

apogee

INSTRUMENTS

OWNER'S MANUAL

CHLOROPHYLL CONCENTRATION METER

Model MC-100



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DECLARATION OF CONFORMITY

CE and ROHS Certificate of Compliance

We Apogee Instruments, Inc.
721 W 1800 N
Logan, Utah 84321
USA

Declare under our sole responsibility that the products:

Model: MC-100
Type: Chlorophyll Concentration Meter

are in conformity with the following standards and relevant EC directives:

EMC Emissions: EN 55022:1998 Class B
EMC Emissions and Immunity: EN 61326:1997 Measurement, Control, and Laboratory Equipment EMC Requirements – For Portable Use

EU directive 2002/95/EC, RoHS (Restriction of Hazardous Substances)
EU directive 2011/65/EU, RoHS2

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials including cadmium, hexavalent chromium, lead, mercury, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE).

Further note that Apogee Instruments does not specifically run any analysis on our raw materials or end products for the presence of these substances, but rely on the information provided to us by our material suppliers.

Bruce Bugbee
President
Apogee Instruments, Inc.
January 2015

INTRODUCTION

Chlorophyll is a green pigment found in plant cells, algae cells, and cyanobacteria. The primary function of chlorophyll molecules is radiation absorption, which provides energy essential for photosynthesis. Chlorophyll concentration in plant leaves is typically expressed in units of quantity per area of leaf surface, micromoles per square meter ($\mu\text{mol m}^{-2}$); mass per area of leaf surface, milligrams per square meter (mg m^{-2}), has also been used.

Hand-held chlorophyll meters typically provide a relative indication of chlorophyll in plant leaves. The patent pending Apogee model MC-100 chlorophyll concentration meter measures relative chlorophyll content and outputs an estimate of actual chlorophyll concentration in units of $\mu\text{mol per m}^2$ of leaf surface, which is closely correlated to the relative measurement. The MC-100 provides an alternative to destructive sampling techniques for determining chlorophyll concentration. It is less time consuming and labor intensive, and allows for leaves to be measured and monitored over an entire growth cycle. It also allows for rapid replicate measurements of the same leaf, or rapid measurement of multiple leaves.

Typical applications of chlorophyll meters include chlorophyll concentration determination for plant nutrient status assessment, environmental stress impact, and fertilizer requirement.

Apogee Instruments MC-100 chlorophyll concentration meters consist of two light emitting diodes (one emitting red radiation and one emitting near infrared radiation) with paired detectors, liquid crystal display (LCD), operation buttons, 9 V alkaline battery, and signal processing circuitry mounted in a plastic housing. The meter also includes a USB port for data download to a computer and RS-232 port for use with GPS. The meter is hand-held and designed for instantaneous, non-destructive, direct determination of leaf chlorophyll concentration. The meter measures the ratio of radiation transmittance from two different wavelengths (red and near infrared) and outputs chlorophyll concentration, which is calculated internally from the transmittance ratio measurement and then displayed on the LCD.

METER MODELS

The MC-100 chlorophyll concentration meter is the only chlorophyll meter model offered by Apogee Instruments. It includes custom coefficients to determine chlorophyll concentration for twenty-two different plant species. It also includes a generic equation for use with all plant species that was derived from the data of all twenty-two species measured. Custom coefficients for additional species can be added, once established from measurement of chlorophyll content index (CCI) and *in vitro* determination of leaf chlorophyll concentration, which requires chemical digestion of leaf samples and subsequent chlorophyll extraction, then optical analysis for chlorophyll determination. The method is detailed and equations for twenty-two different plant species are provided in Parry et al. (2014).

Parry, C., J. M. Blonquist Jr., and B. Bugbee, 2014. In situ measurement of leaf chlorophyll concentration: analysis of the optical/absolute relationship. *Plant, Cell and Environment* 37:2508-2520.



Meter model number, serial number, and production date are located on a label on back of each meter.

SPECIFICATIONS

Displayed Output Unit: μmol of chlorophyll per m^2 of leaf surface

Measurement Area: 63.6 mm^2 (9.0 mm standard diameter), 19.6 mm^2 (5 mm diameter with reducer)

Resolution: $10.5 \mu\text{mol m}^{-2}$ chlorophyll concentration for generic equation (less for specific species),
0.1 Chlorophyll Content Index (CCI) unit

Linearity: $\pm 1 \%$

Repeatability: $\pm 1 \%$

Sample Acquisition Time: < 3 seconds

Storage Capacity: 8 MB for up to 160,000 data measurements
94,000 data measurements with GPS data entries

User Interface: 50 mm by 15 mm graphic display screen
8 pushbuttons for control and data manipulation

Data Output: Mini-B USB port provided for main data transfer
RS-232 port can be used with GPS for integrated measurement

Measured Parameters: Ratio of optical transmission at 931 nm to optical transmission at 653 nm

External GPS Option: RS-232 port (GPS location data is saved with each measurement)

Operating Temperature: 0 to 50 C

Temperature Drift: Temperature compensated source and detector circuitry over full range

Power Requirement: Standard 9 V DC alkaline battery

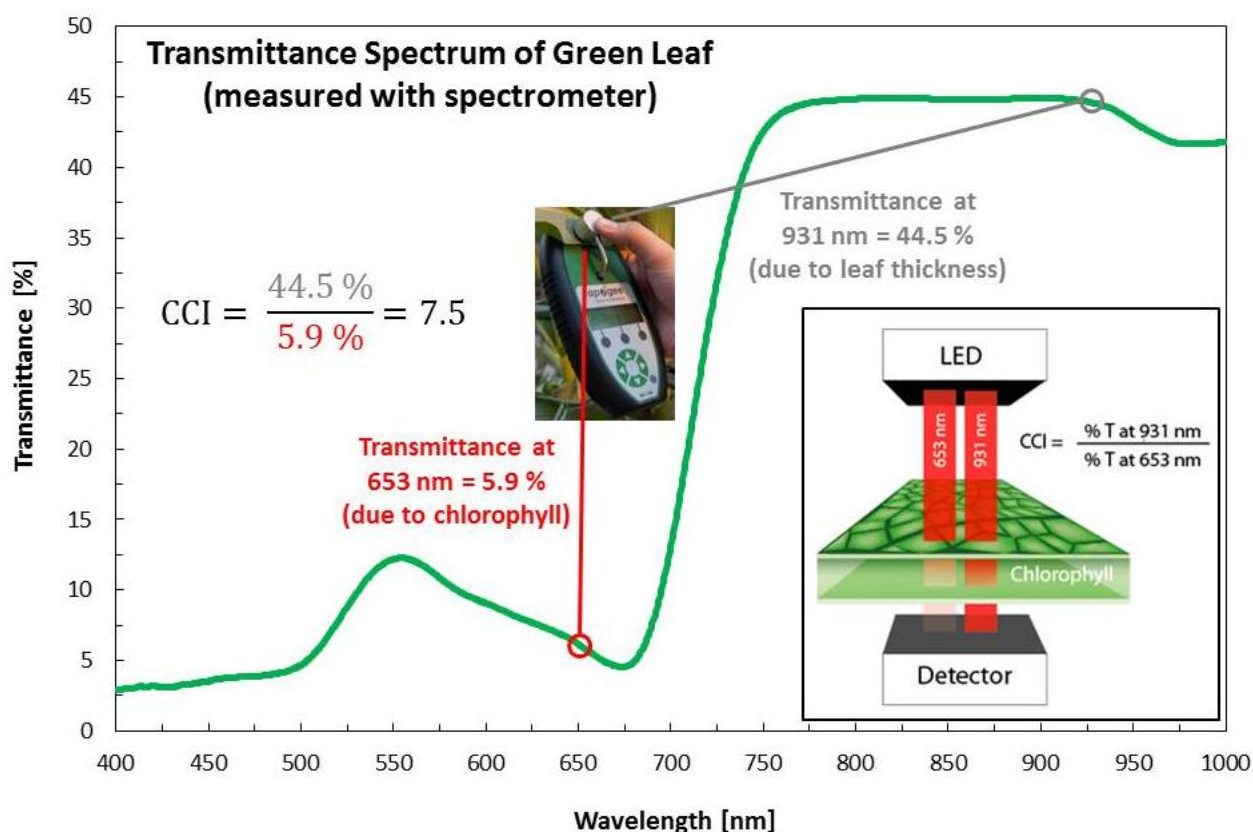
Auto-Off Interval: 4 minutes (with no key press or download)

Dimensions: 152 mm length, 82 mm width, 25 mm height

Mass: 210 g

THEORY OF OPERATION

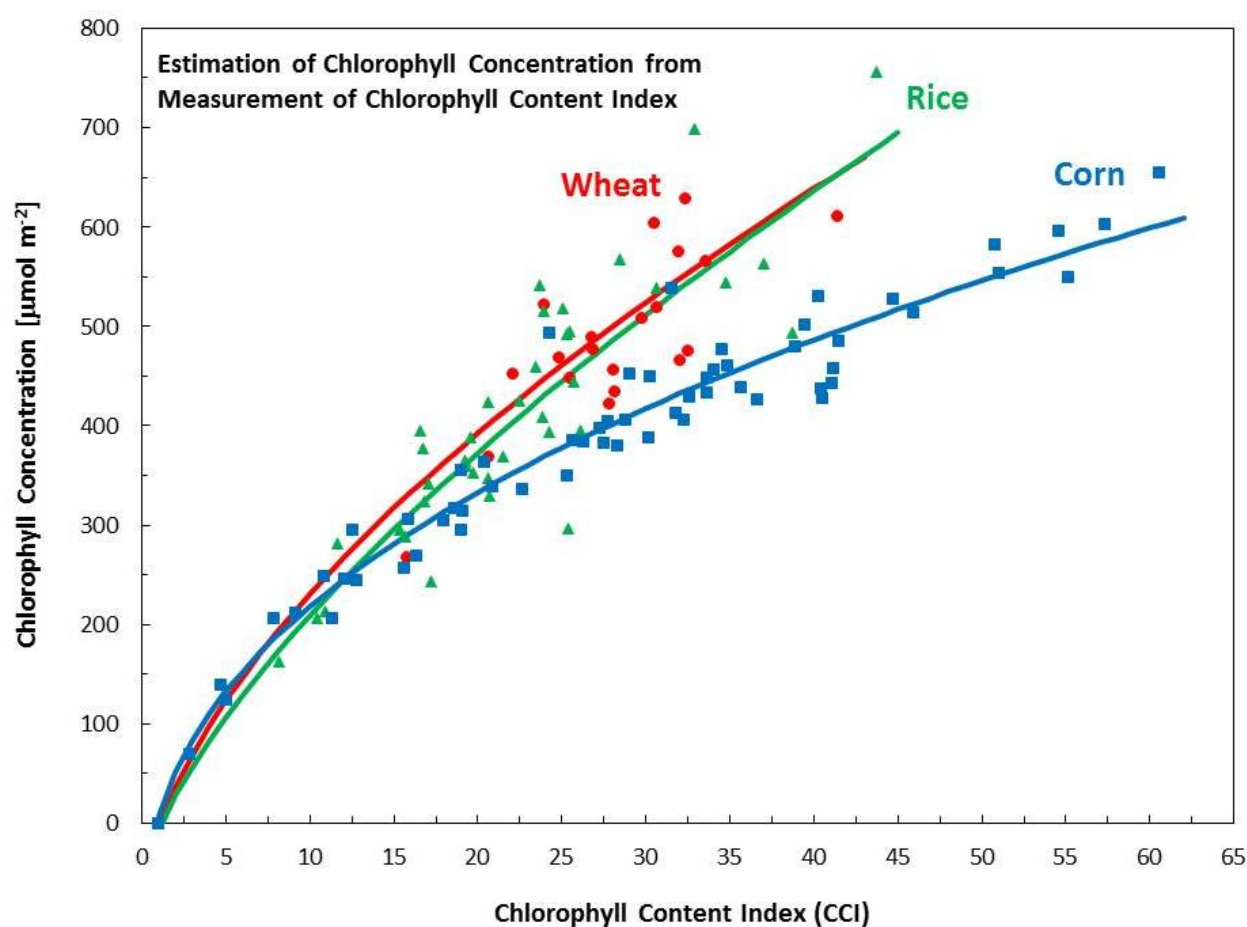
Radiation that drives photosynthesis in plants is called photosynthetically active radiation (PAR). PAR is typically defined as radiation in the 400-700 nm range, the visible wavelengths. Chlorophyll has distinct radiation absorption characteristics and is a strong absorber of all photosynthetically active wavelengths. However, it does not absorb quite as much green radiation as it does blue and red radiation, thus more green radiation is reflected from or transmitted through leaves. This is what gives leaves their green color, and this feature shows up as a characteristic hump near 550 nm in a leaf transmittance spectrum (or reflectance spectrum; leaf reflectance and transmittance spectra are very similar). Chlorophyll absorbs very little radiation at wavelengths greater than 700 nm, thus there is a sharp transition from low to high transmittance near 700 nm (see leaf transmittance spectrum in figure below). This characteristic feature of a leaf transmittance spectrum is called the red edge, where radiation of wavelength greater than approximately 700 nm, termed near infrared (NIR), is not used for photosynthesis.



The Apogee Instruments MC-100 chlorophyll concentration meter exploits the different absorption characteristics of chlorophyll at different wavelengths to determine relative chlorophyll content. Radiation from two light emitting diodes (one centered at 653 nm and one centered at 931 nm) is passed through a leaf sample and intensity is measured by paired detectors to determine transmittance (see inset in lower right-hand corner in graph above). The ratio of transmittance at 931 nm to transmittance at 653 nm provides a measure of relative chlorophyll content because 653 nm is a photosynthetically active

wavelength within the chlorophyll absorption range and 931 nm is a near infrared wavelength outside the chlorophyll absorption range, which serves as a reference measurement to compensate for mechanical differences between leaves (e.g., tissue thickness). The ratio of transmittance at 931 nm to 653 nm is termed chlorophyll content index (CCI). A CCI measurement near one indicates similar transmittance of red and NIR radiation, thus little to no chlorophyll in the leaf sample. A CCI measurement greater than one indicates less transmittance of red radiation relative to near infrared radiation (for example, see CCI values calculated from leaf transmittance spectrum in graph above), with larger ratios indicating more chlorophyll.

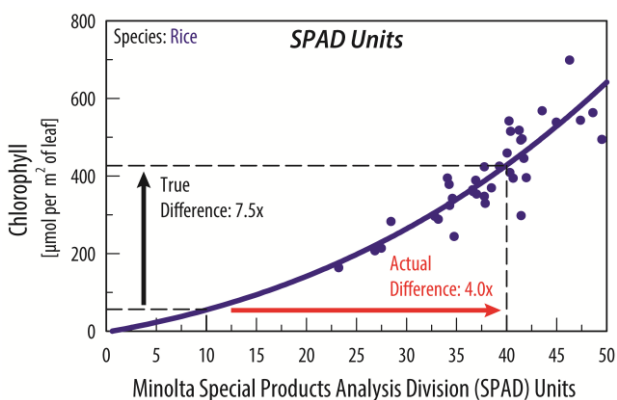
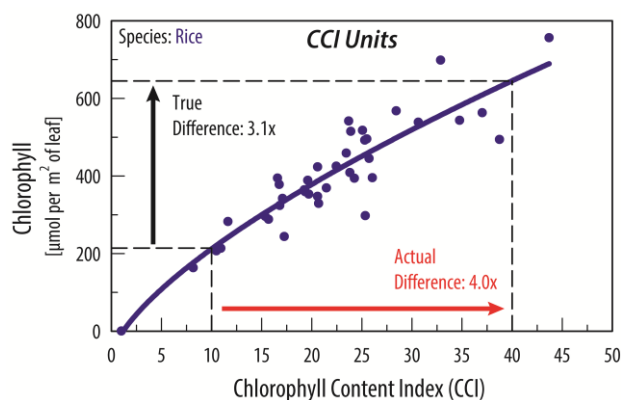
The MC-100 chlorophyll concentration meter is unique in that it converts CCI, a relative measure of chlorophyll content, to an estimate of actual chlorophyll concentration. There is a non-linear relationship between CCI and chlorophyll concentration, and the relationship is different for different plant species (see relationship for three different crop species in figure below). The MC-100 includes equations with species-specific coefficients for twenty-two different species (see table below), an equation with generic coefficients derived from data for all twenty-two species, and an equation to convert CCI to SPAD units (SPAD is the output from a similar chlorophyll meter manufactured by Minolta). As custom coefficients for additional species are generated, they can be added to the database in the meter by Apogee.



Species for which chlorophyll concentration can be directly determined with MC-100

All Species	Generic Equation (used for species not listed below)
Annual Crop Species	Rice
	Wheat
	Soybean
	Barley
	Pepper
	Tomato
	Pea
	Kohlrabi
	Lettuce, cultivar Waldman's Green
	Lettuce, cultivar Buttercrunch
	Corn
	Sorghum
Deciduous Species	Quaking Aspen
	European Birch
	Paper Birch
	Crimson King Maple
	Norway Maple
	Japanese Maple
	Boxelder
	Crab Apple
	Purple Leaf Sand Cherry
	Lilac
	Forsythia

A major advantage of the Apogee Instruments model MC-100 over other hand-held chlorophyll meters is conversion of relative chlorophyll content to actual chlorophyll concentration (i.e., **linearization of the output**). Chlorophyll meters typically output an index that is non-linearly related to chlorophyll concentration (e.g., CCI or SPAD). The MC-100 outputs an estimate of actual chlorophyll concentration in units of $\mu\text{mol per m}^2$ of leaf surface, thus changes in the displayed output are true changes in chlorophyll concentration. For example, a doubling of measured chlorophyll concentration represents an actual doubling in a plant leaf, whereas a doubling of a relative index does not necessarily represent a doubling of actual chlorophyll concentration in the leaf. This concept is illustrated for CCI and SPAD index measurements on rice leaves in the graphs below.



OPERATION AND MEASUREMENT

Apogee Instruments model MC-100 chlorophyll concentration meters consist of two light emitting diodes with paired detectors located in the sampling head, liquid crystal display (LCD), operation buttons, 9 V alkaline battery, and signal processing circuitry mounted in a plastic housing. The meter also includes a USB port for data download to a computer and RS-232 port for use with GPS.

The operational buttons consist of three menu selection keys and four arrow keys to make adjustments to menu functions.



Press the power button to turn on the MC-100. After a few seconds the main menu screen appears. Program flow is organized into three menu groups. The selectable options are **Run** – used to set up and take measurements, **Data** – allows access and downloading of data files, and **System** – used to set up functional features of the meter and view system diagnostics.

Measurements

Jan 1		
00:00:00		
Run	Data	System

From the main menu select **Run**.

Test Menu		
Measure	Back	Setup

Select **Measure** to perform measurements with the MC-100 and **Setup** to make adjustments to data files, test types, and measurement parameters. Select **Back** to return to the main menu.

Run → Setup: Data Files

MC-100 Test Setup	
Save Data	[Yes]
Data File	[MCDATA01]
Exit	Edit

The user can choose to save a data file to memory in addition to naming the file. Select **Edit** to highlight the **Save Data** option. Pressing the up and down arrows will toggle between **Yes** and **No**.

While still highlighted, press the right arrow to enter the File Name Manager. This feature allows the user to select, rename, or create a new data file. Press the up and down arrows to rotate through the following menu options: Use an existing file, Use date as name, Edit default name, Enter a new name. Select **Accept** while the appropriate option is highlighted. A default file will already exist (i.e. MCDATA01), but additional files may be designated using uppercase letters A-Z and/or numbers 0-9. Note that a newly created data file will not appear in the list of existing data files until a measurement is saved to it. The total number of data files is indefinite, as the limit is dependent on available memory.

Run → Setup: Test Types

[1 point no averaging]	
Average ## points [30]	
Record point data [No]	
Exit	Edit

[multi-point average]	
Average ## points [30]	
Record point data [No]	
Exit	Edit

[multi-point std dev]	
Average ## points [30]	
Record point data [No]	
Exit	Edit

There are three test types to select for measurements: 1 point no averaging, multi-point average, and multi-point std dev. A **1 point no averaging** will save every data point to the data file (the parameters Average ## points and Record point data are not applicable with the single point option). **Multi-point average** will record an average of 2 to 30 samples, depending on the Average ## points selected. Selecting **No** under **Record point data** will only save the averaged value, while selecting **Yes** will save all data points in addition to the average value. **Multi-point std dev** will only allow averaging from 10 to 30 samples and will record the standard deviation from these samples. Selecting **No** under **Record point data** will only save the standard deviation value, while selecting **Yes** will save all data points in addition to the standard deviation value. Note that if the difference between measurements is greater than two

standard deviations, the instrument automatically eliminates the outlier and requires an additional measurement.

Select **Edit** and use the up and down arrows to toggle to the appropriate test type and test type options. Pressing the right arrow will advance the highlighted option to the next.

Run → Setup: RS-232 Option

Data Echo Output	[Off]
GPS Data Logging	[Off]
Exit	Edit

The MC-100 includes an RS-232 (serial) output that is primarily used for GPS connection. Compatible GPS devices must be capable of RS-232 communications and have a 9-pin connector output. Additionally, although the transferring of data files over USB connection is recommended, it is possible to transfer using the MC-100's serial output with a custom serial cable. Contact Apogee technical support for more information on connecting to a GPS device or transferring files over RS-232.

Run → Setup: Custom Measurements

Use custom measurement units [No]	
Units File	[SPAD]
Exit	Edit

As detailed above, the MC-100 is capable of measuring in both units of CCI (relative chlorophyll content) and in $\mu\text{mol m}^{-2}$ (actual chlorophyll concentration). The default is to measure in units of CCI whereby the **Use custom measurement** units is set to **No**. For measurements reported in units of $\mu\text{mol m}^{-2}$, select **Edit** to highlight the **Use custom measurement** units. Use the up or down arrow to change the setting to **Yes** and then press the right arrow to select the appropriate species-specific file.

The following tables provide names of specific species and the corresponding file name that appears in menu. The subsequent data file will also include a four letter notation to help track the species selected during measurement. The generic option will calculate chlorophyll concentration from an equation that was fit to CCI and chlorophyll measurements from all species combined. There is also an option that converts CCI to SPAD, where SPAD units are the output from chlorophyll meters manufactured by Minolta.

	Function	Menu Name	Data File Notation
Conversion to SPAD	Converts CCI to SPAD	SPAD	Spad
Combined Species	Generic (equation fit to all data)	GENERIC	Gnrc

	Species Name	Menu Name	Data File Notation
Annual Crop Species	Rice	RICE	Rice
	Wheat	WHEAT	Whet
	Soybean	SOYBEAN	SyBn
	Barley	BARLEY	Baly
	Pepper	PEPPER	Pepr
	Tomato	TOMATO	Tomt
	Pea	PEA	Pea
	Kohlrabi	KOHLRABI	Klrb
	Lettuce – Waldman’s Green	WGLETTUC	WGLt
	Lettuce – Buttercrunch	BCLETTUC	BcLt
	Corn	MAIZE	Maze
	Sorghum	SORGHUM	Srgm

	Species Name	Menu Name	Data File Notation
Deciduous Species	Quaking Aspen	QKASPEN	QkAp
	European Birch	EUBIRCH	EuBr
	Paper Birch	PABIRCH	PpBr
	Crimson King Maple	CKMAPLE	CKMp
	Norway Maple	MWMAPLE	NwMp
	Japanese Maple	JPMAPLE	JpMp
	Boxelder	BOXELDER	BxEI
	Crab Apple	CRBAPPLE	CbAp
	Purple Leaf Sand Cherry	PLSCHERR	PLSC
	Lilac	LILAC	Lilc
	Forsythia	FRSYTHIA	Frsy

Run → Measure: Calibration

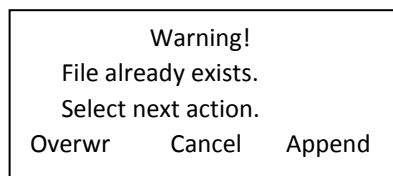
Clear sample area and hold down arm to calibrate. Back	Calibrating. Wait! Status: Busy	Calibrating. Wait! Status: Release Arm
---	--	---

The MC-100 requires a calibration when taking the first measurement after powering on the unit. **Calibration is not required between measurements.** Verify the sample chamber’s optical path is clear and hold down the measuring arm until the **Release Arm** message is displayed.

Run → Measure: Perform Measurement

Sample number: ##### 1 pt ##### Info Exit Delete	Sample number: ##### Ave ####.# Info Exit Delete	Sample number: ##### StDev ####.# Info Exit Delete
--	--	--

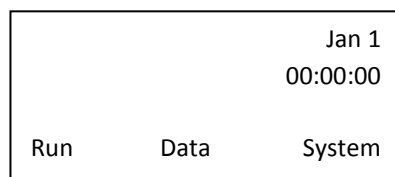
When saving the first measurement to a data table, one of the above three screens will appear, depending on the test type selected. If the data file already holds existing data, the following message will appear. Select **Overwr** to overwrite the existing data in the data file or **Append** to add the next set of measurements to the existing data file. Select **Cancel** to close the menu and start over.



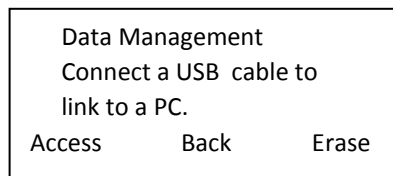
Place the sample under the measuring head making sure the entire measuring area is covered by the sample. Hold down the arm until the screen displays **DONE**. Release the arm and the screen updates with the measured value. When taking measurements in multi-point average or multi-point std dev, a vertical bar will appear on a graph for each data point. The total number of measurements made and the latest measurement value will also display.

An alphanumeric comment, up to 20 characters in length, may be entered for each measurement. After taking the measurement, select **Info** and then **Comment**. Use the arrow keys to customize the field.

Data

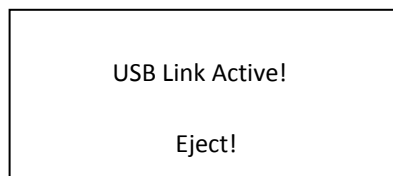


From the main menu select Data.



Connect MC-100 to a PC via USB cable or select **Access** to view data points on screen and **Erase** to delete data files.

Data → Connect to PC



Connect the included USB cable from the MC-100 to a PC (note that any USB cable may be used that has a standard A plug to Mini-B plug). The built-in uSD memory of the MC-100 acts as a flash drive so a storage device window will likely pop up once the connection is made. Select Open folder to view files using Windows Explorer. If the window does not appear, go to My Computer and select the MC-100 drive. Locate the appropriate data files (saved as a .txt file) and copy to the computer's hard drive. **Select Eject before unplugging the USB cable. Do not turn off the PC until the USB cable has been disconnected.**

Data → Access: View Data On Screen

Data Management		
View	Back	Output

Each data point of each data file may be viewed on screen. Select **View** and use the up and down arrows to select the appropriate data file from the list. Once highlighted, select **View** to enter the file. Use the up and down arrows to sequentially traverse through each data point.

Selecting **Output** provides the option of sending data over RS-232 communications with the use of a custom serial cable. *NOTE: Transferring data files over a USB connection is highly recommended. If USB connection is not available please contact Apogee Instruments technical support for more information on transferring files over RS-232. Select **Back** to return to the main menu.

Data → Erase: Delete Data Files

1 Files	[MCDATA01]
Found	[]
	[]
Cancel	Erase

To delete a data file from the MC-100 memory, use the up and down arrows to highlight the appropriate file. Select **Erase** to delete (note there will be no additional check to verify that highlighted file should be deleted).

System

Jan 1		
00:00:00		
Run	Data	System

From the main menu select **System**.

System settings and diagnostics		
Setup	Back	Diag

Select **Setup** to make adjustments to basic meter functions and **Diag** to view system diagnostics.

System → Setup: Time Stamp

24Hr Time	[00:00:00]
Date	[01/01/2015]
Format	[MM/DD/YYYY]
Exit	Edit

Since a time stamp is recorded with each data point it is important to maintain the correct date and time. Select **Edit** to highlight the hour and use the up and down arrows to adjust setting. Use the right arrow button to advance to minutes, seconds, months, and so forth. Select **Enter** when set.

System → Setup: Operational Functions

Key press beep	[Off]
Auto power Off	[Off]
GPS Baud rate	[4800]
Exit	Edit

By default, the MC-100 will beep every time a key is pressed, in addition to a four minute auto-off feature to help conserve battery power. To turn these features off, select **Edit** to highlight the **Key press beep**. Pressing the up and down arrows will toggle between **Yes** and **No**. Use the right arrow to advance to the next setting.

A specific GPS baud rate is required when communicating with a compatible GPS device. Contact Apogee Instruments technical support for more information on connecting to a GPS device.

System → Setup: Baud Rate Output

Serial port output	
Baud rate [USB]	
Exit	Edit

For communication over RS-232 the appropriate baud rate will need to be set, otherwise USB should be selected. Select **Edit** to highlight the baud rate and use the up and down arrows to adjust.

System → Diag: Meter Diagnostics

The diagnostics section consists of five screens that detail system operation and overall performance. The information provided in the diagnostics section is intended for troubleshooting and/or repair.

Using the Field of View Reducer for Small Leaf Applications:

The field of view reducer (FOVR) accessory reduces the sample chamber area from 63.6 mm² to 19.6 mm², roughly 30% of the original size. Field of view reduction errors were less than 5% for all leaves tested using the steps below.



1. To use the reducer you must calibrate the meter without the reducer installed. Installing the reducer prior to calibration results in the error message:

!! Warning !!
Clean Sample Chamber!

2. Install the FOVR carefully by gently pressing it into place on the meter body side of the sample chamber.
3. You are now ready to make measurements on smaller leaves. Important note: If the meter turns off (preset Auto-off in 4 minutes), you will need to remove the FOVR to repeat steps 1 and 2.
4. To remove the FOVR, carefully use a needle to depress the foam washer and pick out the FOVR from the sample chamber (see image below).



Converting from mg per m² to μmol per m²:

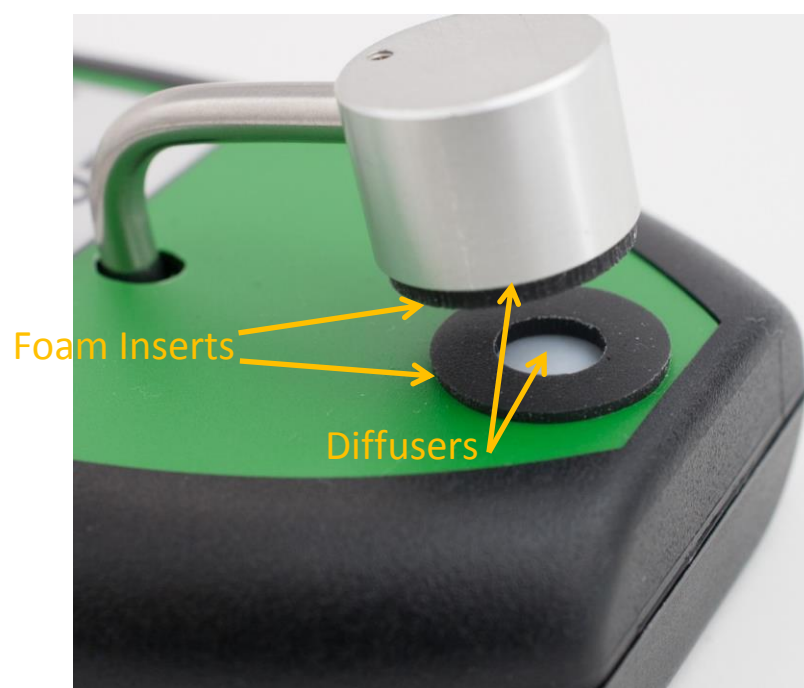
The leaves of higher plants include a mix of both chlorophyll a and b in about a 3 to 1 ratio (Parry et al., 2014). Chlorophyll a has a molar mass of 893.5 grams per mole; chlorophyll b is slightly heavier at 907.5 grams per mole. The typical weighted average mass of both types of chlorophyll in plant leaves is very close to 900 grams per mole (0.9 mg per micromole).

Using this average molar mass you can convert from mg per m² to micromoles per m² by multiplying by 1.11 (1/0.9). For example, a reading of 350 mg per m² is approximately 388.5 μmol per m².

MAINTENANCE AND RECALIBRATION

Moisture or debris on the MC-100 diffusers is a common cause of inconsistent readings. If cleaning is required, organic deposits are best removed using water or isopropyl alcohol and a soft cloth or cotton swab. **Never use an abrasive material or cleaner on the diffusers.**

Over time, the foam insert may become worn or damaged, in which case the unit will need to be returned for repair. Contact Apogee Instruments technical support for more information.



TROUBLESHOOTING AND CUSTOMER SUPPORT

Error Codes and Fixes:

Apogee model MC-100 chlorophyll concentration meters are powered by a 9 V battery. If a meter loses functionality or will not power on try replacing the battery first. Many error codes can be cleared by performing a master reset by removing the 9 V battery, holding down the power switch for 30 seconds, reinserting the battery and powering on the unit. If any of the fixes listed below do not rectify the problem contact Apogee Instruments technical support.

Error Code	Fix
"SD init error Continue"	Perform master reset.
"SD error #xx on command #xx"	
"NV load error Continue"	
"! Error Warning ! File System Corrupt! Perform Format on Unit Continue"	Reconnect the meter to the computer. Go to My Computer, find the MC-100 drive, and right click the drive. Left click Format, and then left click Start. This will reformat the drive and subsequently erase all saved data in uSD memory.
"! nvRAM Init !"	Error code may follow a drive reformat, indicating the system defaults are being restored. Message should clear automatically, otherwise perform a master reset.
"Custom file not found! CCI units will be used"	Message appears if the "Use Custom Measurement Units [Yes]" setting is selected and there are no lookup tables available in uSD memory. Turn feature off to clear the message.
"Warning! Average must be >= 10 pts for std dev mode. A setting of 10 points will be used."	Message appears in standard deviation test mode when number of samples is less than 10. Value must be 10 or greater.
"!! Warning !! Drive is Full"	Clear uSD memory by deleting or downloading data to computer.
"Sample too dense"	Indicates the amount of signal absorbed by the sample is too great for reliable measurements. Try locating to a different part of the sample.
"Hold arm down for whole test!"	Keep sample chamber closed for the duration of the measurement.
"Light Leak!"	Indicates too much light present in the sample chamber. Error may be due to non-flat samples or worn/damaged gaskets surrounding sample chamber.
"Chamber Light Leak!"	Indicates too much light present in the sample chamber. Error may be due to non-flat samples or worn/damaged gaskets surrounding sample chamber.

Error Code	Fix
"Clean Sample Chamber!"	Indicates the light through the chamber is below a certain level, and may be due to dirt on the diffusers or debris in the sample area. Clean chamber as described in section MAINTENANCE AND RECALIBRATION.
"Source/Detector Fail!"	Indicates the unit has detected a fault with one of its sensing components. Perform master reset.
"File is Corrupt!"	Error code may occur after aborting a file transfer to a computer or by removing the 9 V battery instead of using the power switch to turn off the unit. Perform master reset.

RETURN AND WARRANTY POLICY

RETURN POLICY

Apogee Instruments will accept returns within 30 days of purchase as long as the product is in new condition (to be determined by Apogee). Returns are subject to a 10 % restocking fee.

WARRANTY POLICY

What is Covered

The Apogee Instruments MC-100 Chlorophyll Concentration Meter is warranted to be free from defects in materials and craftsmanship for a period of one (1) year from the date of shipment from our factory. To be considered for warranty coverage an item must be evaluated either at our factory or by an authorized distributor.

What is Not Covered

The customer is responsible for all costs associated with the removal, reinstallation, and shipping of suspected warranty items to our factory.

The warranty does not cover equipment that has been damaged due to the following conditions:

1. Improper installation or abuse.
2. Operation of the instrument outside of its specified operating range.
3. Natural occurrences such as lightning, fire, etc.
4. Unauthorized modification.
5. Improper or unauthorized repair.

Please note that nominal accuracy drift is normal over time. Routine recalibration of sensors/meters is considered part of proper maintenance and is not covered under warranty.

Who is Covered

This warranty covers the original purchaser of the product or other party who may own it during the warranty period.

What We Will Do

At no charge we will:

1. Either repair or replace (at our discretion) the item under warranty.
2. Ship the item back to the customer by the carrier of our choice.

Different or expedited shipping methods will be at the customer's expense.

How To Return An Item

1. Please do not send any products back to Apogee Instruments until you have received a Return Merchandise Authorization (RMA) number from our technical support department by calling (435) 792-4700 or by submitting an online RMA form at www.apogeeinstruments.com/tech-support-recalibration-repairs/. We will use your RMA number for tracking of the service item.
2. Send all RMA sensors and meters back in the following condition: Clean the sensor's exterior and cord. Do not modify the sensors or wires, including splicing, cutting wire leads, etc. If a connector has been attached to the cable end, please include the mating connector – otherwise the sensor connector will be removed in order to complete the repair/recalibration.

3. Please write the RMA number on the outside of the shipping container.
4. Return the item with freight pre-paid and fully insured to our factory address shown below. We are not responsible for any costs associated with the transportation of products across international borders.
5. Upon receipt, Apogee Instruments will determine the cause of failure. If the product is found to be defective in terms of operation to the published specifications due to a failure of product materials or craftsmanship, Apogee Instruments will repair or replace the items free of charge. If it is determined that your product is not covered under warranty, you will be informed and given an estimated repair/replacement cost.

Apogee Instruments, Inc.
721 West 1800 North Logan, UT
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OTHER TERMS

The available remedy of defects under this warranty is for the repair or replacement of the original product, and Apogee Instruments is not responsible for any direct, indirect, incidental, or consequential damages, including but not limited to loss of income, loss of revenue, loss of profit, loss of wages, loss of time, loss of sales, accrual of debts or expenses, injury to personal property, or injury to any person or any other type of damage or loss.

This limited warranty and any disputes arising out of or in connection with this limited warranty ("Disputes") shall be governed by the laws of the State of Utah, USA, excluding conflicts of law principles and excluding the Convention for the International Sale of Goods. The courts located in the State of Utah, USA, shall have exclusive jurisdiction over any Disputes.

This limited warranty gives you specific legal rights, and you may also have other rights, which vary from state to state and jurisdiction to jurisdiction, and which shall not be affected by this limited warranty. This warranty extends only to you and cannot be transferred or assigned. If any provision of this limited warranty is unlawful, void or unenforceable, that provision shall be deemed severable and shall not affect any remaining provisions. In case of any inconsistency between the English and other versions of this limited warranty, the English version shall prevail.

This warranty cannot be changed, assumed, or amended by any other person or agreement.

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