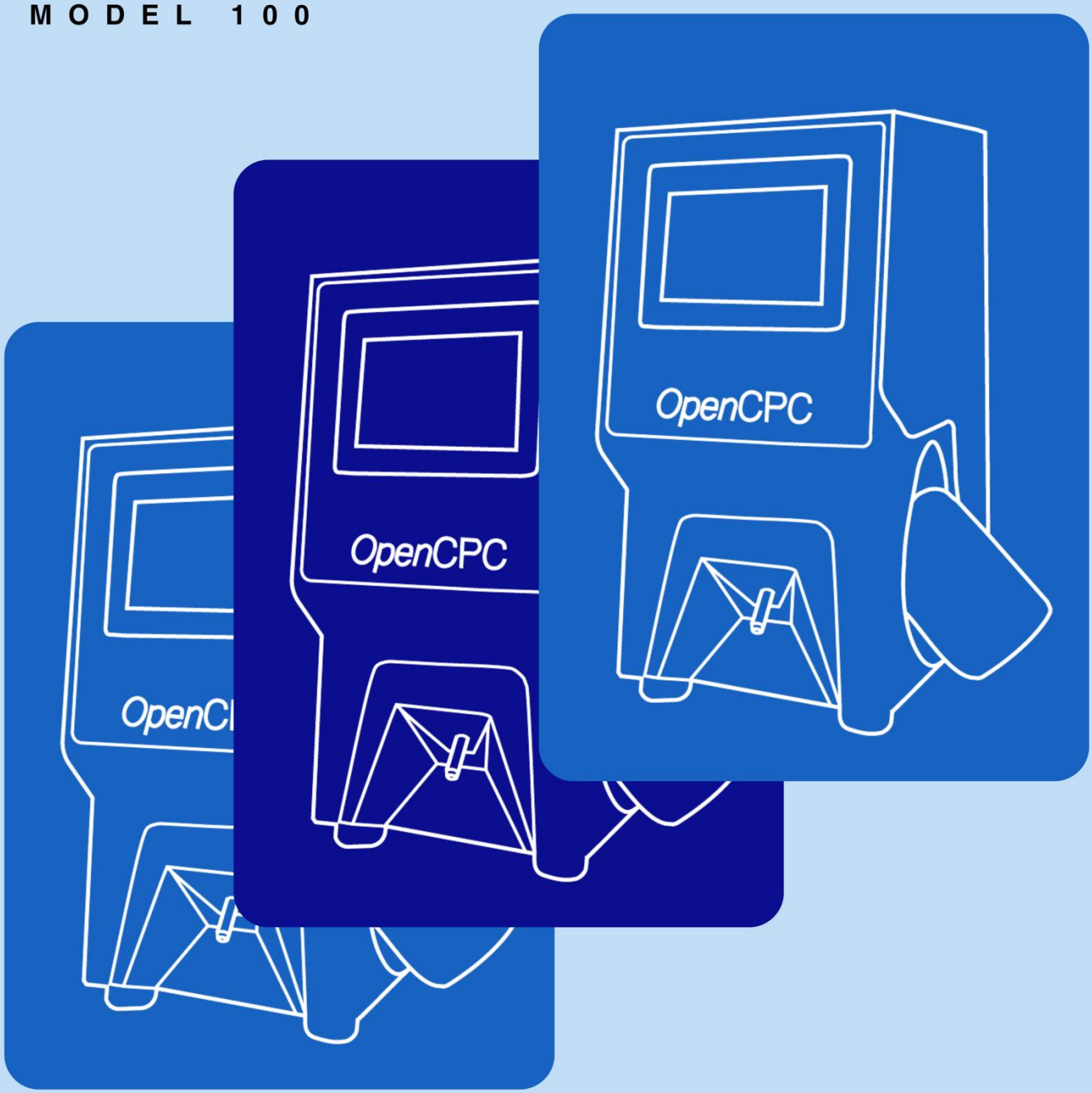
USER MANUAL

OpenCPC™

MODEL 100



OpenAeros

Table of Contents

OpenCPC User Manual

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Version

Ver No.	Date	Changes
1.0	30-Apr-25	Original
1.1	11-Sep-25	Update for version 2A software changes, corrected typos and updated hardware pictures.
1.2	23 -Oct-25	Corrected typos, update to figures, refine specifications

Warranty and Liability Limitations

Limitation of Warranty and Liability

OpenAeros LLC offers a 12-month limited warranty on its hardware products, excluding software and consumable components. This warranty covers defects arising from design or manufacturing flaws. If any such product proves defective during this period, OpenAeros LLC, at its discretion, will either repair the defective product at no charge for parts and labor or provide a replacement in exchange for the defective product. This warranty applies strictly on a return-to-factory basis, with the customer responsible for all shipping costs associated with returning the product. OpenAeros LLC will cover the cost of shipping repaired or replaced items back to the customer. Any repaired or replaced item is covered under the remainder of the original warranty period.

This warranty does not cover damages resulting from misuse, mishandling, or accidents, including but not limited to drops, exposure to extreme environmental conditions, or failure to follow operating guidelines. Additionally, OpenAeros LLC assumes no liability for loss of data, loss of revenue, or any other indirect, incidental, or consequential damages.

To obtain service under this warranty, the customer must notify OpenAeros LLC before the expiration of the warranty period and follow OpenAeros LLC's return procedures. The customer is responsible for properly packaging the defective product and shipping it prepaid to a service center designated by OpenAeros LLC.

Warranty Exclusions

This warranty shall not apply to any defect, failure, or damage caused by:

a) Operation of the instrument in any manner not expressly described or approved in this user manual, including but not limited to exposure to non-inert or hazardous gases, use in explosive or flammable environments, or operation outside the specified environmental and electrical conditions.
b) Improper or inadequate maintenance and care.
c) Unauthorized repair attempts by personnel other than OpenAeros LLC representatives.
d) Use of the product with incompatible accessories or external equipment.
e) Modification or integration with other products in a manner that increases the difficulty of servicing or diagnosing failures.

Integration With Other Products and Systems

OpenAeros LLC is not responsible for failures, damages, or performance issues resulting from integration with third-party products, systems, or software. The customer assumes all risk and liability when integrating the instrument with other hardware, software, or networks. Any modifications, connections, or installations made by the customer or third parties that impact the instrument's operation may void the warranty. OpenAeros LLC does not guarantee compatibility with external products unless explicitly stated in official documentation.

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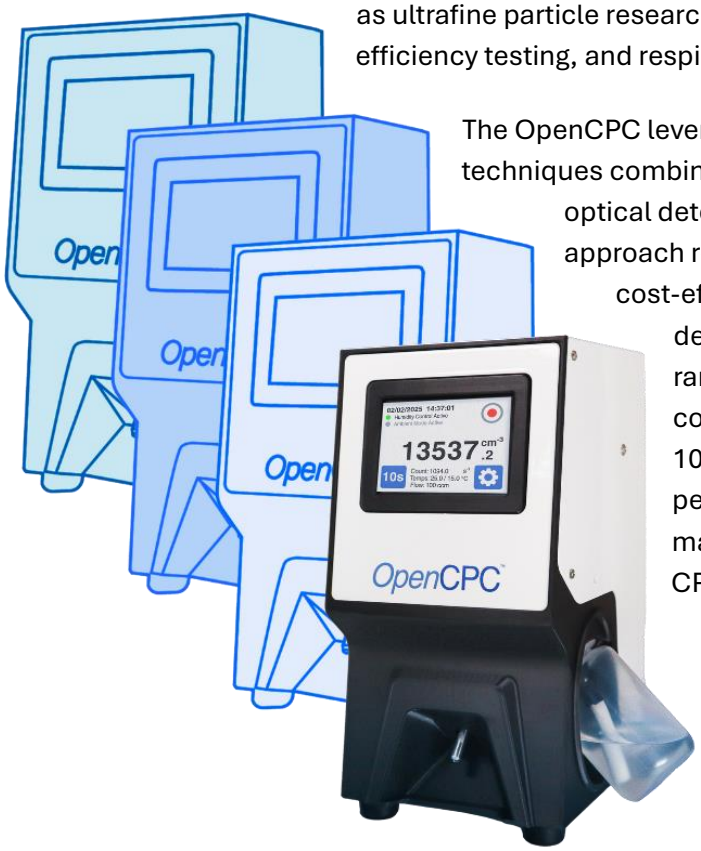
- ANY DAMAGE RESULTING FROM THE USE OF THE PRODUCT IN COMBINATION WITH OTHER SYSTEMS, SOFTWARE, OR HARDWARE NOT SPECIFIED BY OPENAEROS LLC.
- COSTS ASSOCIATED WITH REMOVING, REINSTALLING, OR INTEGRATING THE INSTRUMENT INTO A LARGER SYSTEM OR NETWORK.
- ANY DAMAGE RESULTING FROM USE OF THE PRODUCT IN A MANNER NOT SPECIFIED IN THIS MANUAL, INCLUDING USE OUTSIDE THE STATED ENVIRONMENTAL CONDITIONS, WITH HAZARDOUS GASES, OR WITH NON-COMPATIBLE SYSTEMS, IS EXPRESSLY EXCLUDED FROM WARRANTY COVERAGE. USERS ASSUME ALL RISKS ASSOCIATED WITH SUCH OPERATION.

Trademark

Introduction

The OpenCPC® condensation particle counter is a precision instrument developed by OpenAeros LLC for the measurement of ultrafine aerosol. OpenAeros LLC is an open-source hardware and software company committed to advancing aerosol science through the development of accessible, affordable, and intuitive instrumentation for the clean air marketplace.

Launched in 2025, the OpenCPC uses 2-propanol (isopropyl alcohol) as its working fluid. CPCs are essential tools in aerosol science, enabling the detection of particles that are otherwise too small to measure optically. By condensing vapor onto ultrafine particles, CPCs grow the particles to sizes detectable by light scattering, thereby extending measurement capabilities to the nanometer scale. These instruments are critical for applications such as ultrafine particle research, mobility sizing, filtration efficiency testing, and respirator mask fit testing.



The OpenCPC leverages advanced manufacturing techniques combined with a simplified, low-cost optical detection system. This design approach results in a highly scalable, cost-effective solution capable of detecting particles in the size range of 0.010 µm to 1 µm, and concentration range of 0.1 – 100,000 cm^{-3}, with the performance and quality of market-leading commercial CPCs.

Safety

There are no user-serviceable parts within this instrument. Refer all repair and maintenance to a qualified technician. All repair and maintenance information in this manual is included for use by a qualified technician.

Laser Safety

The OpenCPC is classified as a Class I laser device, meaning it is designed to be inherently safe under normal operating conditions and poses no risk of hazardous laser exposure to the user. This classification indicates that during typical use, the laser's emissions are contained within the device, eliminating the risk of direct exposure to laser radiation. However, disassembling and accessing certain internal parts may expose you to potentially harmful laser radiation in the form of intense, focused light, which could lead to serious eye injury, including blindness.

To ensure safe use and avoid exposure to hazardous laser light, observe the following precautions:

- Do not remove any components from the instrument unless instructed to do so in this manual.
- Do not open or remove the cover, or any internal components of the instrument while it is powered on.
- If the instrument is used in a manner not specified by the manufacturer, the protection provided by the instrument may be impaired.

These measures help to prevent accidental exposure to laser radiation contained within the instrument.

	**CAUTION**
	The use of controls, adjustments, or procedures other than those specified in this manual may result in exposure to hazardous optical radiation.

Chemical Safety

The OpenCPC uses 2-propanol (isopropyl alcohol) as the working fluid within the counter. **2-propanol is a hazardous material.** Do not ingest or allow alcohol to contact your eyes or skin. Refer to the Safety Data Sheet (SDS) for handling precautions and first aid procedures for these materials. Always recap alcohol fill capsule and other containers immediately to prevent absorption of moisture and the escape of alcohol vapors. Dispose of any alcohol with visible contamination.

Chemical Name: 2-propanol
CAS: 67-63-0

	CAUTION
	2-propanol is flammable. Keep away from heat/sparks/open flames/hot surfaces. Take precautionary measures against static discharge. 2-propanol is potentially hazardous if inhaled. Use 2-propanol only in a well-ventilated area.

Description of Safety Labels

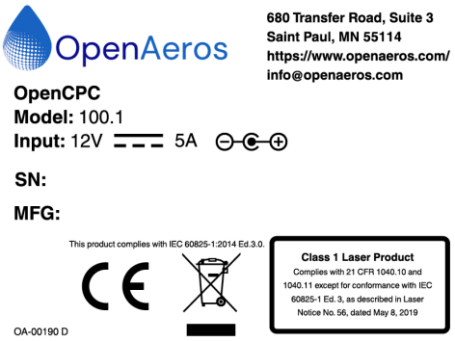
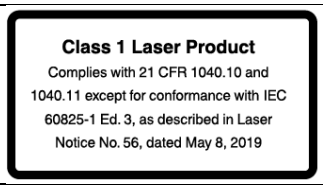
This section provides information about the advisory and warning labels within this manual, as well as those on the instrument.

	CAUTION
	**Caution** indicates the need for careful attention. Failure to follow the procedures outlined in this manual may lead to equipment damage or require rework. It also highlights important information related to the operation and maintenance of this instrument.

	WARNING
	**Warning** indicates that improper use of the instrument may result in serious personal injury or cause permanent damage to the equipment. Always follow the procedures outlined in this manual to ensure safe operation.

Labels

OpenCPC labels are shown in the table below along with their location.

Description	Location	Image of Label
Serial number label	Back of instrument	
Laser safety label	Interior of enclosure, on top of optics unit	
Laser safety certification and ID label	Back of instrument	
European Conformity (CE) label	Back of instrument	
Waste Electrical and Electronic Equipment (WEEE) Directive Label	Back of instrument	
Flammable Label	Working fluid bottle	

To indicate that the operator's manual or card should be read before continuing the operation	Working fluid bottle	

Setup

Contents

Figure 1 - Identifying Contents

Item	Description	Qty
1	OpenCPC	1
2	12V Power Supply for OpenCPC	1
3	USB-Communication Cable	1
4	Inlet Plug for Shipping	1
5	OpenCPC Shipping and Transport Cover	1
6	Display Shipping Cover	1

System Setup

To prepare the OpenCPC system for use please follow the following steps:

1. Remove OpenCPC from shipping box and bag.

NOTE
Please keep all packing material and shipping box in case of return to OpenAeros for service or calibration.

2. Remove the shipping display cover by pulling it away from the display and disconnect the shipping inlet plug from the inlet.

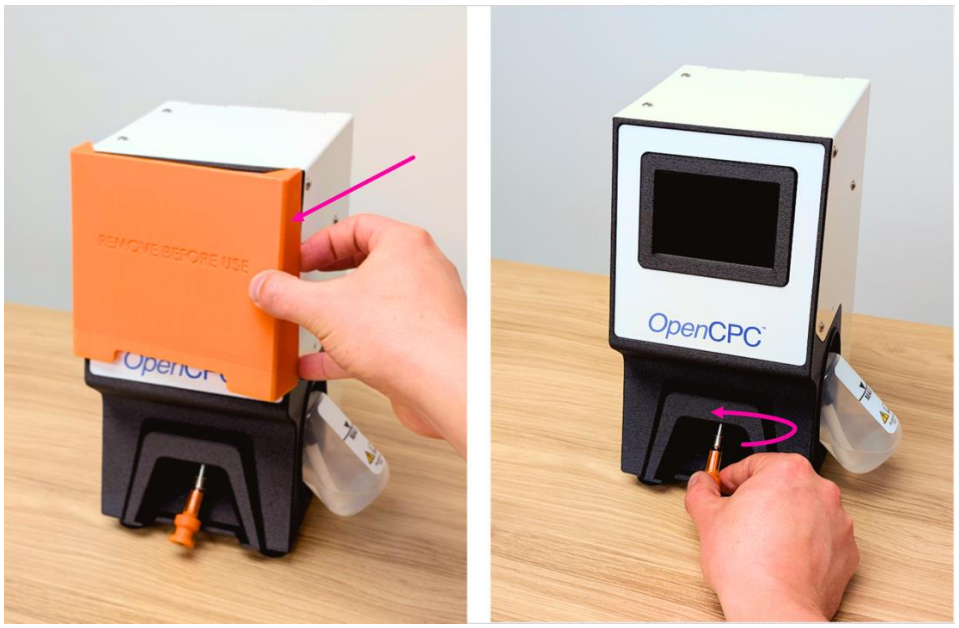


Figure 2 - Removing Shipping Protection

3. If the instrument was in extreme hot or cold conditions, allow it to sit indoors for 1-2 hours until it has reached room temperature to prevent possible electrical or condensation issues.

Figure 3 - Removing Bottle Protector

4. Remove the two thumbscrews securing the Shipping and Transport protective bracket. Note that the second screw is located on the underside of the device.
5. Place the OpenCPC at the edge of a table, or tip OpenCPC, and remove the reservoir bottle.

Figure 4 - Removing Reservoir Bottle

6. Fill the bottle until the level is just below the indicated maximum fill level with reagent grade (99.5% or higher) Isopropyl Alcohol (2-propanol). *Note: The fill volume is approximately 70ml of liquid*

Figure 5 - Fill Bottle Max Level

Figure 6 - Install Reservoir Bottle

7. Re-install the reservoir bottle, taking care to guide the wick through the center of the opening of the reservoir bottle. Avoid excessive displacement of or pulling on the wick, as this may result in reduced

performance of the working fluid transport system. Hand tighten the bottle to ensure leak-free operation.

8. Connect the OpenCPC to the provided power supply, and use the switch located on the left of the instrument to power on.

Figure 7 - DC Power Connector

NOTE
Only use the power supply provided with the instrument or an identical replacement. Use of incompatible power supplies may damage the instrument or cause injury. Use of incompatible power supplies will void the warranty.

NOTE
Always use the switch to power down the system and do not remove the DC power connection or unplug the unit during operation to prevent electrical damage to the instrument.

NOTE
Ensure the system is not connected to any tubing or pressurized lines before startup. During power up, the instrument performs a series of internal flow offset measurements and internal self-checks.

Pressurized or vacuum connected to the instrument during this time can result in failure of internal checks and flow errors.

NOTE
If the system is completely dry as in the case of shipping, wait at least 45 minutes before using the system to allow the working fluid to wick into the saturator assembly.

9. Upon startup, the OpenCPC software will adjust the saturator and condenser to the necessary operating temperatures, start the sample flow pump and begin counting particles. The system will take 3-5 minutes to reach the setpoint temperatures, during this period it will indicate status by displaying "STARTING" on the text indicator and displaying an orange border. When the system is ready the border color will turn off and status notification will state “READY”.

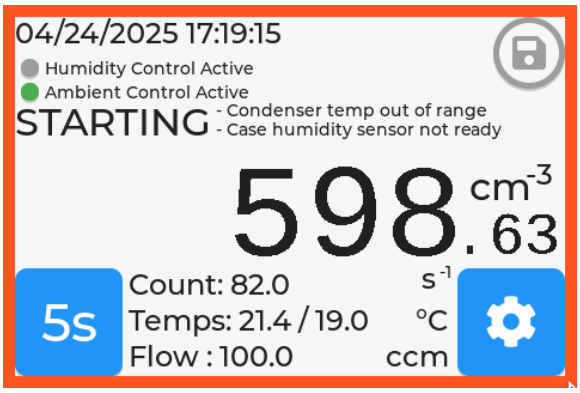


Figure 8. Status Indicator

10. Refer to the descriptions below for a complete explanation of the indicators on the display.

Hardware Overview

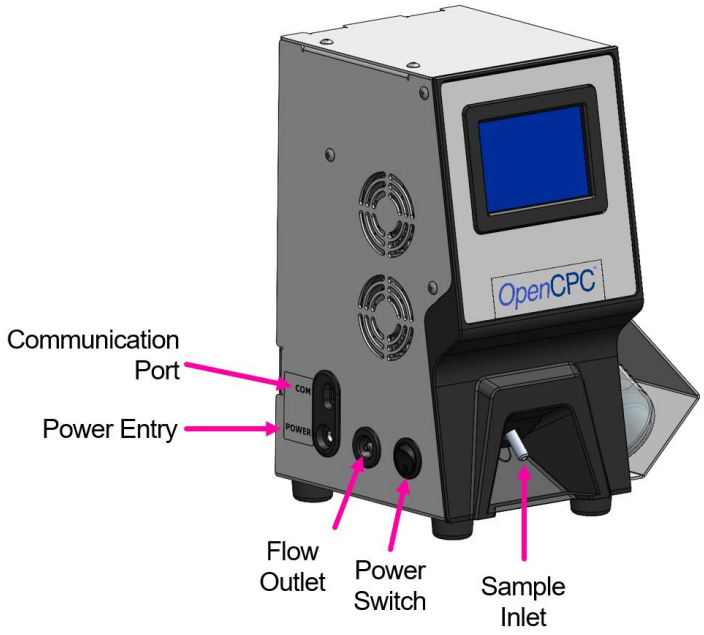


Figure 9. Hardware Connections

Indicator	Description
Sample Inlet	The aerosol sample inlet consists of a 1/4" tube connection. It is recommended to use static-dissipating soft tubing or metal conductive tubing. (Note: plastic ferules should be used if using metal swage connections to prevent damaging the inlet.)
Power Switch	Power switch to power on device after power has been applied to the device.
Flow Outlet	Outlet flow from device, which consists of a barbed connection for 1/8” soft tubing. Tubing can be used to direct the exhaust flow to a vent or carbon filter for safety.
Power Entry	Barrel plug connection for use with factory supplied power supply.
Communication Port	USB-C connection for use in connecting device to PC.

Operation

Main Panel Display

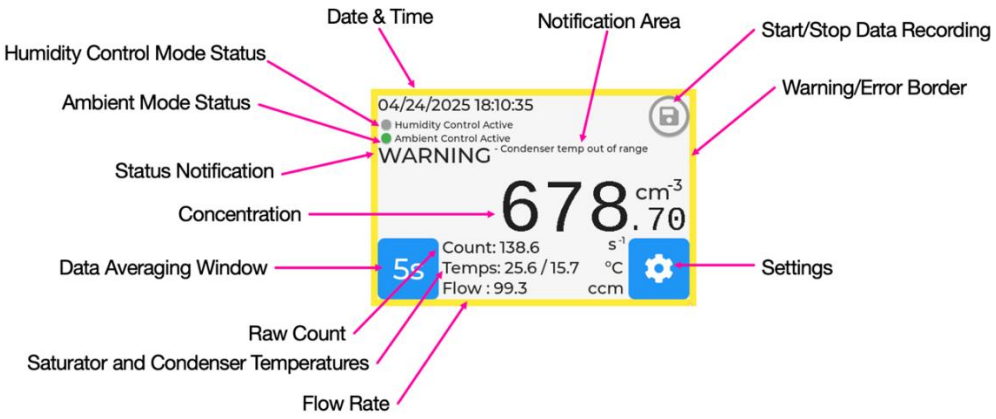


Figure 10. Main Screen Layout

Indicator	Description
Concentration	Measured concentration averaged over data averaging window.
Status Notification	Notifies of possible software warnings, errors and critical errors. See Appendix C - Software Warnings and Errors for more information.
Data Averaging Window Button	Press to change the moving time window length over which concentrations are averaged. Values can be selected as 1, 2, 5, 10, 30 and 60 secs. *Note: If USB-Communication interface is used to set this value, changing the value using the display will override any USB set value.*
Notification Area	Indicates up to two current software warnings, errors or critical errors, additional errors will be indicated by *"(...)"* and can be viewed in the Status panel. See Appendix C - Software Warnings and Errors for detailed description of errors.
Raw Count	Raw count rate measured by the optics before Threshold Count Correction.
Settings Button	Access Settings panel.
Flow Rate	Currently measured flowrate through optical counter in cm^3/min (ccm).
Temperatures	Currently measured Saturator and Condenser temperatures in °C

Humidity Control Mode Status	Indicates if the system is currently operating under Humidity Control Mode. See Appendix B – Theory of Operation for more information
Ambient Mode Status	Indicates if the system is currently operating under Ambient Mode. See Appendix B – Theory of Operation for more information
Start/Stop Data Recording	Use to start or stop internal data logging. *Note current value displayed for Data Averaging will be used for logged values.*
Date & Time	Displays current date in DD/MM/YYYY format and 24hr format time in HH:MM:SS
Warning/Error Border	Border will change color to notify user if a warning, error or critical error has occurred. An orange border indicates a warning is active, red indicates that an error, or critical error as occurred. See Appendix for more information on warnings and errors.

Settings Screen

The settings screen allows selection of six other screens available on the CPC. Details for each are below.

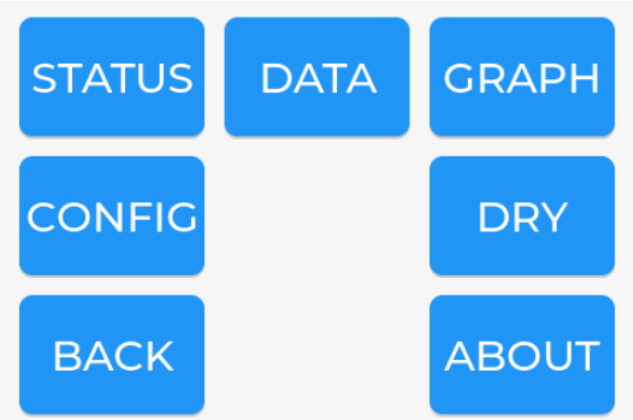


Figure 11. Settings Screen

Indicator	Description
Status	Detailed read-only status information for all instrument parameters.
Data	Set logging frequency and Logging/Transfer modes.
Graph	Plot up to two parameters on a real-time graph on the screen.
Config	Settings for humidity control, ambient control, pump on/off, temperature controls, and time/date.
Dry	Enable Dry mode to quickly dry out the instrument before shipping.
Back	Return to the main screen
About	Device serial number, firmware version/update and other factory information.

Graph Screen

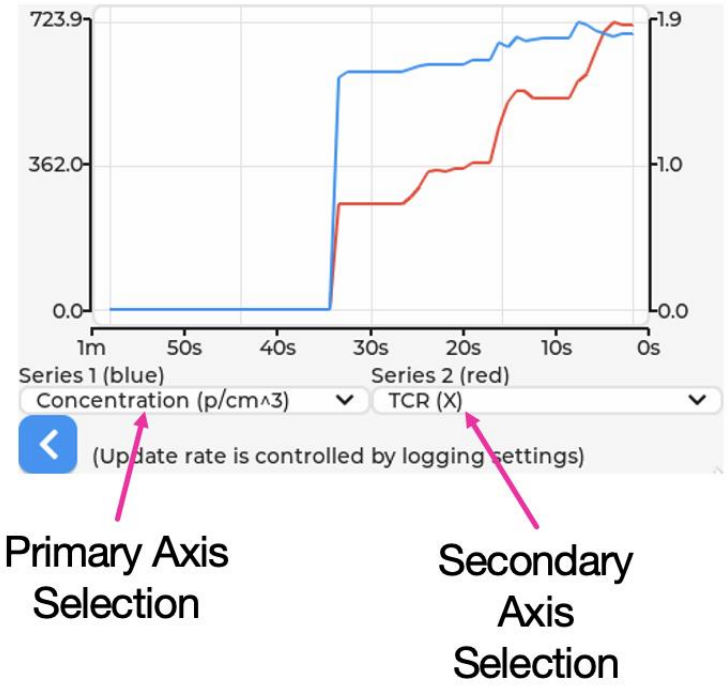


Figure 12. Graph Screen Layout

Indicator	Description
Data Plot Selection – Primary Axis	Select variable to plot on primary vertical axis over the last 60 data points determined by the logging interval (e.g. 1s logging shows 1 min of data while 10s logging shows 10 min of data on the graph).
Data Plot Selection – Secondary Axis	Select variable to plot on secondary vertical axis over the last 60 data points.

Data Logging Screen

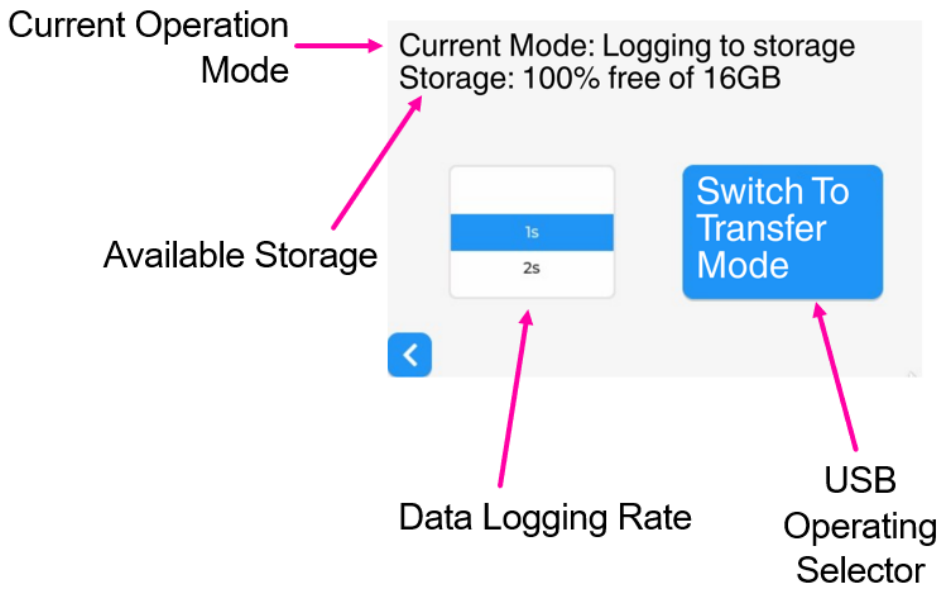


Figure 13. Data Logging Screen Layout

Indicator	Description
Data Logging Rate	Frequency at which data is logged internally and shown on the graph.
USB Operating State	Selection of operating state of the USB-Connection **Transfer Mode** – Enables USB data transfer as removable storage. Note: Allow up to 10 sec for the computer to recognize the device in the new mode before trying to access the files as a mounted drive. **Communication Mode** – Enables serial device communication over USB-As a COM port.
Available Storage	Current total size of stored data, and total storage available

Status Screen

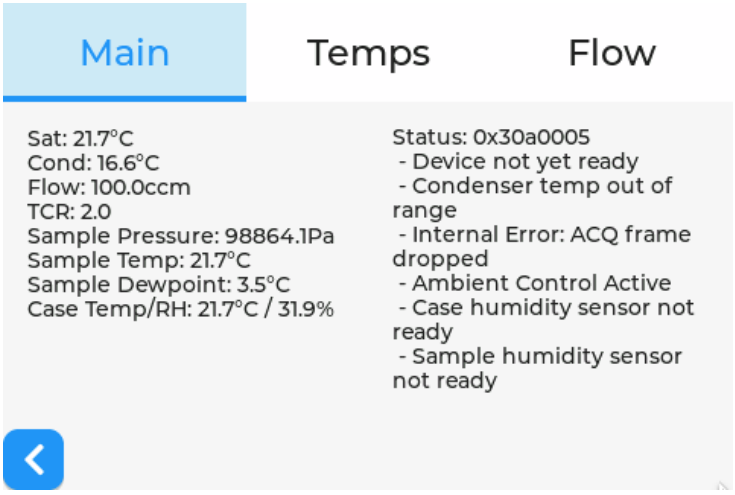


Figure 14 - Status Tab: Main

Indicator	Description
Sat	Current saturator temperature.
Cond	Current condenser temperature.
Flow	Current flow rate of optics.
TCR	Current Threshold Count Ratio, see Appendix B – Theory of Operation for more information.
Sample Pressure	Absolute pressure at sample inlet.
Sample Dewpoint	Dewpoint of sample flow.
Case Temp/RH	Current case temperature and relative humidity.
Status	Indicates bit register of status (for internal and support use) as well as currently active warnings and errors labels.

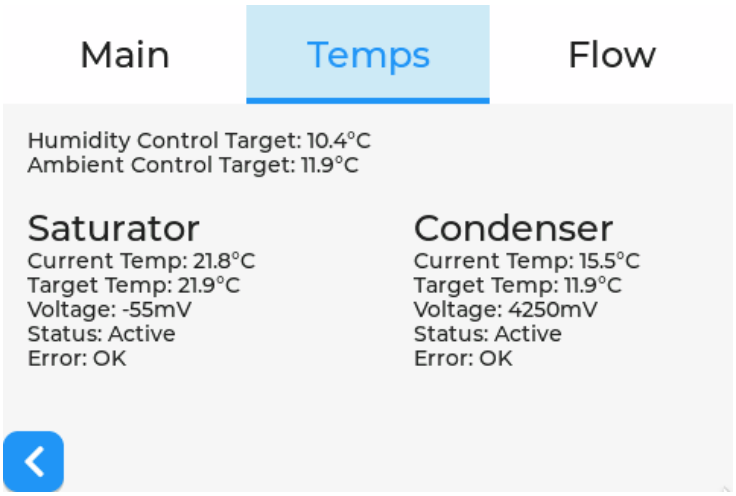


Figure 15 - Status Tab: Temps

Indicator	Description
Humidity Control Target	Target temperature for condenser for Humidity Control.
Ambient Control Target	Target temperature for condenser for Ambient Control.
Current Temp	Current temperature of component.
Target Temp	Target temperature of component.
Voltage	Current drive voltage to TEC (Peltier).
Status	Current state of TEC driver.
Error	Error state of temperature driver.

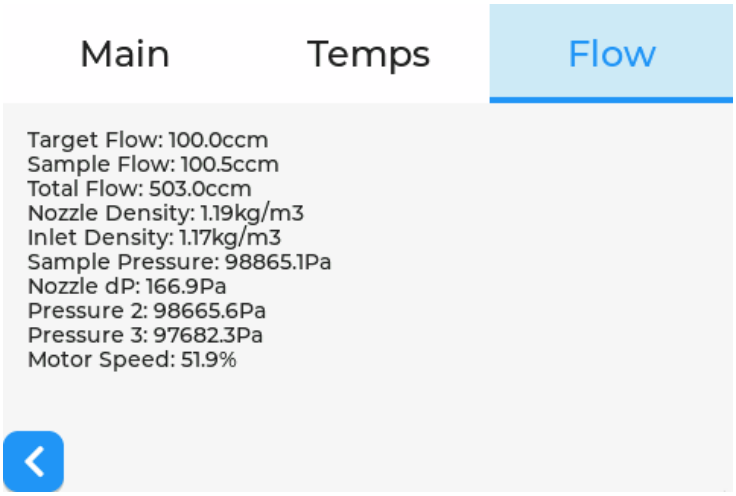


Figure 16 - Status Tab: Flow

Indicator	Description
Target Flow	Current flow target for main optics flow.
Sample Flow	Current flow rate of optics.
Total Flow	Estimated total inlet flow rate
Nozzle Density	Computed gas density at inlet to optics nozzle.
Inlet Density	Computed gas density at inlet nozzle *(Note: System currently uses Case temperature as assumption for sample inlet temperature)*.
Sample Pressure	Absolute pressure of sample flow at inlet.
Nozzle dP	Differential pressure across optics nozzle.
Pressure 2	Absolute Pressure at PID Location 2 (See Flow System in Appendix B – Theory of Operation).
Pressure 3	Absolute Pressure at PID Location 3 (See Flow System in Appendix B – Theory of Operation).
Motor Speed	Pump motor drive speed

Configuration Screen

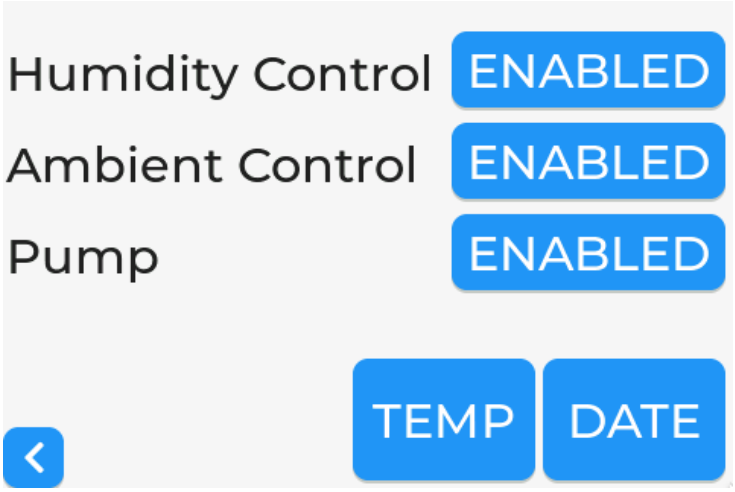


Figure 17. Configuration Screen

Indicator	Description
Humidity Control	Enables operation using internally measured sample dewpoint. See **Appendix B – Theory of Operation** section for more information.
Ambient Control	Enables operation of Ambient Control. See **Appendix B – Theory of Operation** section for more information.
Pump	Enables or disables internal sample pump.
TEMP	Access to temperature configuration screen.
DATE	Access to date and time configuration.

Temperature Settings Screen

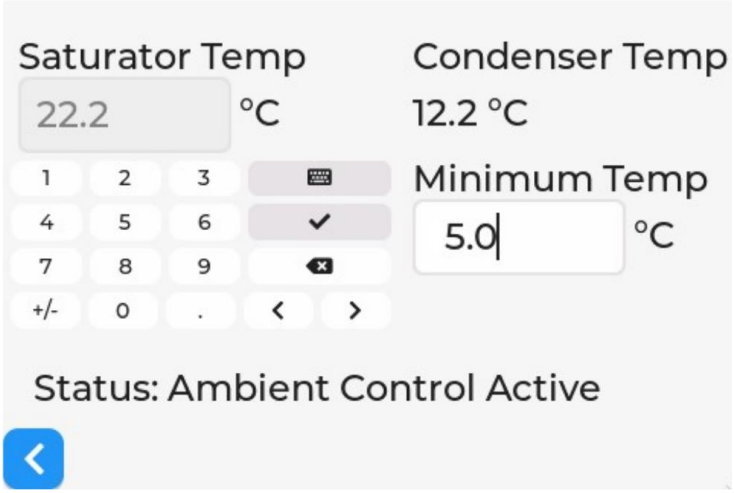


Figure 18. Temperature Configuration Screen

Indicator	Description
Saturator Temp	Indicates current set point of Saturator temperature, if operating with Humidity Control or Ambient Mode this unit will reset. If using in Fixed Mode, the values of the Saturator temp can be modified.
Condenser Temperature	Displays target temperature for Condenser temperature. Note that it will be offset by the default temperature difference of 10°C.
Status	Indicates which temperature control modes are active.

Date and Time

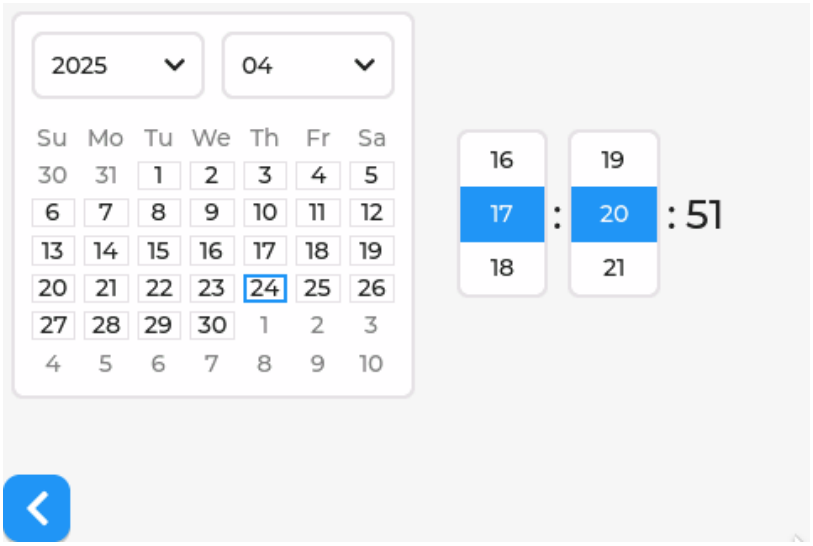


Figure 19. Calendar Configuration Screen

Indicator	Description
Calendar	Use Calendar setting to select month, day and year.
H/M/S	Select current hour, minute. *Note that adjusting the minute value will reset seconds to 00.*

Data and Communication

Logging Data to Internal Storage

With the device operating state “READY”, on the main panel press the Start/Stop Data recording icon as shown in the figure that follows. The circle around the logging icon will slowly blink when logging is active. Note that data logged will be at the averaging time as indicated in the Data Averaging Window. File creation is automatic, and the file name will be the date and time at the start of log file. During long duration logging, new files are automatically generated at the start of the next day (i.e. 00:00:00) such that each file represents a single calendar day.

To stop logging, press the Data Recording icon.

Logged Data Retrieval

To retrieve logged data, ensure the system is in Data Transfer Mode, by navigating to the DATA panel and set unit to Data Transfer Mode.

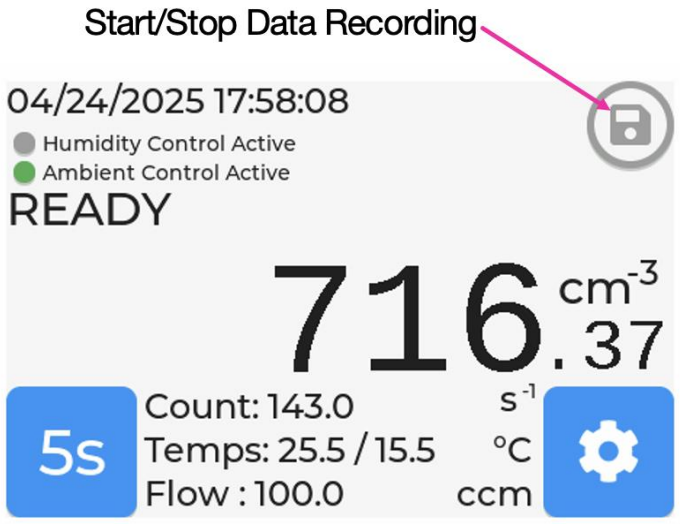


Figure 20: Logging to Internal; Storage

NOTE
System cannot log data in while in Data Transfer Mode. Switching to Data Transfer Mode will halt any active logging.

NOTE
Do attempt to format the internal drive using native OS interface. If Windows or other OS requests to **repair** drive, ignore the request.

Connect the computer to the OpenCPC using the included USB-A to USB-C cable. The OpenCPC will show up as a removable storage device (typically in less than 10 seconds). Use the native file explorer to copy files to the computer and delete files. When complete, safety unmount/eject the hardware using your native OS feature. Once complete, set the Data Transfer Mode back to Serial Communication to re-enable logging or communication of serial port.

Logging File Data Structure

The logged file will include a filename structure of YYYYMMDD--HHMMSS.csv when the file was created. Logging will occur at the rate set in the DATA window with a header located at the first line. Data logged includes:

- Time and Date
- Concentration
- TCR
- Flow Rate
- Saturator Temperature
- Condenser Temperature
- Case Temperature
- Sample Pressure
- Sample Dewpoint
- Active Errors *[In Release 2A and later]*

Serial Data Communication Overview

The OpenCPC features an integrated USB Serial communication enabling simple communication with PC/Linux and Mac systems. To connect use the following steps:

1. Ensure the system is in serial communication mode by navigating to the DATA panel and ensuring that displayed Current Mode is "Logging to Storage."

2. Connect the computer to the OpenCPC using the included USB-A to USB-C cable

NOTE
The use of a USB-A to USB-C connector is required. Use of USB-C to USB-C is unreliable and not supported. Use of USB-C to USB-A may also be successful.

3. Using a serial terminal client such as RealTerm, TerraTerm, Hyperterminal, or programming languages like Python, open the serial port using the following settings:

Parameter	Setting
Baud Rate	115200
Data Bits	8
Parity	None
Stop Bits	1
DTR/CTS	On

4. Use the command tables below to request data by including the command followed by a carriage return (CR, ASCII 13):

Basic Commands

Note that commands by default are echoed back along with the data if the command is successful. To suppress the command echo, use the command: “OA ECHO OFF”.

Command	Example Command and Response	Comments
R.BINDEX	R.BINDEX *32744*	Reads monotonically increasing count frame index (can be used to prevent duplicate responses)
R.CONC	R.CONC *3893.494 p/cm^3*	Reads concentration at current time averaging
R.TCR	R.TCR *1.035 X*	Reads time-averaged TCR value at current time averaging
R.FLOW	R.FLOW *99.754 ccm*	Reads current time averaged flow (if available or can use instantaneous)
R.SAT	R.SAT *26710 mC*	Reads saturator temperature in mC (example converts to 26.710 degrees C)
R.COND	R.COND *16732 mC*	Reads condenser temperature in mC (example converts to 16.732 degrees C)
R.SDP	R.SDP *13.723 C*	Reads inlet sample dewpoint in °C
R.STATUS	R.STATUS *-Saturator temp out of range* *-Moisture accumulation possible*	Reads the status of the instrument, see **Appendix C - Software Warnings** and Errors for more information.
R.FRAVG	R.FRAVG *5.0 s*	Reads current time averaging
R.HEADER	R.HEADER *Buffer index (frames), Particle Conc..*	Provides header information for variable list of R.ALL
R.ALL	R.ALL *1768,5639,834,3.406...*	Provides comma separated response for buffer index, concentration, flow rate, TCR, Saturator temp, Condenser Temp, Case temp and sample dewpoint.

Command	Example Command and Response	Comments
OA STREAM [sec]	OA STREAM 1 *Stream rate set to 1.0* *4435,5734.469,3.399…* *4440,5660.877,3.424…* *4445,5356.869,3.424…*	Provides comma separated response at the specified interval for buffer index, concentration, flow rate, TCR, Saturator temp, Condenser Temp, Case temp and sample dewpoint.
OA STREAM OFF	OA STREAM OFF Stream disabled	Stops the OA STREAM [sec] function
S.FRAVG [sec]	S.FRAVG 1 *Write OK*	Sets the current time averaging value in seconds. Minimum is 0.2 and maximum is 120 seconds.
OA ECHO [ON/OFF]	OA ECHO ON *Echo now ON*	Configure echo (terminal character readback). Default on
OA RESP [ON/OFF]	OA RESP ON *Responses are now ON*	Configure if commands should report success (Default on)

Advanced Commands

Contact OpenAeros for documentation on advanced commands for applications in which high speed data logging is required, or for logging of custom variables. See contact information on Page 4.

Preparing OpenCPC for Transport

Moving Unit by Hand

It is recommended that whenever transporting the system by hand (within lab or building) that care is taken **NOT TO invert the instrument or lay it on its side**. The system must remain vertical whenever operating with alcohol in the reservoir bottle.

If transporting further distances, it is recommended to empty the fill bottle of all alcohol to help reduce the probability of accidental inversion or tipping of the instrument. If this has occurred, please reach out to OpenAeros for tips for drying out the system. It's also recommended to install the *OpenCPC Shipping and Transport Cover* to limit possible impact damage to the screen.

Drying OpenCPC for Shipping

The CPC must be completely dry internally before shipping. This is critical to avoid liquid accumulating in any portion of the system or leaking into the packaging. To dry the system the following steps should be done.

1. Power off system
2. Move OpenCPC to the edge of table and remove alcohol reservoir bottle. System can also be slightly tipped to remove bottle as well. Dispose of any unused isopropyl alcohol.
3. Re-install the empty reservoir bottle, taking care to guide the wick through the center of the opening of the reservoir bottle.
4. Power on the OpenCPC module and select DRY from the settings panel. Allow system to operate for 8-10 hours. Any remaining isopropyl alcohol will evaporate, and the system's interior will dry over this duration.
5. Once complete, the system can be powered off and is now ready for shipment.

Packaging

The OpenCPC will ship with packaging that should be re-used for any return or other shipments. To prepare the device for shipment please use the following steps.

1. Ensure the OpenCPC is dry as per the above section.
2. Power off all systems.
3. Package all power supplies and USB-Cable into one of the clear bags provided.
4. Install Shipping and Transport Cover, Inlet Plug, and Display Shipping Cover.
5. Place OpenCPC module into second clear plastic bag provided.
6. Place all accessories into the provided box, tape close, and place at one end of shipping box

Maintenance and Service

Maintenance and Service should be carried out by qualified personnel with expertise in both electronics and mechanical systems. For questions related to technical issues or application support, please contact OpenAeros.

Cleaning

External surface cleaning may be required for aesthetic reasons or in preparation for shipment.

External Surface Cleaning

1. Power off and unplug the instrument before cleaning.
2. Use lint-free cloth damped with water to gently wipe all external surfaces (housing, display bezel, buttons).
3. Do **not** apply liquid directly to the instrument. Always moisten the cloth first and wring it out thoroughly to avoid dripping.
4. Avoid abrasive cloths or cleaners, which can scratch or damage the enclosure finish.

NOTE
Note to prevent liquid ingress take care to keep moisture away from all inlet and seams on instrument Never spray or pour liquids onto the instrument. If cleaning near openings (e.g., sample inlet, exhaust port), cover them temporarily with a clean, dry cap or plug.

Appendices

Appendix A – Device Specifications

Power
OpenCPC Unit: 12.0V 5A Max.
Typical Power Consumption: <8 W steady state

Power Supply
100 – 250 VAC, 50 to 60 Hz, 1.3-0.6 A

Environmental Operating Conditions
Indoor Use
Temperature: 5 – 35 °C (41 – 95°F)
Ambient Humidity: 0-90% RH non-condensing
Aerosol Sample Dewpoint: <30°C (86°F)
Altitude up to 2500 m (6500 ft)
Inlet Pressure: 75 to 105 kPa Absolute (0.75 to 1.05 atm)
Pollution degree 2

Aerosol Medium
Compatible with air, nitrogen, argon and other inert gases. System shall not be used with hazardous aerosols or gases such as hydrogen or oxygen.

Working Fluid
99.5% or greater reagent grade isopropyl alcohol (2-propanol)

Count Accuracy
±20% at < 1 x 10^4 particles/cm3

Particle Coincidence
<10% at 1 x 10^5 particles/cm^3

Particle Size Range
Minimum Detectable Particle (D_{50}): 10 nm*
**- Tungsten oxide aerosol, isopropyl alcohol working fluid, saturator = 29°C, condenser: 19°C.*
Maximum Detectable Particle Size: >1µm (estimated)

Response Time
< 3 seconds to 95% response to concentration step change

Operating Duration
>120 hours with maximum fill at 23°C (73°F) using isopropyl alcohol

Flow Rate
Sample Flow Rate: Approximately 500 cm^3/min (±6%)

Note: This system has an internal bypass used to shorten transit time in sample tube. Flow can vary ~30 cm^3/min unit to unit.

Nominal Aerosol Flow Rate: 100 cm^3/min

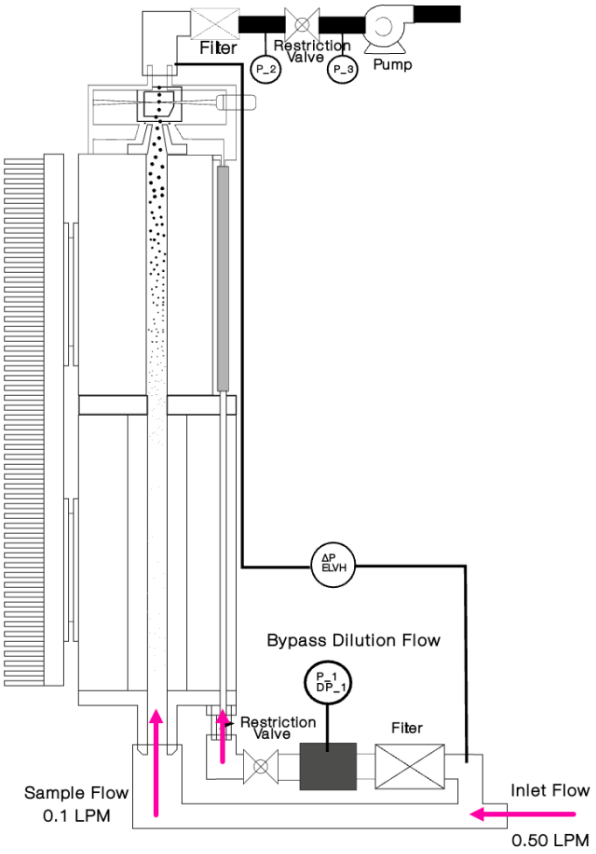
Dimensions
60 mm x 210 mm x 265 mm (6.3 x 8.3 x 10.4 in)

Weight
2.43 kg (5.3 lbs)

Appendix B – Theory of Operation

Flow System

The OpenCPC uses a unique flow configuration, in which a portion of the inlet flow is re-directed through a filter, a relative humidity and temperature measurement section and then re-introduced into the optics as diluting flow. This dilution prevents condensation of the working fluid from occurring within the optics space, as the optics housing in the OpenCPC is not heated. This bypass dilution flow also has the advantage of reducing the transit time in sample lines connected to the instrument.



Flow control uses a differential flow measurement between the inlet of the OpenCPC and the exit of the nozzle, using the pressure drop resulting from the small diameter nozzle to enable the computation of the flowrate. Additionally, the total flow is monitored via the pressure differential as recorded by P_2 and P_3 absolute pressure sensors. This enables monitoring of the flow to detect situations in which the nozzle is clogged, or when there are large changes in the flow rates within the system.

Figure 21. Process and Instrumentation Diagram

Optical Design

The OpenCPC features a focused laser design, in which the laser beam diameter is smaller than the nozzle diameter. This results in only a fraction of the particles exiting the nozzle to intersect the laser, and thus the OpenCPC only fractionally samples the total volume of particles grown. Additionally, since the laser beam has a Gaussian intensity distribution, not all particles passing through the laser will generate a uniform scattered intensity like more traditional designs in which the laser beam is much larger than the nozzle. This results in a distribution of pulse amplitudes that depend on both the particle size, as well as the intensity profile where the particle passes through the laser beam.

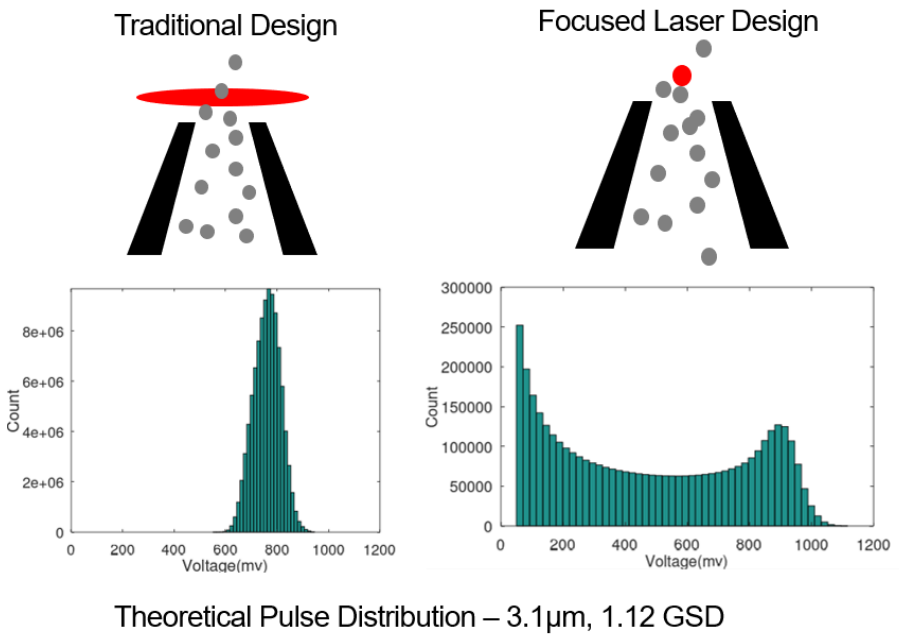


Figure 22. Pulse Height Distributions for Traditional and Focused Laser Design

The range of pulse amplitudes detected by a focused laser design results in some pulses being very small, and many particles not passing through the region illuminated by the laser. To overcome this a correction method is implemented in which the pulse height for each particle is corrected. A summary statistic, the Threshold Count Ratio (TCR), as shown in Equation 1, is created for this distribution of pulse heights by computing the ratio of the number of counts above a set voltage threshold to the number of counts below this threshold but above a lower noise floor threshold.

$$TCR = \frac{Counts\ Above\ Threshold}{Counts\ Below\ Threshold}$$ Equation 1

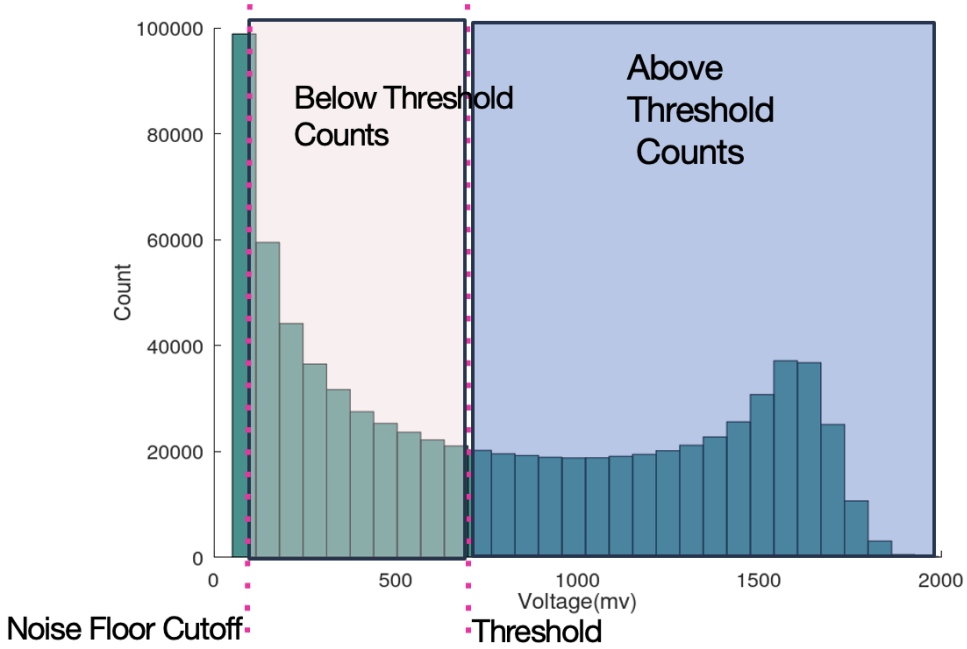


Figure 23. Threshold Cut

Calibration of the OpenCPC

Due to the nature of the OpenCPC's focused laser design in which only a fraction (typically 15%) of the aerosol is counted, the OpenCPC follows a three-step calibration process:

Step 1 – The optical counter portion of the OpenCPC is self-referenced to itself during normal operation. The laser power is adjusted to generate a wide range of TCR values, and the fraction counted is relative to the count fraction at the maximum recorded TCR.

Step 2 – Using a sodium iodide (NaI) test aerosol[1], the OpenCPC has a count reference calibration performed against a reference counter to establish the fraction of particles counted, along with the TCR that occurred at this time.

Step 3 – Using both the optical count fraction and the reference calibration a scaled count fraction curve is generated in which a linear curve fit is applied. The true count fraction can be estimated by measuring both particle count and the TCR and then applying a linear correction curve.

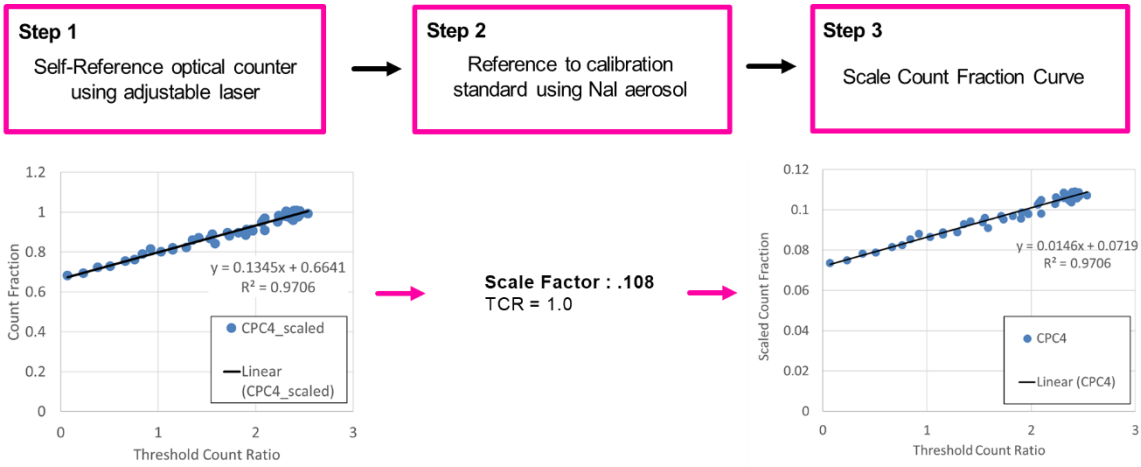


Figure 24. Calibration Steps

1- Krasa, H. *et al.* (2023) 'Toward a simplified calibration method for 23 nm automotive particle counters using atomized inorganic salt particles', *Aerosol Science and Technology*, 57(4), pp. 329–341. doi: 10.1080/02786826.2023.2174410.

Humidity Control Mode, Ambient Control and Fixed Temperature Mode

The working fluid used within the OpenCPC system, Isopropyl alcohol (2-propanol), is hygroscopic and in continued operation at high humidity environment can result in accumulation of water within the system. To overcome this challenge, a humidity control system is used where the temperatures of the saturator and condenser are automatically adjusted in real-time to minimize the impact of the hygroscopic behavior of Isopropyl alcohol.

Ambient Mode Operation (Default)

Due to the bi-direction control capability of both the saturator and condenser, the system can operate at a range of ambient temperatures. In ambient mode operation the temperature of the saturator is maintained at temperatures near ambient conditions measured by the internal case thermistor, except in situations of higher humidity in which the system will automatically switch to humidity control mode. Effectively, the system operates so that it will select the maximum temperature of either ambient temperature, Humidity Control Mode temperature or minimum operating temperature as described by the following equations.

$$T_s = max\ \{T_{ambient}, Dewpoint + 6.5°C + \ \Delta T\ , T_{min} + \Delta T\}$$

$$T_c = T_s - \Delta T$$

Ambient mode is enabled by default and is the recommended operating mode of the OpenCPC as it is the most fail-safe approach and ensures device stability no matter the operating conditions. Additionally, this prevents nozzle condensation, which can occur if the condenser is operated more than 3.5°C above ambient temperatures. This mode is most useful if the device will likely operate in a wide range of ambient conditions, and the consumption of working fluid is to be minimized.

Humidity Control Mode

In this operating mode, the dew point of the incoming sample is measured, and the saturator and condenser temperatures are adjusted so that the condenser temperature is maintained at 6.5°C above the dewpoint, or at the minimum operating temperature whichever is higher. To ensure particles are correctly activated and grown, the condenser is always operated at a

temperature difference relative to the saturator, which is nominally 10°C below the varying saturator temperatures. This is described by the following equations.

$$T_s = max\{Dewpoint + 6.5°C + \Delta T, T_{min} + \Delta T\}$$
$$T_c = T_s - \Delta T$$

Where:
T_s is the saturator temperature in °C
Dewpoint is the measured sample dewpoint in °C
ΔT is the saturator and condenser temperature difference
T_c is the condenser temperature in °C

This mode is useful for operators who often use dry air as the medium for the aerosol, but want ensure that the system will not have water accumulation if the sample line is temporally disconnected from the OpenCPC, or if the aerosol used is not sufficiently dry.

Fixed Mode Operation

This mode enables manual operation of saturator and condenser temperatures. Care must be taken to ensure the incoming aerosol dew point is always 6.5°C lower than the set condenser temperature, otherwise water accumulation may occur. Symptoms of this are low count rates, or continuous reduction in particle counting over long durations. If operated in such environments where this occurs, it is recommended to dry the system overnight to ensure proper operation of the system for future uses. The drying method is outlined in the **Drying System for Shipping** section outlined below.

Additionally, operation of the condenser more than 3.5°C above the ambient conditions may result in condensation occurring within the nozzle and resulting in a plugged nozzle and will result in no measured concentration. This can be rectified by ensuring the temperature of the condenser is below ambient conditions.

Appendix C - Software Warnings and Errors

Definitions

Warning – The OpenCPC has detected a process parameter outside of an allowed range. Measurement accuracy may be compromised. The software will attempt to correct problem.

Error – Data collection and measurement accuracy will be significantly impacted, and measurement data should be discarded. System was not able to correct this error.

Fault – The system has detected a fault condition, and the system and component have been disabled to ensure no damage to the system.

This list is not exhaustive. Contact OpenAeros for any errors that occur that do not appear in this list for more information.

Indicator	Description	Error ID
Device not yet ready	System is currently in the warmup phase after system power-on.	0
Ready	Device is fully operational.	
SAT Temp Out of Tol.	Saturator temperature is currently outside of the allowed process tolerance for greater than 1 minute	1
COND Temp Out of Tol.	Condenser temperature is currently outside of the allowed process tolerance for greater than 1 minute.	2
SAT Critical Fault	A critical fault condition has occurred, and the saturator temperature circuit has been disabled.	3
COND Critical Fault	A critical fault condition has occurred, and the condenser temperature circuit has been disabled.	4
Flow Rate Out of Tol.	Measured flow rate through optics nozzle is out of tolerance range allowed.	5
Pump Motor Hi Limit	Pump speed has exceeded upper limit and disabled to reduce impact on the lifetime.	6
Pump Low Limit	Pump speed is below lower specified limit.	20
ADC Bias Not Detected	Pulse digitization circuit is not functioning, system disabled as no counting will be possible.	7

Conc. Over Range	Upper concentration limit has been exceeded, excess count error may occur and reduced concentration accuracy.	9
TCR Low	Current Threshold Count Ratio is below specified limit, count accuracy may be reduced.	10
SAT FAN stall	Saturator heatsink fan stall has been detected. Debris preventing rotation or failure may have occurred	11
COND FAN stall	Condenser heatsink fan stall has been detected. Debris preventing rotation or failure may have occurred	12
FAILED SAFE-SHUTDOWN	System has detected a critical fault and has disabled system controls.	15
ELVH Zero Not Complete	The differential pressure sensor did not perform a zero offset at instrument startup.	21
ELVH Zero Failed	Differential pressure zero offset that occurs at instrument startup has exceeded tolerance limit	22
Case Humidity Not Ready	Humidity sensor monitoring case humidity is still in startup phase	24
Sample Humidity Not Ready	Humidity sensor monitoring inlet sample humidity is still in startup phase	25
Moisture Accumulation Possible	The sample inlet dew point is exceeding the allowed limit of the system, water dilution in saturator may occur.	27
Total Flow Out of Bounds	System monitored total flow outside of specified tolerance systems. Low total flow may indicate clogged nozzle.	30