

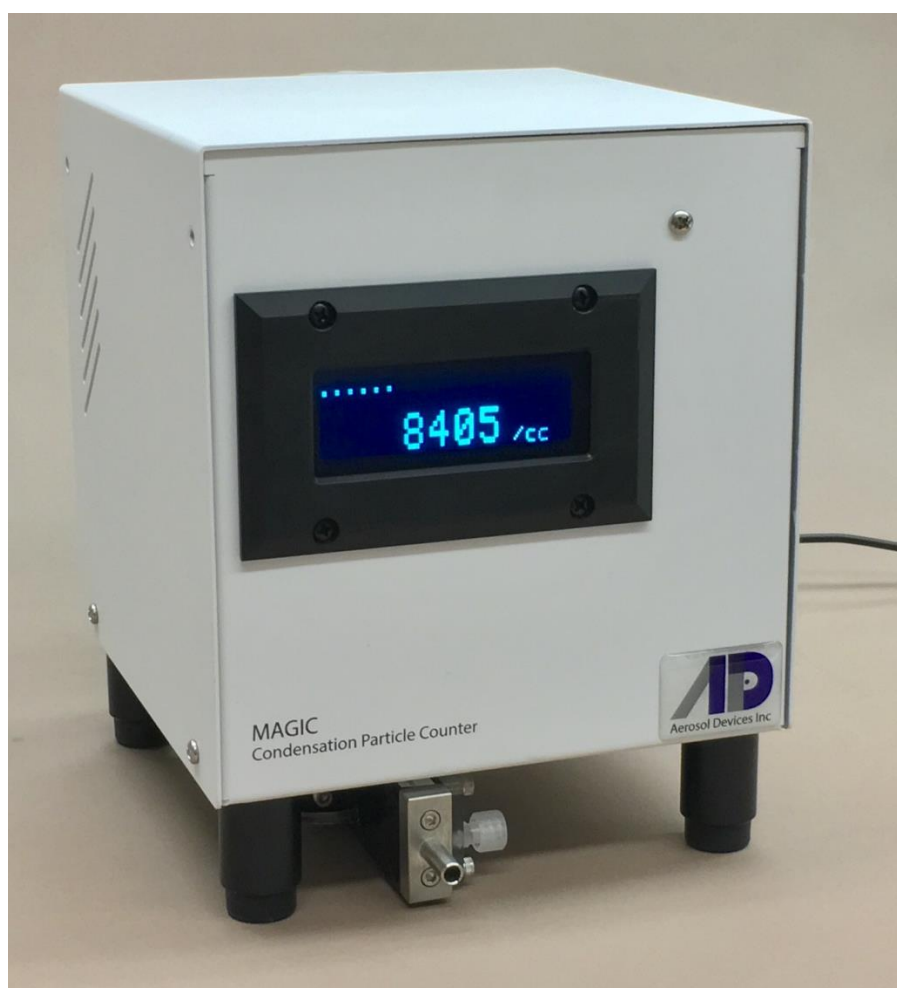
OPERATING MANUAL

MAGIC™ 200/210

Water –Based Condensation Particle Counter

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1 OVERVIEW

1.1 Components:

MAGIC™-200/210 water-based condensation particle counter and collector
Wick-wetting fixture
12 VDC power supply
Inlet Humidifier with water bottle
Optional bracket, battery and battery charger for autonomous operation

1.2 Specifications:

Measured parameter: airborne particle number concentration
Particle size range: ~5 nm to 2.5 µm
Sample flow rate: nominal 300 cm³/min
Transport flow rate: nominal 100 cm³/min
Averaging time: user selectable between 1 second to 30 minutes
Operating fluid: distilled water (grocery store quality OK)
Communications: RS-232 and USB, digital pulse BNC
On board data storage: 131072 records, approximately 1 week of 5-s averaged data
Orientation: insensitive to tipping, shock or vibration. Upright orientation recommended for long-term operation.
Weight: 2.4 kg, with humidifier and power supply.
Dimensions: LWH 18.5 cm x 16.5 cm x 21 cm

1.3 Theory of Operation:

The MAGIC™ CPC is a condensation particle counter, in which the acronym “MAGIC” stands for Moderated Aerosol Growth with Internal water Cycling.

The MAGIC™-200/210 is a self-sustaining, water-based condensation particle counter that utilizes a three-stage “moderated” condensational growth system (Hering et al., 2014), with a continuous wick. As in all condensational particle counters, the MAGIC™-200/210 enlarges ultrafine particles through condensation and then detects them optically. Unlike conventional counters, the MAGIC™-200/210 has no internal water reservoirs, and thus it tolerates tipping and vibration. Once the wick is wetted it operates using water that is extracted from the sampled air stream or is recovered internally within the wick. If operated with the Inlet Humidifier, it will sustain many weeks of operation without servicing.

Condensational growth is provided by the growth tube. This consists of a single, wet-walled channel with laminar flow passing through three temperature regions. During operation the sampled aerosol is first cooled and humidified by the conditioner stage. Flow then passes into the warm, wet-walled initiator stage where it becomes supersaturated, initiating condensational

growth. This supersaturation is created due to the diffusive transport of water vapor from the warm, wet initiator walls, which occurs more rapidly than the flow warms. The higher the temperature difference between the initiator and conditioner stages the higher the supersaturation, and the smaller size of particle size that may be activated. Condensational growth continues in the subsequent cooler moderator stage, which removes both water vapor and heat while maintaining the supersaturated conditions.

The three-stage approach, combined with a continuous wick, provides for internal cycling of water within the growth tube. With the continuous wick spanning all three sections, water condensing in the cooled moderator and conditioner sections is carried to the warmed initiator section via capillary action. This passive recycling allows extended operation without the need to replenish the wick. As the maximum supersaturation and hence instrument performance is independent of the moderator stage temperature, its temperature can be adjusted to control the amount of water vapor carried by the exiting flow. When the water content of the exiting flow matches that at the input, the system can be self-sustaining.

Provided the Inlet Humidifier is attached, MAGIC™ CPC can be operated in a fully self-sustaining mode through control of the moderator temperature. MAGIC™ CPC's moderator temperature is controlled based on the measured input dew point, which errors on the side of letting slightly more water vapor escape with the exiting flow than enters with sample flow. In this mode, the wick will run wet. The MAGIC™ CPC has a small solenoid pump to remove excess wick water.

1.4 Instrument Description

The MAGIC™ CPC system is shown in Figure 1. Components are: (1) an Inlet Humidifier; (2) Inlet Block, which includes a pre-cut; (3) growth tube for condensationally enlarging ambient particles; (4) droplet detection optics; (5) particle counting and control electronics; and (6) an internal manifold containing a pump and flow metering orifices.

(1) Inlet Humidifier: The Inlet Humidifier is mounted on the inlet to increase the inlet humidity. The Inlet Humidifier consists of a 2.7 cm length of Nafion® membrane tubing, surrounded by water, which partially humidifies the incoming airstream, and allows for at least seven days of operation. The Inlet Humidifier's water reserve is a bottle on the back of the unit.

(2) Inlet Block: Preceding the growth tube is the inlet block, which contains a 2.5 µm pre-cut and a port allowing the unit to monitor the sample relative humidity (RH). Tubing leads from this port to a valved quick-disconnect plug in the base of the case. The flow carried in this path is approximately 100 cm³/min and is carried to the RH sensor in the internal manifold. If the plug is disconnected, the RH sensor will pull from the empty socket, and a valve in the plug closes to isolate the Inlet Block. In this configuration, the inlet flow should equal that displayed in the data record.

(3) Growth Tube: The growth tube consists of a single, wet-walled channel with three temperature regions: a cool conditioner; a warm initiator; and a cool moderator. The wetted walls are provided by a continuous wick that spans all three temperature stages. The wick is formed from rolled membrane filter media (Durapore DVPP). The temperatures of each region are maintained by individual thermo-electric devices (TEDs) that share a common heat sink. The heat sink is cooled by ducted case ventilation.

During the operation the sampled aerosol becomes supersaturated, initiating condensational growth as the aerosol passes from wet-cold conditioner stage into the warm, wet-walled initiator stage. The flow is laminar. Condensational growth continues in the subsequent cooler moderator stage, which removes both water vapor and heat while maintaining the supersaturated conditions.

With a continuous wick spanning all three sections, water condensing in the moderator and conditioner is carried to the initiator via capillary action. This passive recycling allows extended operation without the need to replenish the wick. Neglecting the water in the droplets themselves, if the output dew point matches that of the input, the system can be self-sustaining. The moderator temperature is adjusted based on the measured input dew point, erring slightly on the side of accumulating water. Excess liquid is extracted from the bottom of the wick once per minute and ejected into the exiting flow. Only when the dew point downstream of the humidifier (at the inlet to the growth tube), drops below about 10°C will there be a net loss of water, and even under these dry conditions there is sufficient water stored within the wick to maintain operation for 24 hours.

(4) *Optics:* Droplets formed in the growth tube pass through a nozzle and are detected in the optics head. This is a forward-scattering architecture, with a folded path for the input laser beam, as shown in Figure 1. The laser is focused at the exit of the nozzle carrying the droplet flow. A collimating lens followed by a cylindrical lens focuses the laser beam, while the position of this assembly relative to the nozzle exit, and the steering by the mirror places the focal point just above the flow nozzle exit. After passing above the nozzle, the incident beam is diverted into a beam dump, and the near-forward scattered light is collected by a pair of condenser lenses onto an avalanche photodetector. Each droplet passing produces a light scattering pulse that is captured by the detector. Typical pulse width is ~1 μ s.

(5) *Particle Counting Electronics:* The detector produces a digital pulse for each detected droplet. A counter records the number of pulses during one sampling period, typically one second. Another counter measures the dead time, which is the fraction of time the system is busy detecting one droplet and therefore unavailable to detect a coincident droplet. The effective dead time is larger than this measured dead time, due to the finite threshold for particle detection. The “live time” is then the effective dead time fraction subtracted from unity. The reported number concentration is calculated using the measured counts, measured flow rate, the live time fraction, and the sampling period. The digital output on the BNC connector on the back of the instrument produces a positive, 5 volts signal for each detected droplet.

(6) *Flow System:* As shown in Figure 2, air enters the humidifier at approximately 0.4L/min. At the inlet block, a 0.3 L/min aerosol flow is directed through the growth tube and optics, and a 0.1 L/min transport flow is sent to the temperature-humidity sensor. Aerosol flow exiting the optics passes through a coalescing filter and a pair of orifices to the pump. The aerosol flow is inferred from the pressure drop across the upstream (metering) orifice. The transport flow is directed inside the case through a clip-lok connector, to the temperature-relative humidity sensor, through an orifice, and to the pump. The T/RH sensor, orifices and pump are contained within the manifold. The pump is operated at constant power, and the flow split between the aerosol and transport flows is determined passively.

(7) *Storage Preparation Button:* The valves on the ejection pump can stick if stored dry for a long period of time. There is a button on the back that is used to wet the pump in preparation for long term storage. See section 7.1.

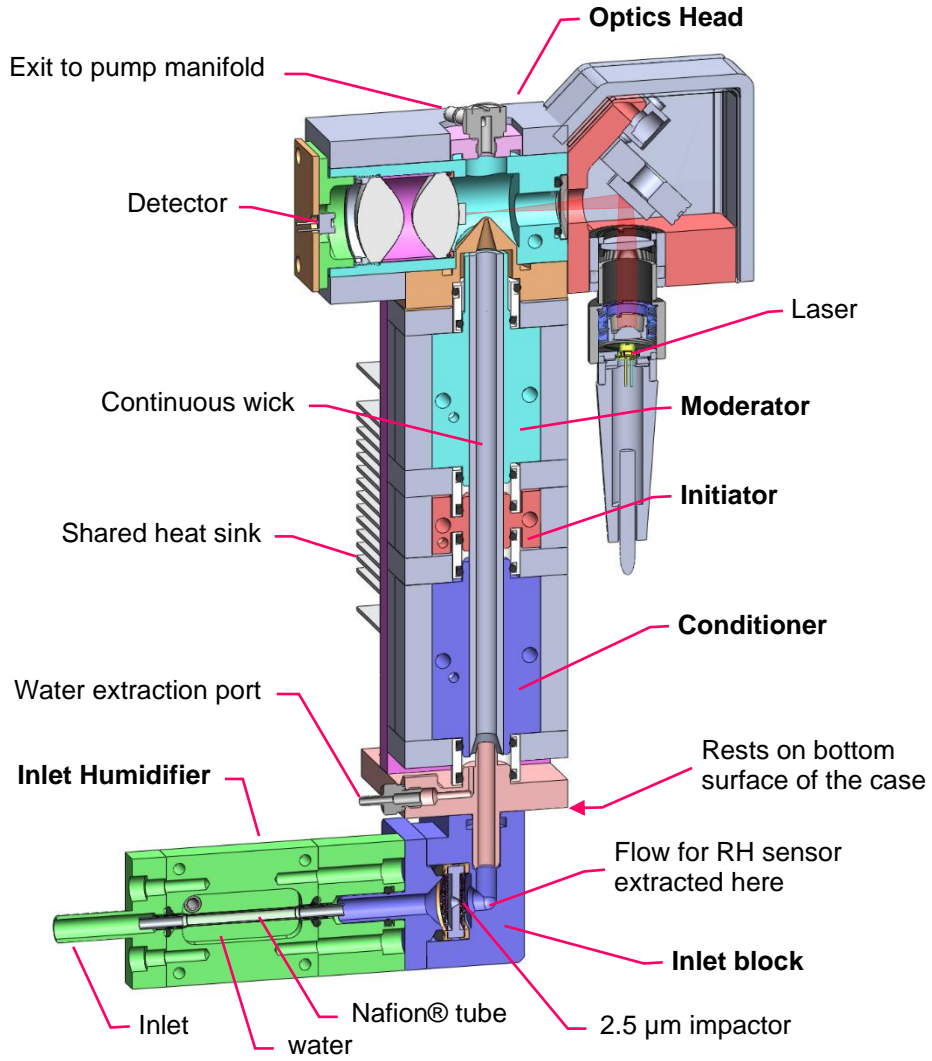


Figure 1: Diagram showing Inlet Humidifier, Growth Tube, and Optics Head.

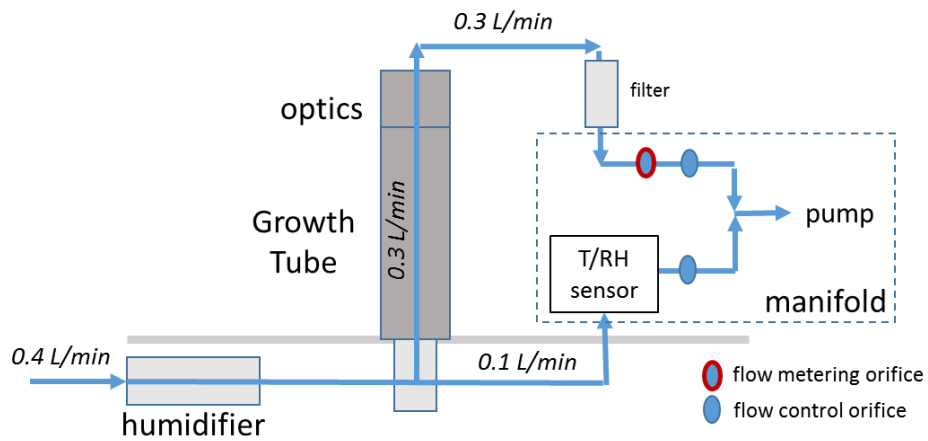


Figure 2: Flow Diagram for MAGIC™ CPC

2 OPERATION

2.1 Basic Set-up

- Wet the wick, as described in Section 4.
- Prepare the Inlet Humidifier, and attach it to the inlet, as described in Section 3.
- Supply 12V DC via the connector in the back.
The pump should turn on after ten seconds provided the optic head is at least 5 degrees above the moderator temperature. Pump should turn on after sixty seconds regardless of optics and moderator temperature.
- Error/status codes are displayed in the upper left side of the screen as the system comes to temperature. Although counts will display once the pump starts, these may not be accurate until the conditioner and initiator have come to temperature, which typically takes about 4 minutes.

2.1.1 Serial Communications:

Serial communications allow the operator to log data, adjust data reporting interval, and change system operating parameters.

Serial communications can be established through either the RS-232 or the USB connections on the back panel of the instrument. The system can also be connected to the internet using a serial to ethernet converter such as the NET232+ by gridconnect.com.

If connecting via the USB to a PC running an operating system prior to Windows 10, then you need to first download the USB driver. The USB uses an FTDI (FT232R) serial interface chip, and the “VCP” (virtual comport) driver may be found at

<http://www.ftdichip.com/Drivers/VCP.htm>

Open serial communications using a PC running a terminal emulator such as Hyperterminal or TeraTerm, or another device capable of serial communication. Communications settings are:

Baud rate:	115200
Bits:	8
Stop bits:	1
Parity:	none
Flow Control:	none

2.1.2 Recommended terminal settings:

Send/receive “CR” and “No Local Echo”

2.1.3 Data Record:

The data output record is comma-separated ASCII, and includes both particle concentrations, and various operating parameters including temperatures, flows, particle counts and dead time. Data may be streamed to the serial port or saved to internal flash at a user settable interval of 1 to 2000 seconds. The reported concentrations, counts, flows, live time and dead time are average

values over the reported interval, but the temperatures and pressures are the value during the last second of the interval.

An example record is (line breaks added for clarity):

```
2018/06/14 17:58:54, 12466,
20.8, 25.5, 75.0,
10.5, 45.6, 18.8, 39.9, 28.6, 31.1, 27.2,
12.0, 38.3, 998, 289,
2, 8697, 1146, 104438, 105395,
0000, . . . . ., 043
```

Fields are (grouped by lines shown above):

CPC datetime, internal date and time at the start of the sampling interval.

Ncc, Particle number concentration in #/cm³

DPin, Dew point at the inlet, calculated from Tin and RHin

Tin, Temperature at the RH sensor, after humidifier if used

RHin, Relative humidity at the RH sensor, after humidifier if used

Tcon, Temperature of the conditioner (1st) stage

Tini, Temperature of the initiator (2nd) stage

Tmod, Temperature of the moderator (3rd) stage

Topt, Temperature of optics head

Thsk, Temperature of the heat sink (reference when in relative mode)

Tpcb, Printed circuit board temperature

Tcab, Cabinet Temperature

PSVult, Supply voltage (useful if operating on battery)

dPres, Differential pressure (mbar) across flow monitoring orifice

Pabs, Absolute pressure, mbar

Qccm, Flow rate in cm³/min

Interval time, number of seconds elapsed in counting interval

Corrected Live Time, as fraction of interval * 10000

Measured dead time, as fraction of interval * 10000

Raw Counts at lower detection threshold.

Raw Counts at higher detection threshold.

Flags: Error/status codes, (hexadecimal).

FlagC, character translation of some error codes

Serial Number

2.1.4 Hexidecimal Error/Status Codes:

Bit 0	00001:	conditioner temperature out of range
Bit 1	00002:	initiator temperature out of range
Bit 2	00004:	moderator temperature out of range
Bit 3	00008:	optics temperature out of range (not critical to performance)
Bit 4	00010:	Laser off
Bit 5	00020:	Pump off
Bit 6	00040:	RH data is stale (i.e. not updated since last read)*
Bit 7	00080:	I2C communication error (pressure and RH sensors use the I2C bus)*
Bit 8	00100:	RH sensor error*
Bit 9	00200:	Unit over heated. TEDs and Optics power turned off until unit is cooled.
Bit 10	00400:	reserved
Bit 11	00800:	Moderator switched to absolute mode after 10 consecutive RH sensor failures.
Bit 12	01000:	water extraction pump was activated
Bit 13	02000:	invalid flash record
Bit 14	04000:	flash full
Bit 15	08000:	FRAM data invalid.
Bit 16	10000:	reserved

* these codes are usually temporary and are corrected one next sensor read, one second later.

The error/status code is a hexadecimal number which is the sum of the numbers in the second column listed above. For example, if the conditioner (00001) and moderator (00004) temperatures are out of range and the pump is off (00010), the code will be 00015. If the conditioner, initiator, moderate, and optics temperatures are all out of range the error code will be 0000F.

The codes with an asterisk* indicate an error that is not important unless it persists. These 0040, RH data is stale; 0080, I2C communication error; and 0100, RH sensor error. Usually this means a reading of the RH sensor which occurs once per second, or a reading of one of the pressure sensors which occur four times per second failed. Most often the next reading succeeded. A non-zero code is shown if an error occurs at any time during the logging/recording interval, even if the system recovers immediately. E.g. if one logging or recording data once a minute, one may get an RH data stale error or a temperature out of range error even if the reported value for that interval is correct or in range. Note: the reported concentrations, counts, flows, live time and dead time are average values over the reported interval, but the temperatures and pressures are the value of the last second of the interval.

If the moderator is in relative mode and there are ten or more consecutive RH sensor errors, the moderator control will switch to absolute mode with a set temperature of 15°C. The moderator control will switch back to relative mode when the RH sensor returns a valid reading.

Error code 0200 indicates the unit overheated. This occurs if the optics temperature exceeds 50°C, the heatsink temperature exceeds 60°C, or the case temperature exceeds 50°C. In this case the laser, TEDS and optic heater will turn off. The MAGIC™ CPC will restart when all three temperatures fall below 40°C.

Error code 0008 (optics temperature) does not indicate a critical problem unless the temperature is below the set point. To conserve power, the default set point (35°C) is substantially lower than the anticipated maximum case temperature of 50°C. In warm conditions, the optics head will drift above this set point without affecting the performance.

2.1.5 Error/Status Characters:

The last field of the data records (recorded to flash or sent over the serial port) shows character codes which are translation of some of the hexadecimal error codes. Each space represents a specific code. The codes are “cimoplh” for conditioner, initiator, moderator, and optics temperatures out of range, pump off, laser off, and relative humidity sensor read failure. If there is not an error a period will be displayed instead: i.e. “.....” The error codes are also displayed on the front screen. On power up almost all the codes will be displayed. After 12 seconds the pump and laser will turn on, typically displaying “cimo..” with each character being replaced by a period as the temperatures become within 1.25 deg C of the set point. If one of the thermistors fails (most often because a thermistor wire is loose), a ‘0’, ‘1’, ‘2’, ‘3’ or ‘4’ will be displayed for the conditioner, initiator, moderator, optics or heatsink thermistor.

‘h’ will be displayed if reading the relative humidity sensor failed. This is often temporary, so the last successful reading will be used for a maximum of 10 consecutive readings. After 10 consecutive failed attempts to communicate with the relative humidity sensor, the serial port data will report zero for the input temperature RH and dewpoint. The moderator will switch from relative mode to absolute mode with a set point of 15°C (tmod,a,15) and the ‘h’ will change to an ‘H’. The mode will change back to relative and the ‘H’ flag will be cleared if the communication with the RH Sensor resumes. If the moderator was in absolute before the ‘H’ will not be displayed.

‘w’ indicates that the water extraction pump was activated. Normally occurs once every 60 seconds.

Additionally, if data is being saved in internal flash memory, the display will show “rec” on the upper right of the front display. The serial data will append “rN” to the character code where N is the record interval in seconds.

2.1.6 On-Board Data Storage:

The MAGIC™ CPC has on-board flash memory for capturing and storing data records. Data recording is actuated through the serial command “rec, n” where “n” is the number of seconds between records. When data are being recorded to the on-board flash memory, an “R” is displayed on the top right corner of the screen. Data continues to be recorded until stopped with the serial command “rec, 0”, or until the memory fills. The flash can hold 131,072 records. Thus, there is enough storage for just over 1.5 days of one second records, and 61 days of one-minute records. Power cycling does not change the state of data recording – if recording when powered down, then it will resume recording when repowered. When recording using on board flash memory, “rec” will be displayed on the upper right part of the display. “rN”, where N is the recording interval in seconds will be appended to the FlagC error/status character codes. Data

recording can be done simultaneously with serial output, and the time intervals may be different. Stored data is downloaded through the serial port (see Section 2.2), and the format of the data stream is the same as for the serial output. Serial commands for data recording, memory download and erasing stored data are outlined in Section 2.2

2.2 Serial Commands

Commands are not case sensitive. Spaces are ignored. Commands that take a parameter will display current value if no parameter is given.

2.2.1 Help Commands

?	displays help messages for help commands
d? or l?	display help messages for optics commands (i.e. laser and detector)
m?	display help for miscellaneous commands
q? or f?	display help for flow commands
p?	display help for preset commands
r?	display help for recording (flash) data
t?	display help for temperature commands

2.2.2 Logging & Miscellaneous Commands

Log[,N]	output ASCII data every N secs, "Log,0" turns off. $0 \leq N \leq 2000$.
Log,0	stops data logging
Log,2	data logged every 2 seconds
Logadj,N	delay log next output by N seconds
Logadjms,N	Delay log output by N milliseconds
Logf [, (0 1)]	Log at high frequency (16,32, or 64 Hz). Toggles hi frequency logging if no parameter.
Logsf, (16 32 64)	Set high frequency logging interval to 16, 32 or 64 Hz. Does not start logging.
ejp,N	Set water ejection period, number of seconds
poll	Returns most recent one second concentration
svs	Save current settings.
scant,[0 1]	Scan between preset temperatures. (see presets details).
sflow,N	Use N cc/min as flow value instead of stored value. Does NOT survive power cycling.
clrsettings	Clear current settings. Will change to factory defaults on power cycling.
hdr	Displays a header describing the data output
rtc, yy/mm/dd	Sets Real time clock, enter two-digit year/month/day.
rtc, hh:mm:ss	Sets Real time clock, enter hour:minutes:second.
ver or rv	returns software version and instrument serial number

2.2.3 Detector and Laser Commands

dthr, N	set detector threshold to N millivolts ($0 \leq N < 800$)
dthr2,N	set upper detector threshold to N millivolts ($0 \leq N \leq 4000$)
doff,N	Set detector offset to N milli-volts ($0 \leq N \leq 400$)
dvlT,N	Set detector voltage to N volts ($0 \leq N \leq 100$)
Lasr,0	turn laser off

Lasr,1	turn laser on
Lcur	display laser current
Lset, N	Set laser power to N microwatts ($0 \leq N \leq 6553$)
sod	Do not use. Set optics to default. (This is not unit specific, and may be different from the 'factory default')

2.2.4 Flow Commands

pmp,1	Turn pump on
pmp,0	Turn pump off
qset,n	Set flow, $0 \leq n \leq 255$. arbitrary units, nominally 150
qcf,N or fcf,N	Set flow Calibration factor ($40 \leq N \leq 255$)

2.2.5 Preset Commands

psclr,N	Clear preset N ($0 \leq N \leq 5$)
psdsp,N	Display preset N ($0 \leq N \leq 5$)
psld,N	Load preset N ($0 \leq N \leq 5$)
pssv,N	Save current settings a preset N ($0 \leq N \leq 5$)

2.2.6 Temperature Commands

Tcon	returns current conditioner setting
Tcon,A,10	sets conditioner to 10°C
Tcon,R,-12.5	set conditioner to 12.5°C below Heat Sink Temperature
Tini	returns current initiator setting
Tini,A,45	sets initiator to 45°C
Tini,R,17	sets initiator to 17°C above heat sink temperature
Tmod	returns current moderator setting
Tmod,R,-2	sets moderator to 2°C below lookup value based on Input Dew Point
Tcon[,R,-nn.n ,A,nn.n]	nn.n is in °C, new values are stored. Decimal is optional
Tini[,R,nn.n ,A,nn.n]	"
Tmod[,R,-nn.n ,A,nn.n]	"

2.2.7 Flash Data

Rec,N	save data record to flash every N seconds. $0 \leq N \leq 2000$. $N=0$ turns off recording
Rerase	erase all saved records from flash
Rdrec	displays number of records stored in flash
Rdrec,N	display record number N
Rdrec,N,M	display record numbers N to M inclusive. Numbers start from zero

2.3 Recommended Settings

2.3.1 Storing Settings

“Log” and “rec” commands will persist when power cycling. All other commands will not persist upon power cycling unless the command ‘svs’ (save settings) is issued. To revert to factory settings, issue the ‘clrsettings’ command and then power cycle the unit.

2.3.2 Logging Data

NOTE: As of Firmware version 2.75, The date & time of the logged data is the start of each sampling interval. Previous version reported the time at the end of the interval.

There are two methods of recording data. The first is to record data in real time on a computer connected via the RS-232 serial port or USB. This is done with the 'log, N' command and logging the data on the terminal program. The second method is to use internal flash which can be downloaded later. This is done with the Rec, N command. The data can then be downloaded later over the serial port.

'Log, N' will start at the next even multiple of N. i.e. log,15 will output data when the real time clock is at 0,15,30,45 after each minute.

'Logsf, N' will set the frequency of sampling data but does not start sampling. Issue, set 'log,0' then issue logf to start. Output is "raw counts at lower detection, dead time sample, dead counts, flow rate" at 16, 32, or 64 Hz. The dead counts will be approximately 11500 divided by N. (i.e. within a few counts of 7200, 3600, or 1800). Not the concentration is not reported but can be calculated

'Logf', 'logf,0', 'logf,1'. 'Logf' toggle, turn on or turn off sampling rate set with logsf. Generally 'log,0' should be issued before high frequency sample is turned on.

'Logadj, N' will delay the next data record by N seconds. This can give the user time to see what they are typing, read a help command, or read the data header without having to restart the data records. It can also be used to synchronize the start of multiple MAGIC™ CPC units.

'Rec, N' starts recording data to internal memory. The recording interval can be different from the "Log" N interval. 256K records can be stored. This is just over 3 days of one second data or six months of one-minute data.

2.3.3 Flow control Commands

'qset, N' sets the voltage to the pump determining the flow rate. The flow is not actively controlled. The reported flow is determined by the differential pressure across an orifice. Both the differential pressure and flow are reported in the data records.

'qcf, N' and 'fcf, N' set the flow calibration factor which is used to convert from flow to pressure.

2.3.4 Preset Commands

The six presets store temperature settings, optics settings, and ejection period. There are 5 possible presets. These can be used to store settings that can be easily recalled. The units are shipped with the presets undefined.

'pssv, N' saves current settings as preset N. ($0 \leq N \leq 5$)

``psld,N'` load preset N. Set current settings to stored value.
``psclr,N'` clear (erase) preset N.
``psdsp,N'` display values stored in preset N.

Presets are also used in the scanning mode, where temperatures (and hence lower cut off) can be changed continually. The optics settings may need to be adjusted if the condition-initiator temperature difference is significantly different from the default setting. Scanning Temperatures is an experimental research mode. Contact Aerosol Dynamics if one wishes to use this feature. To use this, all 5 presets must be defined, and the initiator temperature must monotonically increase with the preset number. ``scant,1'` and ``scant,0'` turn scanning mode on and off.

2.3.5 Recommended Temperature Settings

The factory settings for the growth tube temperatures are listed below. Our standard mode of operation is to operate with fixed (absolute) temperature setpoints for the conditioner, initiator and optics head, and relative setpoint for the moderator. The relative moderator setpoint means that the moderator temperature setpoint is calculated from the temperature and relative humidity measurement at the inlet block.

The recommended factory settings are:

<code>TCON,R,-18</code>	<i>sets conditioner to 18°C below heat sink temperature</i>
<code>TINI,R,17</code>	<i>sets initiator to 17°C above heat sink temperature</i>
<code>TMOD,R,-2</code>	<i>sets moderator to lookup table value minus 2 deg (see appendix A).</i>
<code>TOPT,A,35</code>	<i>sets optics to 35°C</i>

These factory temperature settings were used for the system evaluation testing, and should be used when possible. Laboratory testing was not done at ambient temperatures in excess of 35°C, and if the instrument is operated under warmer conditions, some adjustment may be necessary (see below).

2.3.6 Relative and Fixed Temperature Operating Mode

Each of the three stages of the growth tube, the conditioner, initiator and moderator, may be operated in either an absolute or relative temperature mode.

In absolute mode the temperature setpoint is a fixed value, set by the commands `"TCON,A,nnn"`, `"TINI,A,nnn"`, `"TMOD,A,nnn"` for the conditioner, initiator and moderator, respectively, where `nnn` is the setpoint value in degrees Celsius. In absolute mode `nnn` must be a positive number with at most one decimal digit (e.g. `Tcon,a,10.5`).

In relative mode, the temperature setpoint is an offset from a reference temperature. The commands are `"TCON,R,-nnn"`, `"TINI,R,nnn"`, `"TMOD,R,-nnn"`, where the `"R"` indicates relative, and `nnn` is the difference in degrees Celsius between the desired setpoint and the Reference Temperature. For the conditioner, and initiator the Reference Temperature is the temperature of the heat sink. For the moderator, the relative mode is the standard operating mode. The reference temperature is from the Moderator Reference Temperature Lookup Table (given in Appendix A) and uses as input the dew point calculated from the measured input block temperature and relative humidity. This lookup table lists the experimentally determined

temperature setting for the moderator that provides output flow with the same water vapor content as at the inlet, as a function of the input dew point conditions. Since the MAGIC™ CPC has a means to eject excess water, it is acceptable to operate at slightly lower moderator temperatures than listed in the table. Our recommendation is “ $T_{MOD, R} - 4$ ” which sets the moderator to 4°C below lookup table value.

2.3.7 Operation below 10°C:

The instrument needs to be operated in a protected environment, for example, an environmental enclosure, a trailer, or an indoor facility. We recommend keeping the enclosure temperature above 10°C. Once enclosed, the unit’s waste heat will likely keep the instrument itself above 10°C. At a minimum, MAGIC™-200/210 needs to stay above freezing.

The counting efficiency is not affected by cold conditions, but there are a few issues to be aware of when the temperature is below 10°C:

- In relative mode, the conditioner and initiator set points might be automatically raised to keep the conditioner above freezing. The difference in temperature will remain that implied by the settings.
- The humidifier performs less well when cold, causing the wick to dry more quickly. Thus, the wick may require re-wetting within a few days.

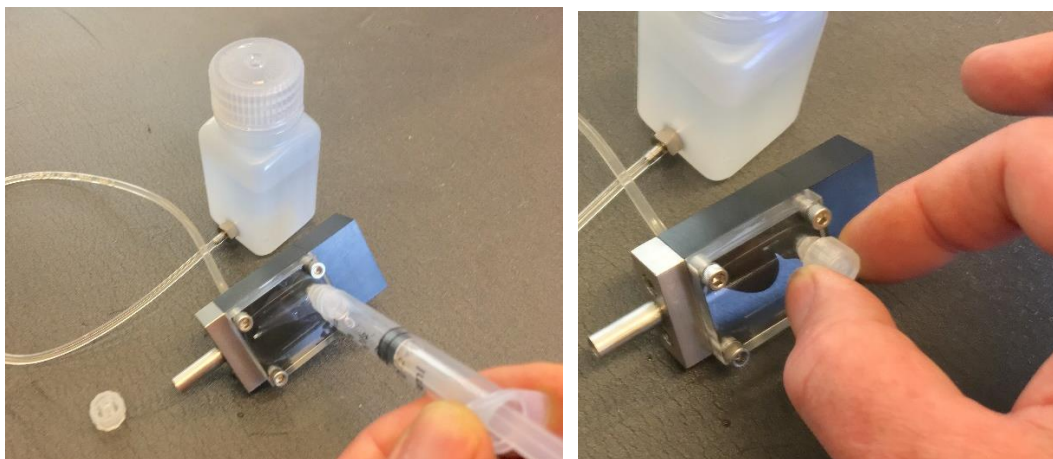
If the unit is powered on in a warm environment immediately following storage in a colder environment, it is possible for condensation to form inside the optics head, resulting in a display of 999,999 #/cc. The unit should recover from this state after a few minutes.

3 PREPARING THE INLET HUMIDIFIER

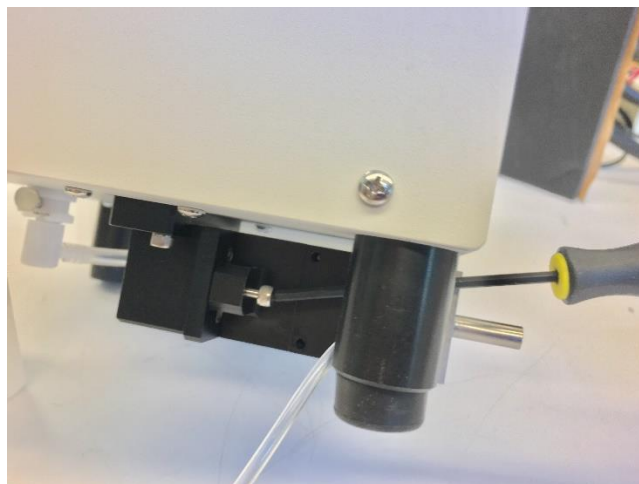
The Inlet Humidifier should be ready to use as shipped. But if you see a lot of air accumulated behind the window, follow these instructions to purge the device.

Fill bottle with distilled water

- Attach bottle to 1/16" barb fitting on Pre-Humidifier
- Remove the cap to the Luer-Lok™ fitting.
- Purge air from the Pre-Humidifier. One can use a syringe as shown, or simply elevate the bottle to push water through the device.
- Replace the Luer-Lok™ cap. Tighten lightly with a dainty touch, as shown in the figure. It seals tighter than you might think.



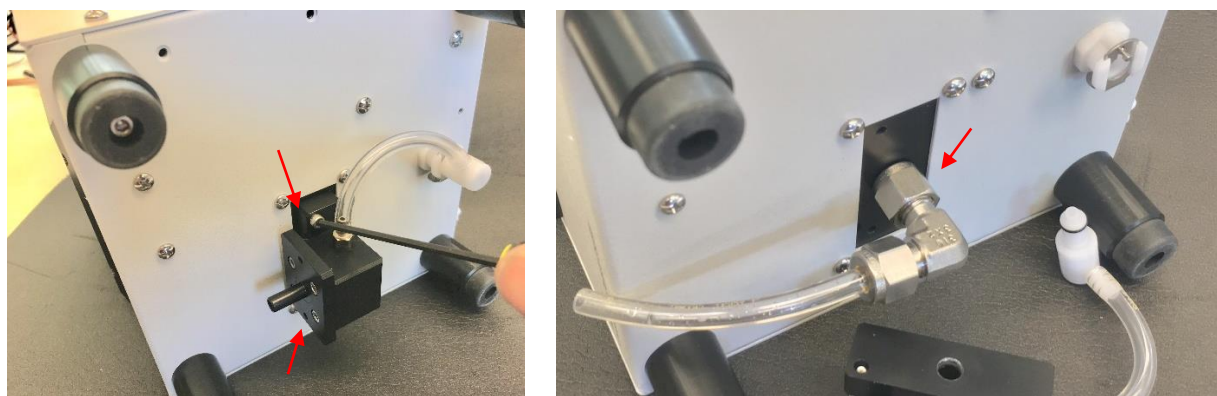
- Check window to ensure Nafion® tube is completely submerged in water.
- Install the Pre-Humidifier onto the Inlet Block by sliding it onto the tube and securing with the captured screw.



4 WICK-WETTING PROCEDURE

The system will stop counting if the wick dries up. Wetting the wick is the easiest way to diagnose if that is the problem.

- Disconnect the power.
- Set the system on its side.
- Disconnect the quick-disconnect plug from the bottom of the unit.
- Use a 7/64" Allen wrench (provided) to release the two screws holding the Inlet Block in place. They will remain captured.
- Pull the Inlet Block directly away from the base of the instrument and set it aside. Expect some friction from the radial o-ring seal.
- Slide the Wick Wetting Fixture (WWF) onto the inlet tube as shown. The fitting has a nylon ferrule which can be gently tightened/loosened as necessary.



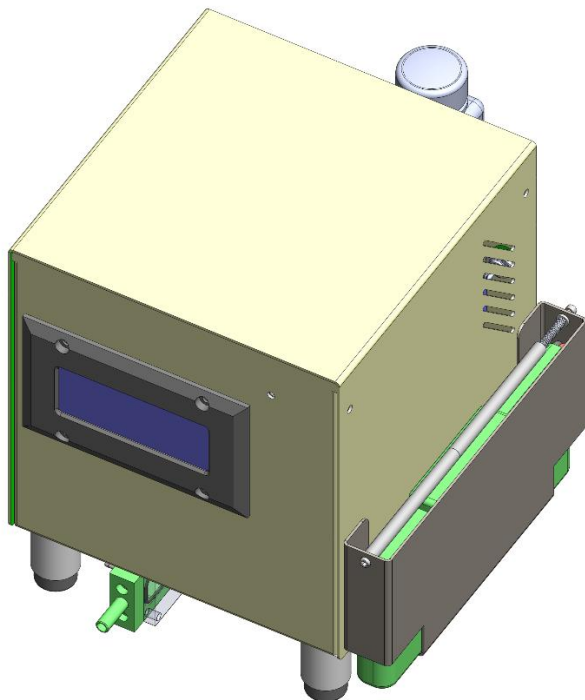
- Set the instrument upright.
- Be sure the unit is powered off.
- Fill a syringe with 3.0 mL of distilled water and attach it to the tubing.
- Inject the water; wait 60 seconds; draw it back out again.



- Disconnect the syringe. When troubleshooting, it can be helpful to note how much water was consumed.
- Remove the WWF, re-attach the Inlet Block, and re-connect the tubing connector.
- The screws attaching the inlet block to the bottom of the instrument need be only gently tightened; they are not compressing an o-ring.

5 ATTACHING THE BATTERY BRACKET

The battery bracket is located on right side of the unit. The bracket is attached to the bottom of the case with 3 Philips-head screws. The wires should exit downward out the rear of the bracket.



6 AUDITING THE AEROSOL FLOW

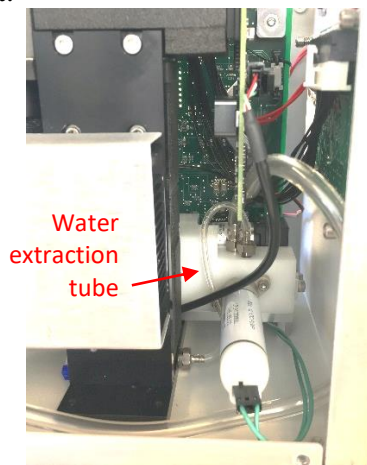
To audit the aerosol flow, disconnect the transport flow at the clip-lok on the bottom side of the instrument. Then place flow meter at the humidifier inlet. Simultaneously, note the flow reading in the serial data output record.

Note: The clip-lok connector contains an automatic shut off valve, so that when disconnected the transport flow is now drawn from the room at the bottom of the case. If measuring an in-line flow with a significant pressure drop to the instrument, then the passive flow split will be altered. Specifically the aerosol flow will drop compared to the transport flow if the transport flow inlet (now at the clip-lok on bottom of the case) However, the aerosol flow reading on the instrument, as compared to that on the inlet flow meter, should agree. If not, use the flow calibration factor may be adjusted using the qcf command (see Table 2.2.4)

7 MAINTENANCE:

7.1 Priming the Water Extraction System

The water extraction system uses a solenoid pump which is self-priming. However, if it completely dries out, its valves can stick. If the unit is to be stored for longer than two months, we recommend fully wetting this pump. This procedure uses the button on the back of the unit. In normal operation, a short press of the button will toggle the pump on and off. Holding the button down for more than five seconds will put the unit into ‘Storage Preparation Mode’ and indicate this status on the display. The only way to exit ‘Storage Preparation Mode’ is to power cycle the unit.



For long term storage, or to test the water extraction system:

- (1) Depress the button for 5 seconds. The air pump should turn off, and the display will show “Storage Preparation Mode”
- (2) Attach the wick-wetting fixture and inject water into the growth tube. This is the same operation as described in first few steps the wick-wetting procedure (Section 4), except that the power remains on.

Take care not to cycle the power while there is water in the growth tube.

- (3) Leaving the syringe depressed, repeatedly press the button. Each press activates the solenoid pump, producing a pair of clicks: a loud one followed by a quieter one.
- (4) After about ten button presses the second click will become very quiet, indicating that the water has reached the solenoid pump. It can be helpful to remove the cover and watch the Water Extraction Tube, visible from the left side of the instrument. The water extraction tubing leads from the base of the growth tube to the manifold, which is a large plastic block between the growth tube and PCB. The plug of water should advance by a sudden 20mm jump at each cycle.
- (5) Pull the syringe plunger to remove the water from the growth tube.
- (6) Remove wick-priming fixture from the unit.
- (7) Power the unit down.
- (8) When the unit is next operated, you might hear an intermittent crackling sound. This is normal and is caused by the liquid merging with the exhaust air flow.

WARNING: Be sure to pull back the syringe plunger and remove the wick wetting tool before power cycling the unit, or you may flood the optics!

7.2 Cleaning the Inlet Screens and 2.5 µm impactor

The Inlet Block contains a pair of screens and a nozzle impactor, designed to capture particles larger than 2.5 µm. After extended operation, it may be necessary to remove debris from this fixture.

Disassemble one side of the Inlet Block by removing the four screws shown (7/64" Allen wrench).

The impactor consists of two acetal (plastic) rings, two stainless steel screens, and a stainless-steel disk serving as nozzle and main body. These parts can be sonicated and rinsed with to water or alcohol as necessary.



To reassemble, first assemble the impactor, by joining the plastic rings and stainless-steel parts as shown above. Attach the o-ring to the inlet plate as seen below. Slide the assembled impactor into the body of the Inlet Block with the arrow pointing inward. Attach the plate so that the o-ring slides in behind the impactor assembly. Tighten the screws until the plate bottoms out on the body. The o-ring seals on three surfaces.

8 APPENDIX A

8.1 Dew Point Lookup Table

In the standard operating mode, the temperature of the moderator stage is set in accordance with the dew point calculated from the measured temperature and relative humidity at the inlet, downstream of the Inlet Humidifier. The moderator reference temperature equals that which has found through experimental measurements to give the same dew point in the outlet flow as measured at the inlet. The factory setting is to operate 2°C colder than the value in the table to ensure that the wick remains wet. This offset amount can be changed through user accessible commands.

Moderator Reference Temperature Lookup Table

Inlet Dew Point	Moderator Reference Temperature
0	0.5
4	-3.5
8	-4.0
12	-3.5
16.0	-2.5
20.0	-1.8
24.0	-1.4
28.0	-1.0
32.0	-0.5

The control code linearly interpolates between values in table. Note the first two rows sets the temperature to 0.5 degrees for dew points less than 4 °C

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