigation.**
- **ADC introduced the *first* portable IRGA system with hand held leaf chamber in 1983.**
- **The *first* micro-environmental control system for photosynthesis was an ADC innovation in 1987.**
- **ADC now offers "truly portable" high precision gas exchange instrumentation. Compact light weight electronics, innovative IRGA design, a very easy to use human interface, and a sixteen hour built in battery make this the perfect field companion instrument to heavier transportable green house gas exchange instruments.**

Portable systems were introduced to the market place by ADC in the early 1980s.

1983: LCA1
1984: LCA2
1987: LCA-3
1993: LCA-4
1997: LCA-4M
2001: LC*pro*

Current Models

LC*i* - *Current model for portable ambient differential CO_2 & H_2O gas exchange measurement.*

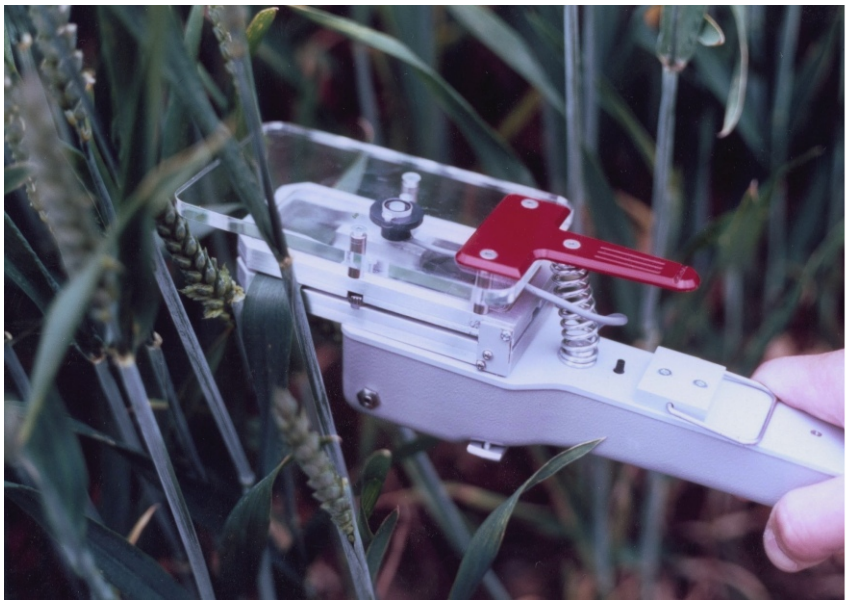
LC*pro*+ - *Current model for portable micro- environmental control, A/Ci curves and Light curves.*

Easy to use and program

Designed specifically for field use, the LCi is shown with a belt carrying strap and broad leaf chamber

A	Net assimilation rate of CO_2	E	Transpiration	Ci	Intercellular CO_2 concentration
Gs	Stomatal conductance	TLc	Chamber leaf temperature	U	ASU measured mass flow rate
Uset	Mass flow rate setting	Power	Battery life remaining	Record	measurement number

Main Parameter Screen



LCi hand held leaf cuvette with broad leaf chamber in operation

Close-up

Paying attention to detail

The ***Lci*** is designed to provide truly portable *ambient* photosynthesis measurement with a high degree of repeatability and reliability. To accomplish this goal, ADC uses the same high quality CO_2 IRGA components, and the same high quality laser trimmed relative humidity sensors that are found in their more advanced LCpro+ system.

Auto-Zero **-** All IRGA light sources and sensors made by all manufacturers drift electronically. If multiple IRGA chambers are used, then all light sources and sensors drift independently and in many cases they drift in opposite directions. To solve this problem, ADC uses a single CO_2 IRGA that measurements both ambient air, and also air that has flowed through the leaf chamber.

To ensure that the instrument provides highly repeatable and reliable measurements, an auto-zero routine is preformed every 16 seconds. During this routine the instrument takes ambient air and scrubs CO_2 and H_20 from the sample. It then enters the IRGA chamber and a measurement is taken. Since this reference air does not contain CO_2 or H_2O, the instrument electronic gain can be automatically adjusted to zero out electronic drift.

The CO_2 IRGA and the H_2O sensors are in the hand held leaf measuring head. -
Placing the IRGA next to the leaf chamber, solves a few problems. Measurement response times are improved dramatically, and other problems associated with longer distances are eliminated.

When the path to the IRGA is long, there can be gas hang-ups and water vapor drop out. Changes in ambient lighting, sun flecks, and changes in temperature, can be greater sources of error because they can affect the gases as they flow throw the long tube.

Differential IRGA **-** There are absolute and differential plant IRGA systems. Absolute systems measure CO_2 level against an absolute CO_2 calibration. Differential IRGAs compare the measurement of CO_2 and H_2O before the leaf chamber to the measurement of CO_2 and H_2O after the leaf chamber. Almost all commercial plant IRGA systems are of the differential type. Certainly, the most advanced systems are of the differential type because they provide more reliable measurements.

ADC developed the first differential plant IRGA in 1970. Both current plant gas exchange systems, the LCi and the LCpro+, are of the differential type.

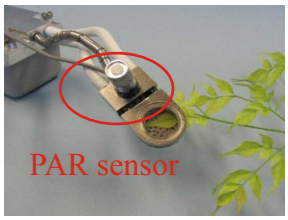
Laser Trimmed Relative Humidity Sensors **-** The measurement of H_2O is a secondary measurement necessary to correct CO_2 measurements. Since CO_2 and H_2O both absorb infrared in a similar spectral range, it is important to measure H_2O content and barometric pressure to provide reliable CO_2 measurements. Other manufactures still use a set of separate IRGA chambers to measure water content. ADC has found that modern solid-state humidity sensors provide a more than reliable solution for the measurement of relative humidity while offering the advantages of lighter weight, greater power efficiency, and greater stability. In the 1980's humidity sensors were highly variable. Today the opposite is true.

ADC's laser trimmed relative humidity sensors offer advantages for 95% of plant applications.

Paying attention to detail

Leaf temperature **-** Leaf temperature may be determined by either the energy balance equation or directly measured by a movable solid state thermistor.

Automatic barometric pressure compensation -for all measurements. Barometric pressure is constantly being measured.



PAR or Photosynthetically Active Radiation is measured by a silicon diode PAR Sensors. It can be mounted near the leaf chamber, or moved to other areas to measure PAR. The sensor is cosine corrected.

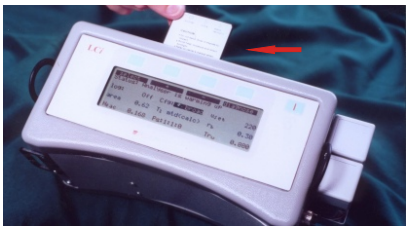
Optional adjustable light source - for cloudy and partly cloudy days

In many parts of the world, ambient measurement provides highly variable data due to clouds. The attachable adjustable halogen lamp allows the user to set the lamp intensity to ambient sunny, or ambient cloudy conditions when standardization of irradiation is desired.

The light source may also be used to manually create light curves. However, if automation of light curves is needed, or if one needs to make a significant number of light curves, ADC recommends the LCpro+

Equations used - for measurements come from: S.von Caemmerer and G.D.Farquhar (1981) “Some relationships between the biochemistry of photosynthesis and the gas exchange of leaves”, *Planta* 153:376-387.

Measurement File and Data Storage

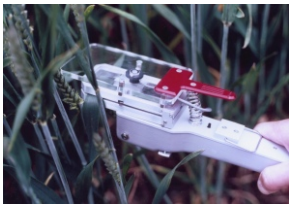


Unlimited data storage - The storage of all data files and measuring files are located on PC Cards. Each card is capable of storing up to 8000 data sets. Of course storage is increased with more cards or cards with more storage capacity. Standard cards contain 512 kilobytes fo storage. Cards with memory storage up to one megabyte can be used. Data from files may be reviewed with the console display.

Designed for research organizations with several users.
Since each user can have a data card, preprogramed measuring routines, data files, and curves can be stored on an individual card. Files do not need to be reconstituted if the system is used by many researchers. Simply insert your card, open a file, and the system will be set up the way that you programed it earlier.

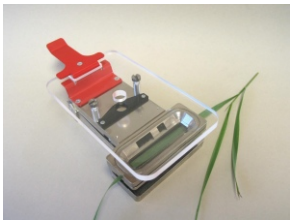
Interchangeable chamber heads - for optimal air flow and special applications.

The LCi is available with a range of interchangeable heads. These are easily and quickly exchanged in the field using only a small coin. *Boundary layer resistances and concentration gradients are minimized irrespective of which head is in use*. Chamber materials, such as nickel plating, have been carefully chosen to ensure that there is minimal interaction with CO_2 or water vapor. Chamber windows are silica coated to reduce scratching. While attaching each chamber the system is auto configurable, removing the requirement for complex reprogramming whenever a different head is used. The LC*i* chamber is simple to operate with a thumb trigger opening



Broad Leaf Chamber

The broad leaf chamber is *the most widely used* chamber and the one most suited for the largest number of plant species. It features both a self-positioning leaf temperature sensor and a manual placement temperature sensor.



Narrow Leaf Chamber

This is designed especially *for long grasses and narrow leaves under 1cm in width.* For leaves wider than 1cm, we recommend the broad leaf chamber. The *LCi* narrow leaf chamber features both a self-positioning leaf temperature sensor and a manual placement sensor. *The chamber sides are chamfered to prevent shading of the measured area from the sun.*

Soil Chamber- Designed for Soil Survey Measurements

A high quality Soil chamber, that includes a detachable collar, provides accurate soil flux measurements in ambient field conditions. It features a pressure release valve that minimizes any potential pressure gradients. When the Soil chamber is fitted to the *LCi* unit, it will calculate soil flux Ce, and net CO_2 exchange rate NCER.

The *LCi* *is the perfect tool for doing short-term survey Soil Flux measurements.*

A light weigh, highly portable system, the *LCi* offers an open differential design for maximum measurement reliability.

- Ce and NCER can be read directly from the display screen.
- It comes with a well designed soil collar for a good seal
- It has a pressure release valve (not a vent) to eliminate pressure gradients
- The CO_2 IRGA and H_2O sensors are attached to the soil sample chamber to eliminate gas hang-up and water vapor drop out.
- Because the soil chamber is transparent, samples Net CO_2 exchange rate can be measured
- A soil temperature probe with thermistor is provided for integrated soil temperature measurement with Ce and NCER values.

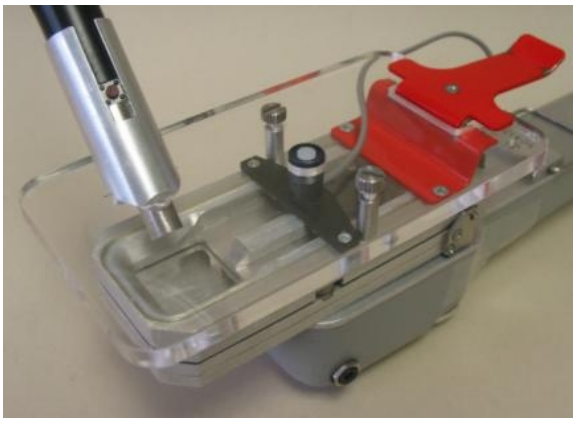
Interchangeable chamber heads for special applications

ADC's innovative approach has led to many firsts. specialty chambers shown below are yet more examples of forward thinking.

Conifer Leaf Chamber

The ambient light Conifer chamber has a cylindrically arranged chamber, and a transparent bottom for illumination on all sides.

Fluorometer Adapter Chamber



For simultaneous gas exchange/chlorophyll fluorescence studies. The chamber features a fiber optic cable adapter to allow use with chlorophyll fluorescence devices.

Unique Small Leaf Chamber

Unique Arabidopsis Leaf Chamber

ADC Arabidopsis and Small leaf Chambers offer a significant improvement over competitive models. Adjustable articulating mechanical arms are provided with a locking mechanisms. *Now small leaves may be easily oriented in the desired position and locked before measurement*, even when the leaf is close to the soil surface. The window size of the Arabidopsis chamber is 11mm in diameter. The window size of the Small Leaf Chamber is 16.5 mm.

ADC - The “truly portable” compliment to transportable instrumentation.

CO_2 Gas exchange understanding and comparing measuring terms.

Resolution- is the ability to read in fine incrementation. Resolution is directly related to the length of the infrared gas analyzer chamber length. The longer the tube, the finer the resolution. It is important to understand, however, that just because a tool can read to 0.2 umols of CO_2 or .03 mb of H_2O does not mean that the measurement is accurate, repeatable, reliable or even necessary. For example, a measuring gauge may read to millionths of an inch, but the measuring tool may only be capable of reliable measurements to a thousandth of an inch due to heat, humidity, measuring standards, measuring technique, electronic drift, or other conditions. It is also important to understand that measuring a 2X4 board to millionths of an inch is of little value. The same can be true of gas exchange measurements. ***If a measurement is of high resolution but not repeatable, it is normally of limited use.***

Repeatability is the ability to repeat the same measurement over again. All measuring tools repeat measurements within a certain tolerance range for specific conditions. For most gas exchange applications, repeatability is much more important that resolution. In all IRGA designs made by all manufactures, the light sources and the infrared sensors that are used, drift electronically over time. If four IRGA tubes are used with four different light sources and four different sensors, then all components can drift independently of each other. This is an important component of a machine's ability to achieve repeatability.

ADC, the company that developed the first differential plant IRGA analysis system, now uses a single IRGA tube next to the leaf chamber to measure CO_2 level before and after the leaf chamber. Such a design was chosen because there is only one infrared sensor and one light source to cause drift as opposed to many components that drift. In addition, the single chamber IRGA is ideal for lightweight portable use. ADC has found that the repeatability of the LCi is similar to that of its primary competitor for most applications.

H_2O measurement is a secondary type of measurement required to eliminate humidity as a source of error in measurement. Water absorbs infrared in a similar range as CO_2 so one has to correct for water content in the air. Most companies use separate IRGAs to measure water content. ADC has found that modern laser trimmed humidity sensors provide high repeatability and the necessary resolution for 95% of CO_2 gas exchange measurements and applications. While such humidity sensors were not adequate in the 1980's, advances have significantly improved results. Such sensors provide a lightweight solution with minimum sensor drift.

ADC's repeatability is similar to competitor's precision.

Accuracy If one is shooting an arrow at a target, then accuracy is the ability to hit the bull's-eye. *In Gas exchange, accuracy is determined by the standard CO_2 gas that is used to calibrate the tool.* If the quality of the standard is good, then the accuracy is likely good. Systems that are more subject to drift require calibration more often to maintain accuracy.

ADC's systems are designed to minimize sensor and light source drift.

Reliability- A reliable measurement is one that is accurate and repeatable.

CO_2 Gas exchange - understanding and comparing measuring terms.

Leaf equilibrium It normally takes between 45 seconds and two minutes for a leaf to reach equilibrium in the leaf chamber. This is species dependant and it is independent of the instrument used for measurement. Of course, the process of equilibrium can be monitored on the graphic display screen.

As with all differential non-dispersive IRGA systems, the incoming ambient air is scrubbed of H_2O and CO_2. In ambient conditions, a measurement of this air is made before it enters the leaf chamber and then again after it passes through the leaf chamber.

Under microclimate control conditions, CO_2 and water may be added to the air. Temperature and light irradiance may also be controlled, after the ambient air is initially scrubbed for CO_2 and H_2O.

In both of the cases listed above, the leaf is required to reach equilibrium before the measurements are made. Since measurements are made before air enters the leaf chamber, and after the air leaves the leaf chamber, the plant is only required to reach equilibrium once as is true for all differential IRGA systems.

Measurement takes only a few seconds after the leaf reaches equilibrium.

IRGA location (infrared gas analyzer) While ADC developed the first non-dispersive differential IRGA, the first open system, and the first microclimate control system, it was Licor that was the first to put the IRGA next to the leaf chamber. In the past, IRGAs had been in the console and not in the hand held leaf cuvette.

By placing the IRGA next to the leaf chamber, Licor solved a few problems. Measurement response times were improved dramatically, and other problems associated with longer distances were eliminated. When the path to the IRGA is long, there is gas mixing in the transfer tube from the before chamber and after chamber measurements. In addition, changes in ambient lighting, sun flecks, changes in temperature, and relative humidity can be greater sources of error because they can affect the gases as they flow throw the tube.

ADC uses a single non-dispersive differential IRGA in the hand held leaf cuvette next to the leaf chamber. This improves upon previous designs by making the hand held leaf cuvette lighter for greater portability and it reduces the problem of IRGA light source and sensor drift.

Open system vs. closed system. Close systems measure the concentration of CO_2 and H_2O before the experiment begins and after some time. Early systems were closed systems. Today most commercial systems are open systems where ambient air is taken and scrubbed of CO_2 and H_2O, and CO_2 and H_2O are added back in a constant predetermined mole fraction. This air is measured before the leaf chamber and after the leaf chamber. The flow rate of air passing over the leaf surface is adjustable and it is part of the calculation. Open systems provide a faster measurement and greater control over mole fraction measurements.

ADC plant gas exchange systems are all open systems.

While specifications can be valuable and helpful, the only way to be sure that an instrument works best for an application is to try it.

Call us for a test drive today.

Prove it to your self.

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Technical specifications

Measurement range and technique:

CO_2:	0-2000ppm, optional 0-3000ppm,1ppm resolution. Infrared gas analysis, differential open system, auto zero, automatic atmospheric pressure and temperature compensation.
H_2O:	0-75mbar, 0.1mbar resolution. Two laser trimmed, fast response water vapor sensors.
PAR:	0-2000 umols / m^2 / sec Silicon photocell. Cosine corrected.
Chamber temperature:	0°C - 50°C Precision thermistor.
Leaf temperature:	0°C - 50°C Self positioning microchip thermistor / Energy balance / manually positioned thermistor.
Flow rate to Plant Leaf Chamber:	100ml to 500ml min
Repeatability:	CO_2: 0.1% of reading at 350ppm H_2O: 0.5% Relative Humidity
Linearity:	CO_2: 0.5% of reading H_2O: 0.5% of Relative Humidity
Temperature effect on span:	CO_2: <0.05% of f.s.d. per °C
Programming:	Internal LCi menu driven software.
Display:	240 x 64 dot matrix super twist LCD.
Recorded data:	Removable PCMIA type 1 compatible cards storing unlimited data. 128k Byte cards store up to 2000 data sets. The system supports cards up to 1M Byte.
Battery:	2.6 Ah rechargeable lead acid battery. Life up to 10 hours. Battery charger: 100 -120 Volt or 200 - 240 Volt. User selectable 50/60 Hz.
RS232 output:	User-selectable rates of up to 19,200 baud for printer or computer connection.
Analog output:	Two channels. 0 - 5 V user-selectable parameters.
Operating temperature:	5°C - 45°C
Weight and Dimensions: Console:	5.3 lbs or 2.4 kg, 24 cm X 12.5 cm X 14 cm
Plant Leaf Chamber:	1.3 lbs or 0.6 kg, 30 cm x 8 cm x 7.5 cm

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