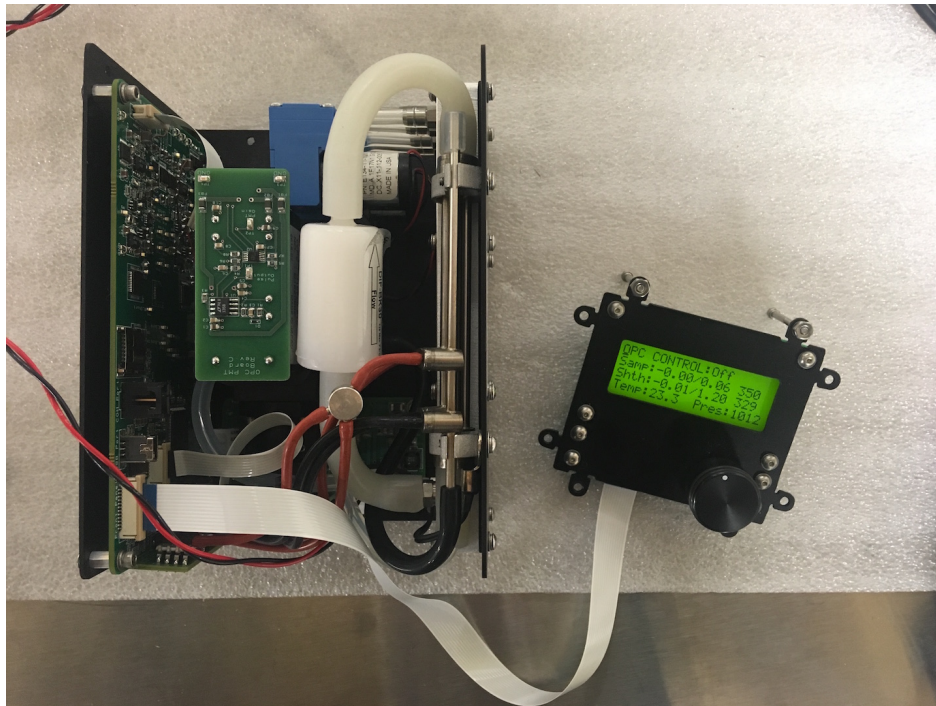


BRECHTEL

Instrument Manual Ver. 1.1 mini-OPC 9405

For UAV Reader version 6.3 and firmware version 1.4



BMI PN: 83-00032-01

July 28, 2020

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1 Caution

Read this section before running your BRECHTEL instrument. This device has the following operating conditions that can be hazardous or harmful to your product without proper care.

1.1 Electro-static discharge

Handle the unit during sampling, cleaning and other activities by the metal components, avoid touching the circuit boards and ground yourself before touching the unit.

1.2 Shock during shipping

If the shock watch installed on the shipping case has tripped, contact BRECHTEL. Operate the unit to confirm proper operation before using for actual measurements.

2 Changes

| Change Description | Page | Date | Author |
|---|----------|-----------|--------|
| v1.0 New Release | N/A | 3/1/2019 | FJB |
| v1.1 SW/FW update; SD Card; Specs updated | Cover,13 | 7/29/2020 | FJB |

3 Contact BRECHTEL

3.1 Getting Help

Contact BRECHTEL for any questions or assistance with this product.

Include the model and serial numbers when contacting Brechtel.

1789 Addison Way
Hayward, California 94544

Telephone: (510) 732-9723
Fax: (510) 732-9153
Email: sales@brechtel.com

4 Unboxing

Each BRECHTEL mini-OPC is inspected and tested in-house at BRECHTEL to ensure out of the box operation upon delivery. Prior to opening, inspect the packaging container and ShockWatch impact indicators.

Carefully open the package and inspect the instrument and any accessories for broken parts, scratches, dents or other signs of damage incurred during shipping. Notify BMI within 2 days of receiving the package if the shock indicator (Fig 1) has activated or of any other visible damage.

Notify BMI within 2 days of receiving your product if the shock indicator has activated and/or there is any other visible damage.

Verify the contents of the shipment using the information provided in this manual.

Retain all shipping packaging, foam inserts and cushions to ensure a safe delivery should the instrument need to be returned.



Figure 1: The dark arrows on the shock-watch indicate the package experienced excessive shock during shipping. Red arrows indicate no shock above the G level indicated.

4.1 Before First Use

Any caps installed on air flow inlet or exhaust flow outlet tubing must be removed before first use. If the UAV Reader software will not be used, attach the front panel display using the supplied ribbon cable. The blue/black colored strip on the cable must face the darker brown piece on the connector.

5 mini-OPC Overview

5.1 Description

The mini-OPC (Optical Particle Counter) has been designed in a small and light form factor for applications where space, weight and power availability are important constraints. For example, the unit has been deployed on-board Unmanned Aerial Vehicles (UAVs) and on small research aircraft. The mini-OPC measures the number size distribution of particles twice every second over the diameter range 0.19 to 3 micrometers. The unit has a counting efficiency of 100% over this size range. Although smaller particles can be detected, they are detected with less than 100% efficiency and therefore not reported. Data are reported at 1Hz when using the UAV Reader software. Individual particles are detected using light scattering, the amplitude of the scattered light pulse is proportional to particle size and the concentration is determined by dividing the number of particles counted over a time period by the sample flow rate. The unit is calibrated with size-selected ammonium sulfate (180-600 nm diameter) and polystyrene latex spheres (PSL, 600-2500 nm diameter) to confirm sizing performance.

The mini-OPC sample flow rate is measured by a precision laminar flow element on the inlet and controlled in real-time by modulating the speed of the integrated sheath flow and vacuum pumps. The mini-OPC has 0.9 lpm of filtered sheath flow to focus the 0.06 lpm particle flow tightly to better intersect the 405 nm wavelength laser light. The sheath flow rate is measured by a precision laminar flow element. The sample flow rate is maintained by balancing the sheath flow rate into the unit with the exit flow rate out of the unit.

Do NOT change the values of the sample and sheath flow rates from 0.06 and 0.9 lpm, respectively. Doing so invalidate the size calibration of the mini-OPC.

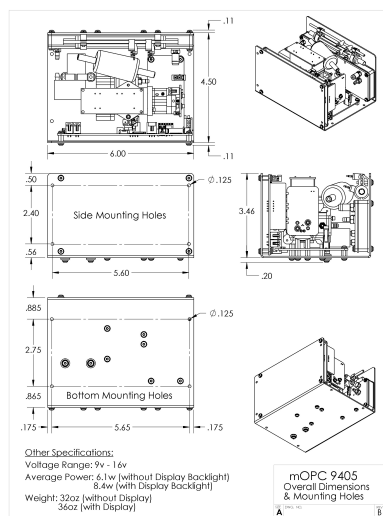


Figure 2: Major dimensions and specifications of the mini-OPC.

Particles take up water under conditions of high humidity, which is one reason the mini-OPC sample flow should be dried before entering the unit to remove particle-bound water that will influence particle size. Contact Brechtel if you require a sample flow drying solution.

The mini-OPC does not require an external computer for data logging and instrument control. The internal software (firmware) in the mini-OPC provides the functionality for measuring signals (particle light pulses, flow rates, sample temperature, pressure, etc.) and controlling the hardware (laser, pumps, PMT, front panel, saving data to SD card).

When combined with the mini-OPC Graphical User Interface UAV Reader Software, the mini-OPC displays the particle number size distribution. The UAV Reader uses the USB connection to communicate with the mini-OPC. All data collected is saved and displayed in real time for analysis. Software communication to the mini-OPC for remote control of the instrument is established through the serial port on the main control board of the instrument using the RS-232 protocol. When using the UAV Reader software data are acquired at 1Hz, users can access the 2Hz raw count distribution data by communicating directly with the RS232 port on the mini-OPC.

5.2 Theory of Operation

Introduction

The mini-OPC is a high size resolution device capable of rapid number size distribution measurements necessary for UAV, urban, or other sampling conditions where fast time response is required to capture rapidly changing aerosol properties. A focusing nozzle is employed with filtered sheath flow surrounding the aerosol sample flow to focus the particle beam and optimize the intersection of the particle flow and laser light. The laser light is focused with lenses and apertures to optimize the beam quality and photon density to maximize PMT response. Low and high gain settings for the PMT are used in real-time to capture pulses from large and small particles, respectively. A light trap is used to capture the direct laser beam light and minimize background photons detected by the PMT. Flow rates are controlled at 2Hz through a feedback loop with laminar flow elements on the sheath and sample flows and the speed of the two pumps.

Particle Refractive Index

The interaction of light incident on a particle depends upon the particle refractive index, which depends on the chemical composition. The refractive index has real (light scattering) and imaginary (light absorbing) components. For the range of compositions typically encountered in ambient aerosol, the real refractive index typically ranges from around 1.3 (water) to 1.7 (salts). For this range, the particle size determined by the mini-OPC can vary by 20-30% due to differences in refractive indices of particles having the same physical size. It is important to calibrate the mini-OPC with monodisperse particles that have refractive indices as close as possible to those anticipated during sampling.

Coincidence Correction

Coincidence occurs at higher sampling concentrations when more than one particle is present within the optical scattering volume at the same time. Since the mini-OPC is not capable of counting multiple particles that are simultaneously present in the scattering volume, the indicated, or measured, concentration will be smaller than the actual, or true, concentration. To improve the accuracy of the measured concentrations, the following equation may be used to correct the measured concentrations for coincidence:

$$N_a = N_i e^{N_a Q_{det} \tau_{det}} \tag{1}$$

where: N_a is the actual, or true, number concentration (cm^{-3}), N_i is the measured number concentration (cm^{-3}), Q_{det} is the volumetric flow rate through the scattering volume (1.0 cc/sec), and τ_{det} is the residence time of particles in the scattering volume (2.0 μ sec). From the equation above and the parameter values given, the coincidence error at 10,000 cm^{-3} is 2% and increases to 18% at 100,000 cm^{-3} .

Note: Saved concentration data have NOT been corrected for coincidence.

5.3 Component Technical Descriptions

The BRECHTEL mini-OPC system includes three separate components.

Component 1 mini-OPC main assembly (body, detector board, main board, pump all integrated to 'U' bracket mount)

Component 2 A front panel display connected by ribbon cable to the main board.

Component 3 A ship kit with weatherproof case, power supply, cables and other items to operate the unit.

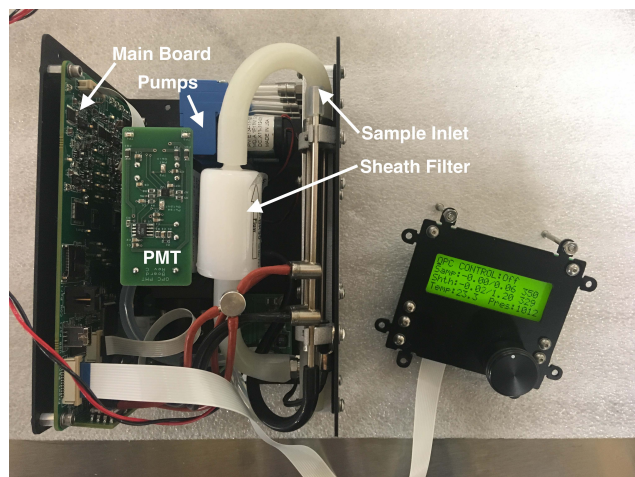


Figure 3: Major components of the mini-OPC.

5.4 mini-OPC Options

There are several optional accessories external to the device that can be added at any time depending on your changing measurement needs.

Table 1: mini-OPC Accessories

| PN | Option | Description |
|-------------|--|--|
| 8008 | 0.5 µm Round Jet Impactor | Remove particles larger than 0.5 µm at 0.6 l min ⁻¹ |
| 8009 | 1.0 µm Round Jet Impactor | Remove particles larger than 1.0 µm at 0.6 l min ⁻¹ |
| ACC-Dryer | Sample Flow Dryer | Dry sample flow to remove particle water |
| ACC-mOPCKit | Maintenance Kit for 9405 mini-OPC | Orings, grease, cleaning tools, etc. to maintain your mini-OPC |
| ACC-PWR | Additional 12 VDC power supply for ground operation of any ACCESS module | Duplicate supply to operate mini-OPC in two locations |
| ACC-PC | Computer loaded with UAV Reader Software | Easily operate mini-OPC in multiple locations. |

5.5 mini-OPC Specifications

Table 2: mini-OPC Specifications

| Description | Value |
|--|--|
| Particle Diameter Range (100% detection) | 0.19 to 3 microns |
| 50% Detection Diameter | 0.18 microns |
| Size bins | 84 (60 bins 0.19-1 microns; 24 bins 1-3 microns) |
| Concentration range | 0 to 50,000 cm ⁻³ (Error<10%) |
| Laser Wavelength | 405 nm |
| Sample flow | 0.06 lpm |
| Sheath flow | 0.9 lpm |
| Vacuum Requirement | None |
| Noise level (1 sigma) | <0.001 cm ⁻³ |
| Communications | USB and RS-232 |
| Operating Temperature | -20 to 35°C |
| Operating Pressure | 200-1,100 mb |
| Operating Humidity | 0-95% RH non-condensing |
| Physical size | 3.7 x 4.7 x 6.0 in/9.4 x 11.9 x 15.2 cm |
| Weight | 2.2 lbs/1.0 kg |
| Supply voltage | 12 VDC (9-16 VDC) |
| Power usage | 6-9 watts (without/with display) |
| Mounting | Hard mounting points in metal body bracket |

6 System Setup

6.1 Packing List

The mini-OPC will arrive in a sturdy weatherproof case holding the base unit and the ship kit. If accessories were ordered they may be packaged in the case or in additional boxes.

See the Appendix for a complete list of all the parts that come with the mini-OPC. Table 3 shows the parts needed to prepare the unit for operation.

6.2 Assembly

The mini-OPC will arrive with the front display uninstalled. Follow the discussion below together with the figure and table to assemble the various pieces.

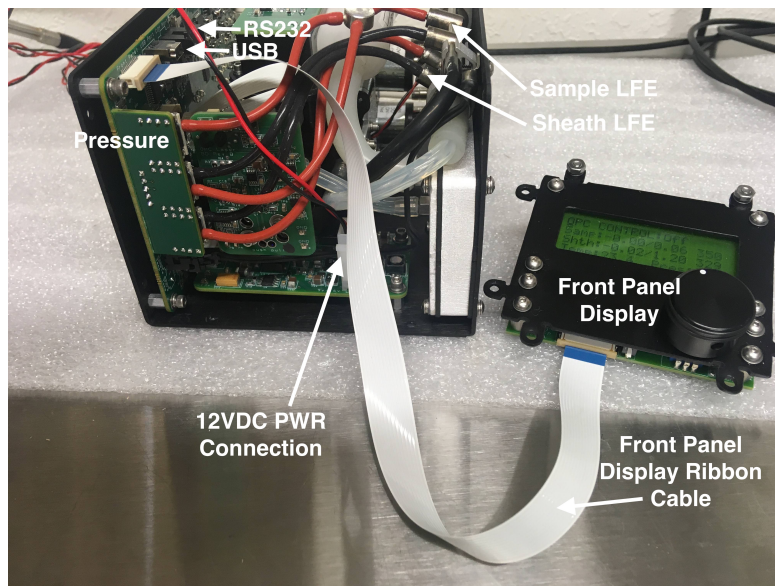


Figure 4: View of mini-OPC assembly.

Table 3: Assembly Parts

| # | Description | QTY |
|---|----------------------|-----|
| 1 | Base Unit | 1 |
| 2 | Front Panel Display | 1 |
| 3 | Display Ribbon Cable | 1 |
| 4 | Ship Kit | 1 |
| 5 | Power supply | 1 |

6.3 Tubing Connections

Connect the sample LFE inlet in Fig. 4 to the aerosol source or other inlet using the black conductive tubing supplied.

6.4 Electrical Connections

When connecting the ribbon cable in Fig. 4 be very careful that it is inserted perpendicular to the mating brown connector on the circuit board. Be sure to connect the provided display ribbon cable to the main board before applying power if the instrument will be configured using the user interface via the display.

Warning: Be sure the blue or black colored side at the ends of the ribbon cable is against the darker brown connector clamping piece on the mating connector. Do NOT connect or disconnect the ribbon cable while power is applied.

NOTE: the front panel display for the mini-OPC is NOT compatible with other 9400 series ACCESS instruments. It employs a wider, 12 conductor cable instead of the 10 conductor cable used on other devices.

Connect the AC-DC power supply from the ship kit to the power input connector on the two-pin connector shown in Fig. 4. To facilitate the use of a battery to power the mini-OPC, DC voltages between 9 and 16 Volts may be used and should be connected to the Molex power in connector provided with the unit. Any AC adapter with an output of 9-16 Volts DC at 1 AMP can be used to power the mini-OPC. The instrument firmware automatically runs when power is connected. Ensure the power plug is fully seated in the connector before connecting the instrument to a computer.

6.5 Communication Connections

Connect the various cables provided with the mini-OPC as described in the table below.

Table 4: mini-OPC Cable Connections. Numbers refer to figure below.

| Port | Description |
|-------------|--|
| 1. USB Port | Mini USB port for communication with computer running UAV Reader software. |
| 2. COM Port | RS232 Serial communication port between the mini-OPC and user PC. |

Connect the USB cable provided in the ship kit to the USB mini connector on the main board, in figure 4.

The RS232 port in figure 4 is used to send remote control commands directly to the mini-OPC from a user computer using the cable provided in the ship kit. The mini-OPC uses a simple 3 wire RS232 connection. The board connector uses a 3 position C-Grid SL connector. A DB9 adapter is included with each mini-OPC ship kit.

The detailed settings for the serial port: RS232: 8 data bits, 1 stop bit, no parity, Baud rates: 38.4k, 57.6k, 115.2k and USB with 230k.

Computer Connections

The UAV Reader interface software requires a USB connection between the control computer and the USB Port on the mini-OPC main board as shown in figure 4. The UAV Reader software may be purchased as an accessory to the mini-OPC installed on a ruggedized tablet, contact BRECHTEL for information.

Connect the USB cable prior to running the software. Do not disconnect the USB cable while the software is running.

The RS232 port, in figure 4, may be used to establish serial communication with the mini-OPC from a user-supplied computer. An interface cable with a serial connector is provided in the mini-OPC ship kit. The port configuration and commands available are described later in this manual.

6.6 Mounting

The mini-OPC is shipped integrated with a mounting bracket with holes for mounting bolts. See figures below for detailed mounting dimensions of the various items. Alternatively, the mini-OPC can simply be placed on a table top. Threaded standoffs may also be used to mount the mini-OPC to a shelf. Be sure to employ at least three hard mounting points to properly support the mini-OPC. Bolts should not extend into the cover so much that they would interfere with the main control board connections.

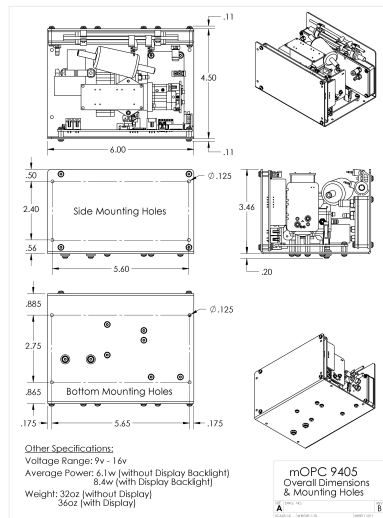
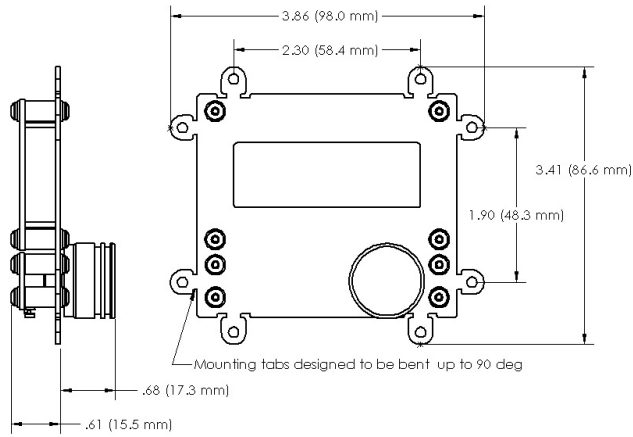


Figure 5: mini-OPC assembly overall dimensions (inches and millimeters in parentheses).



UAV Instrument Front Panel Dimensions

Figure 6: Front panel display mounting bracket detailed dimensions (inches and millimeters in parentheses).

7 Operating the mini-OPC

The mini-OPC measures the optical size and number concentration of particles in the 0.19 to 3 micron diameter size range by detecting the light scattered from individual particles. The mini-OPC is an extremely sensitive measurement device, capable of high size resolution number size distribution measurements at 2Hz under a broad range of concentration conditions.

Practicing good electrostatic discharge (ESD) procedures and understanding proper drying of the particle sample flow are two key aspects of properly operating the mini-OPC. The exposed circuit boards of the unit are susceptible to ESD damage, be sure to install the provided grounding strap and to ground yourself prior to handling the device. Particle size depends on the relative humidity (RH) of the air around the particles since most particles take up water via condensation and grow when exposed to elevated RH. If water is evaporating from particles during sizing in the mini-OPC then the particle size is not stable and a 'true' size will not be determined. Be sure to dry the particle sample flow to RH's below 20% before entering the device.

There are three ways to interact with the mini-OPC, the mini front panel, serially via a RS232 port, and through the mini-OPC UAV Reader GUI program which runs on windows computers and connects to the mini USB port.

Caution: It is important to operate the unit at a fixed sample flow rate of 0.06 lpm and a fixed sheath flow rate of 0.9 lpm. If the flow rates are changed the size calibration will be invalid.

The mini-OPC provides raw size-bin number counts, raw number concentrations versus size, and number size distributions (dN/dlogD) in real time when using the UAV Reader software to interact with the unit. Monitor the flow rates, temperature and pressure during operation to confirm proper operating conditions.

7.1 Electrostatic Discharge Practices

The mini-OPC employs an extremely sensitive detector capable of measuring extremely small electrical signals. To protect the detector, good ESD practices are critical to maintaining and operating your device.

- Be sure to always ground yourself before handling the unit
- Be sure to always connect the unit to earth ground

7.2 Startup & Shutdown

Start the mini-OPC by applying 12V power to the mainboard. Monitor the flow rates and other operating parameters.

To confirm the unit is leak free, install a HEPA filter on the inlet and confirm zero particle count readings from the unit while sampling from the filter. Remove the filter for normal operation.

Shutdown the mini-OPC by turning File Save to 'Off' in the UAV Reader software (if in use) and then removing 12V power from the unit. Be sure to practice good electrostatic discharge procedures if the mini-OPC will be moved.

7.3 Front Panel & Firmware

Although it is possible to run the mini-OPC without the mini front panel, using the mini front panel makes operating the mini-OPC much easier. The mini front panel has a four line character display with a data knob for user input. As well as turning, the data knob can be pressed. A short press will move the onscreen cursor and change the item that the data knob adjusts. A long press will take users from "READINGS" mode to "DEFAULT SETTINGS" mode and back again. Settings are saved when going from "DEFAULT SETTINGS" mode back to "READINGS" mode. The sections below discuss the details of each menu in the mini-OPC firmware.

SD Card Menu

Rotate the data knob to select the SD Card menu. The menu will display the following lines:

SD Save: (Off/On)

File: (Current Filename)

Files: (Total number of files on SD Card)

Size: (SD Card size in megabytes)

Used: (% of the SD Card currently filled)

The only user-settable item in this menu is 'SD Save', all other items are set by the mini-OPC automatically. A quick push of the data knob will select the SD Save value, rotate the knob to change the value.

mini-OPC Control Menu

Rotate the data knob to select the mini-OPC Control menu. A quick push of the knob will allow the mini-OPC to be turned Off or On. The menu will display the following lines:

Sample Interval: (1-60 seconds, can only be changed in settings mode)

Flow: measured sample flow / flow setpoint (both in lpm)

P: pump power (0-200 = duty cycle 0-100%)

Pres: (pressure in mbar)

Temp: (temperature in deg C)

Display Menu

The Display menu displays all mini-OPC readings, the data knob is used to select the readings to display. The following readings are available:

Date & Time Menu

The current date and time of the mini-OPC is displayed. Use short knob presses to move the cursor to adjust the time and date if required. If the UAV Reader software is used as the user interface, then each time the software connects with the mini-OPC the date and time of the unit is reset to the current date and time of the Windows PC running the UAV Reader software.

In "DEFAULT SETTINGS" mode there are six available menus:

COM Defaults Menu

baud_rt: (baud rate: 38.4k, 57.6k, 115.2k, USB)

delimit: (data delimiter: <CR>, TAB, SPACE)

autorpt: (auto report: Off, On)

rpt_lbl: (report labels: Off, On)

Main Defaults Menu

flow_sp: (flow setpoint: 0.04 to 0.1 lpm)

shflow_sp: (sheath flow setpt: 0.9 to 1.1 lpm)

intervl: (averaging interval: 1-60 seconds)

mini-OPCctl: (mini-OPC Control: Off, On)

Diagnostics Menu

psvolts: (power supply voltage)

err_rpt: (error report numbers)

Calibration Values Menu

flow_c2: (sample flow x2 coefficient)

flow_c1: (sample flow x coefficient)

flow_c0: (sample flow offset coefficient)

shflow_c2: (sheath flow x2 coefficient)

shflow_c1: (sheath flow x coefficient)

shflow_c0: (sheath flow offset coefficient)

flwcalt: (temperature during calibration)

prsslop: (slope for pressure reading)

prsoffs: (offset for pressure reading)

vltslop: (slope for power supply voltage reading)

vltoffs: (offset of power supply voltage reading)

Raw Readings Menu

flw_raw: (raw sample LFE flow reading (0-4095))

shflw_raw: (raw sheath LFE flow reading (0-4095))

prs_raw: (raw pressure reading (0-4095))

vlt_raw: (raw power supply reading (0-4095))

Manufacture Info Menu

The Manufacture Info menu displays the following lines:

version: (firmware version)

ser_num: (serial number)

mfgyear: (mfg year)

mfg_mon: (mfg month)

mfg_day: (mfg day)

All settings and calibration values are saved to the on board EEPROM memory when users return to "READINGS" mode from "DEFAULT SETTINGS" mode. If changes are made without returning to "READINGS" mode, e.g. powering off while in "DEFAULT SETTINGS" mode, the new settings will not be stored. If settings are changed via serial communication be sure to send the 'store' command before powering down the unit, otherwise the new settings will NOT be saved.

7.4 Data Files

The UAV Reader software running on a Windows PC stores data to the PC hard disk. A sample data set is included below. The .dat files contain particle count data for each of 84 size bins. The diameter array is written as one of the header rows in the file. The file may be opened with any text editor. The mini-OPC does not currently save data to its own SD Card. The file naming convention is "OPC_XXX_YYMMDD_HHMMSS.dat", where "XXX" is the unit serial number, "YY" designates the year (e.g. 16 for 2016), "MM" designates the month, "DD" designates the day, "HH" denotes the hour, "MM" is the minute, and "SS" is the second. As new files are created on a given day they are named with the corresponding date and time at which the acquisition started. Turning SD Card save to "ON" will save the same format data files described below to the SD Card.

Data File Format

The header of each data file is defined by the lines with the "#" character as follows (descriptions in () do not appear in the file):

```
#OPC Serial Number:98 (serial number of the unit)
#firmware:1.1 (version of the firmware installed on the EEPROM)
#mfg_date:1/29/19 (manufacture date, MM,DD,YY)
# (blank line)
#sample_c2=-1274.3 (sample LFE quadratic cal coef)
#sample_c1=259.7 (sample LFE linear cal coef)
#sample_c0=-33.3 (sample LFE constant cal coef)
#sheath_c2=-5998.1 (sheath LFE quadratic cal coef)
#sheath_c1=1375.7 (sheath LFE linear cal coef)
```



```
#sheath_co=-203.3 (sheath LFE constant cal coef)
#cal_temp=25.0 (temperature during LFE calibration, deg C)
#press_slop=3696.5 (pressure linear slope cal coef)
#press_offs=-143.1 (pressure constant cal coef)
# (blank line)
#pmt_cal=2400 (baseline calibration for PMT)
#hg_pdhoffs=40 (high gain pulse discriminator)
#lg_pdhoffs=40 (low gain pulse discriminator)
#pmt_gain=37 (PMT gain setting)
#lsr_brt_pot=110 (Laser brightness pot setting)
#lsr_cur_pot=127 (Laser current pot setting)
# (blank line)
#cal_hg1=170,460 (high gain size cal, point 1 of 20)
#cal_hg2=180,568
#cal_hg3=190,760
#cal_hg4=200,1032
#cal_hg5=210,1392
#cal_hg6=220,1792
#cal_hg7=250,4096
#cal_hg8=260,4704
#cal_hg9=280,5760
#cal_hg10=310,6784
#cal_hg11=330,7936
#cal_hg12=340,8832
#cal_hg13=380,11008
#cal_hg14=390,11262
#cal_hg15=430,14336
#cal_hg16=470,15360
#cal_hg17=520,15872
#cal_hg18=550,16000
#cal_hg19=590,16200
#cal_hg20=610,16300
#cal_lg1=300,960 (low gain size cal, point 1 of 10)
```

```
#cal_lg2=350,1536
#cal_lg3=410,2432
#cal_lg4=490,2816
#cal_lg5=650,4096
#cal_lg6=700,4352
#cal_lg7=1500,13770
#cal_lg8=2200,16383
#cal_lg9=2200,16383
#cal_lg10=2200,16383
#xover_pt=12000 (low-high gain cross over point)
# (blank line)
# bin_limits=190.0 192.0... (85 diameter values defining the bin diameter limits for each
of the 84 OPC size bins)
```

Data File Column Definitions

Below the header data in each data file, the numeric data is stored in columns as follows:

1. YY/MM/DD: Year, Month, Day
2. HR:MN:SC: Hour, Minute, Second
3. opc_cntl: opc control (0=off, 1=on)
4. sample_sp: sample flow setpoint (lpm)
5. sheath_sp: sheath flow setpoint (lpm)
6. bin_time: time to accumulate bin data (0=0.5 sec, 1=1sec, 60=60sec)
7. total_conc: raw total counts divided by sample flow rate
8. sample_flw: measured sample flow (lpm)
9. sheath_flw: measured sheath flow (lpm)
10. sample_temp: sample flow temperature (deg C)
11. sample_press: sample flow pressure (mbar)

12. lasr_brt: laser brightness reading (0-4095)
13. lasr_cur: laser current reading (0-4095)
14. pmt_base: pmt base offset voltage (0-4095)
15. pmt_offs: setting of pmt offset pot (automatically controlled)
16. sheath_pwr: sheath pump power level (0-400)
17. exit_pwr: exhaust pump power level (0-400)
18. sd_install: whether or not SD card is installed
19. opc_errs: opc error number
20. bin1...bin84: 84 bins of raw count data

7.5 UAV Reader Software

The mini-OPC will interface with the Model 9400 Base Module and UAV Reader Software. The reader (see Fig. 7) provides a graphical user interface (GUI) allowing number size distributions and timelines of total number concentration data to be viewed in real time on a Windows PC. When using the reader software the small front panel display is not necessary and can be disconnected before power up.

The UAV Reader software has been designed to allow multiple instruments to be connected simultaneously so data can be logged and instrument performance monitored all using one user interface. Each instrument has a "main" tab (display) in the software as well as a "details" tab (display) where key operating parameters are shown. If a particular instrument is not connected to the reader software then the tab is greyed out. To see which instruments are connected, go to the "ALL" tab. Multiple mini-OPCs may also be connected to the reader software at the same time, a simple drop-down menu allows selection of the desired serial number unit.

Pay attention to the Program Status light in the top right corner of the software. If it shows red there may be a communication problem.

Various instrument settings may also be controlled via the GUI. For example, on the main tab in Fig. 7 the mini-OPC control (On/Off), SD Card data save (On/Off - Not yet functional), as well as sample and sheath flow rate settings may be controlled. "White" boxes

designate values changeable by the user. If more than one mini-OPC is connected to the reader, any individual unit can be selected by serial number using the drop down button in the top left corner of the main tab. For example, OPC SN 4 is shown selected in the figure. The measured sample pressure and temperature are also displayed. Data must be stored on the PC. The GUI creates the opportunity to remotely control the mini-OPC through external serial port commands. This feature can be useful during UAV flights or remote location deployments. Be sure to click the "Save Settings" button if you change any of the values on the main tab and would like them to be saved as defaults.

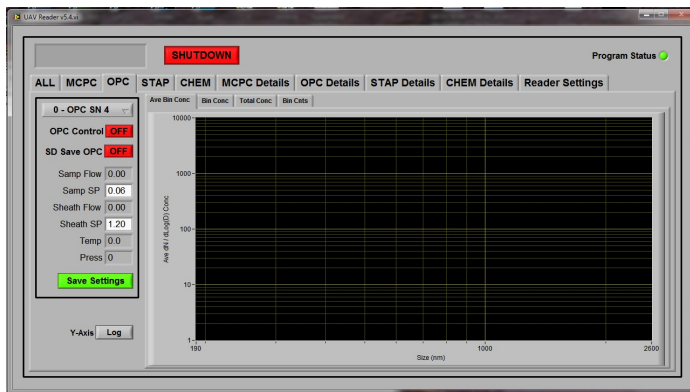


Figure 7: Main mini-OPC tab in UAV Reader software).

There are four different data displays of the number size distribution data on the OPC main tab in Fig. 7. The rightmost tab displays the 84 bins of 1Hz raw count data versus bin number. This is a useful display for checking size calibrations. The total number concentration timeline is also displayed on a separate "Total Conc" data tab, derived by simply dividing the summed raw count data by the sample flow rate. The two other data displays are dN/dlogD data, one ("Bin Conc" tab) is the instantaneous data and the "Ave Bin Conc" tab data are dN/dlogD averaged over the time period entered in the OPC Details tab. The user can change the Y-axis of these plots from linear to log using the button shown.

When using the reader software with the mini-OPC you **MUST** set the mini-OPC firmware baud rate to 'USB'.

The mini-OPC details tab is shown in Fig. 8. Starting in the top left, the mini-OPC real-time clock can be read by pushing the button "Read OPC Clock". OPC hardware settings

and readings are shown in the middle of the display. "PMT" is photo-multiplier tube, the pulse detector in the unit. There are numerous potentiometers set by the firmware to optimize pulse detection. "PDH - Offset HG" designates the pulse detection and hold offset setting for the high gain (small particle) PMT mode, whereas the "PDH - Offset LG" designates the same value for the low gain (large particle) detection PMT mode. The sheath and exit PWR designate the sheath and exit pump power duty cycles.

Error-free operation is designated by a 0 in the OPC Errors box. If a non-zero number is displayed contact the factory.

The laser brightness and current are controlled by the firmware to maintain stable sizing performance. The PMT baseline is also optimized to maintain good small particle detection.

The calibration coefficient values for the sheath and sample LFEs (quadratic), pressure (linear), and the PMT baseline are shown on the details tab. DO NOT change the calibration coefficients unless you have re-calibrated a sensor. You must record the flow temperature during calibration if you re-calibrate an LFE. Use the Raw Readings in the top right of details tab during the calibration.

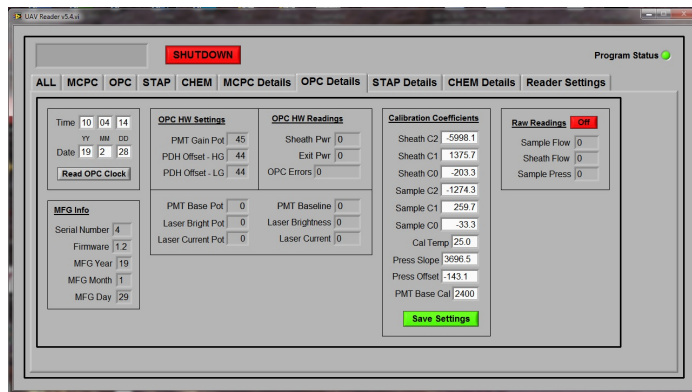


Figure 8: mini-OPC Details tab in UAV Reader software).

If remote control commands will be used via the reader tablet serial port, using the 'o_select' command allows the reader to address the desired mini-OPC if multiple mini-OPCs are connected. To delineate the mini-OPC from other instrument modules that may be connected to the reader, the 'o_' prefix is added to each command. This prefix is ONLY

necessary when sending remote serial commands to the mini-OPC via the UAV Reader tablet.

When using remote control RS232 commands with the reader software and tablet, send the command values in decimal format.

Each time the reader software initiates a new mini-OPC run, the mini-OPC real time clock is synchronized with the clock on the computer running the reader software.

Be sure the computer clock is set to the desired time.

Command syntax for external serial commands to control a mini-OPC via the UAV Reader software/tablet (not for direct serial communication with the on-board mini-OPC RS232 port):

- o_read - Returns readings from currently selected mini-OPC
- o_settings - Returns settings for currently selected mini-OPC
- o_rtclk - Returns real-time clock setting for currently selected mini-OPC
- o_mfginfo - Returns serial number, firmware version, and mfg date for currently selected mini-OPC
- s_select - sets which mini-OPC to communicate with if there are multiple mini-OPCs connected
- o_file_save - sets data file saving on/off by UAV Reader (1=on, 0=off) for currently selected mini-OPC
- o_opc_cntl - sets mini-OPC on/off (pumps) (1=on, 0=off)
- o_sd_save - sets SD Card save on/off (1=on, 0=off) NOT IMPLEMENTED
- o_sample_sp - sets sample flow setpoint (lpm)
- o_sheath_sp - sets sheath flow setpoint (lpm)
- o_clk_sec - set clock seconds
- o_clk_min - set clock minutes
- o_clkhour - set clock hours
- o_clk_day - set clock day
- o_clk_mon - set clock month
- o_clkyear - set clock year

7.6 External Serial Commands

Many of the mini-OPC functions and parameters may be controlled or changed via remote RS232 commands from a user-supplied computer. The commands listed below may be sent directly to the RS232 port on the mini-OPC main board using the Serial-USB converter cable and DB9-Cgrid adapter cable provided with the mini-OPC.

DO NOT use the commands below when communicating with the serial port on the tablet computer running the UAV Reader connected to a mini-OPC. Use the commands listed in the UAV Reader Software section of this manual.

Be sure to set the same communication baud rate on the mini-OPC and the computer used to send the serial command. This MUST be a serial baud rate (e.g. 38400) and NOT 'USB'.

When using remote control RS232 commands DIRECTLY with the mini-OPC, send the values within the commands in decimal format. This is in contrast to other Model 9400 series ACCESS modules the employ a different chip architecture and require hexadecimal format.

Command syntax with commands shown in " " and example response data below each command for the mini-OPC when a computer is connected directly to the mini-OPC main board RS232 port (e.g. NOT using the reader software):

```
"read"  
total_conc=0.0  
sample_flw=0.00 (lpm)  
sheath_flw=0.00 (lpm)  
samp_temp=23.9 (deg C)  
samp_press=1012 (mbar)  
lasr_brt=2769 (0-4095)  
lasr_cur=2698 (0-4095)  
pmt_base=2200 (0-4095)  
pmt_offs=147 (0-255, auto controlled)  
sheath_pwr=340 (0-400)  
exit_pwr=360 (0-400)
```

sd_install=0 (0=no SD, 1=SD)

opc_errs=0

"settings"

opc_cntl=0 (0=off, 1=on)

sample_sp=0.06 (0.03 - 0.12 lpm)

sheath_sp=1.20 (0.6 - 0.18 lpm)

bin_time=1 (0=0.5 sec, 1=1 sec, 60=60 sec)

sd_save=0 (0=off, 1=saving)

auto_rpt=1 (auto_rpt readings, 0=off, 1=on)

rpt_labels=1 (0=off,1=on)

delimiter=0 (0=CR LF, 1=SPACE, 2=TAB)

"calib"

sample_c2=-1274.30

sample_c1=259.70

sample_c0=-33.30

sheath_c2=-5998.10

sheath_c1=1375.70

sheath_c0=-203.30

cal_temp=25.0

press_slop=3696.5

press_offs=-143.1

pmt_cal=2200

"raw"

sample_raw=326 (0-4095)

sheath_raw=336 (0-4095)

press_raw=2981 (0-4095)

"pulse_cal"

cal_hg1=170,460


```
cal_hg2=180,568
cal_hg3=190,760
cal_hg4=200,1032
cal_hg5=210,1392
cal_hg6=220,1810
cal_hg7=250,4096
cal_hg8=260,4704
cal_hg9=280,5760
cal_hg10=310,6784
cal_hg11=330,7936
cal_hg12=340,8832
cal_hg13=380,11008
cal_hg14=390,11262
cal_hg15=430,14336
cal_hg16=470,15360
cal_hg17=520,15872
cal_hg18=550,16000
cal_hg19=590,16200
cal_hg20=610,16200
cal_lg1=300,960
cal_lg2=350,1536
cal_lg3=410,2432
cal_lg4=490,2816
cal_lg5=650,4096
cal_lg6=700,4352
cal_lg7=1600,13770
cal_lg8=2200,16383
cal_lg9=2200,16383
cal_lg10=2200,16383
xover_pt=12000
```

”dig_pots” - changing any of these will change pulse calibration
pmt_gain=45 (0-255)

lsr_brt_pot=110 (0-127)
lsr_cur_pot=127 (0-127)
hg_pdhoffs=44 (0-255)
lg_pdhoffs=44 (0-255)

"rtclck"
clk_sec=44
clk_min=5
clk_hour=10
clk_day=1
clk_mon=3
clk_year=19

"bin_lim" - read only
bl1=190.0
.
.
.
bl85=2600.0

"mfg_info" - read only
ser_num=4
firmware=1.2
mfg_year=19
mfg_mon=1
mfg_day=29

8 Maintenance

8.1 Cleaning the mini-OPC

The sheath flow filter will become clogged with particles over time. Replace annually or whenever the sheath flow control becomes unstable.

If lenses within the unit become dirty, use a Q-tip soaked in IPA to clean them.

O-rings inside the unit will become dry with use. Apply fresh grease to the O-rings. Visually inspect the o-rings for damage and replace any that appear cracked or deformed.

Under persistent high aerosol loading conditions, the sample LFE may become clogged or partially blocked with particles. Remove the LFE from the unit and flush with clean DI water and IPA. Sonicate for 2 hours submerged in water. Blow dry with filtered air after sonication and re-install. The sheath flow LFE is protected by a particle filter and should not require cleaning.

Under persistent high aerosol loading conditions, the sample nozzle may become clogged or partially blocked with particles. Remove the nozzle from the unit and flush with clean DI water and IPA. Sonicate for 2 hours submerged in water. Blow dry with filtered air after sonication and re-install.

9 mOPC Errors

Each mini-OPC error is assigned a bit in the ERROR number. Convert the ERROR number to binary to check the bits. If an error is occurring, the bit for that error will be 1 instead of 0.

The error table below is preliminary, work is ongoing to finalize the list of errors. Contact the factory if errors are reported by your unit.

| Bit Number | ERROR |
|------------|---------------------|
| 1 | EPROM ERROR |
| 2 | BAD Stored Value |
| 3 | Clock - Check time |
| 4 | Clock ERROR |
| 5 | SD Card ERROR |
| 6 | SD Format not FAT32 |
| 7 | SD Card Space ERROR |
| 8 | Bad Thermistor ERR |
| 9 | PUMP MAXED OUT ERR |
| 10 | |
| 11 | |
| 12 | |
| 13 | |

An example error number, converted from HEX to Binary might be: 1000000010000, bit number 1 and 9 are both 1, indicating error 1: EPROM ERROR and error 9: PUMP MAXED OUT ERR.

10 Troubleshooting

Table 5: Common Troubleshooting Solutions

| Problem | Likely Cause | Solution |
|------------------------------|------------------------------------|-----------------------|
| Will not power on | No AC/DC pwr | Plug in supply |
| | Connector not plugged in | Plug in connector |
| Firmware resets | Program-Data Switch set to program | Set switch to data |
| Sample/Sheath flow too low | Pump issue | Test pump flow |
| | LFE clogged | Ensure LFE is clean |
| Sample/Sheath flow incorrect | Calibration drift | Recalibrate LFE |
| | LFE clogged | Clean LFE |
| | Sensor failure | Replace main board |
| Concentration too low | Detector failure | Replace PMT board |
| | Laser failure | Replace laser board |
| | Sample flow incorrect | Calibrate LFE |
| Sizing incorrect | Calibration shift | Recalibrate |
| | Laser shift | Replace laser board |
| | Sample flow out of range | Check LFE calibration |

A Packing Lists

A.1 mini-OPC Ship Kit, PN 51-00032-01B

| Part Number | Description | QTY |
|--------------------|--|------------|
| 001720002B | Certificate of Origin | 1 |
| 001720003B | Certificate of Conformance | 1 |
| 83-00032-01A | Product Manual, mini-OPC | 1 |
| 900200016A | Filter, Capsule, 3.23L x 1.00 OD x .25 Tube | 1 |
| 900700036A | Tubing, Conductive Rubber, 1/4 ID x 3/8 OD, Black | 0.5 ft |
| 902600012A | Cable, USB A to USB Mini | 1 |
| 902600032A | Cable, Serial Converter, RS232 x USB, 2 Meter | 1 |
| 34-00055-01A | Cable Assy, Serial Communication, RS232 to Cgrid SL | 1 |
| 34-00056-01A | Cable Assy, 12VDC Power, Female Barrel Connector | 1 |
| 34-00057-01A | Cable Assy, 12VDC Power, Flying Lead | 1 |
| 34-00058-01A | Cable Assy, Grounding Strap | 1 |
| 902800040A | Power Supply, 12v, 100 W, 8.3 A, Desktop | 1 |
| 903100027A | Flash Drive, 4 GB, USB 2.0 | 1 |
| 903100030A | Flash Memory, SD Card, 4 GB, Micro and Adapter | 1 |
| 903100031A | Memory Card Reader, USB | 1 |
| 96-00004-01A | IM2450 - foam filled (Pick n Pluck) - black case | 1 |
| 96-00007-02A | Shock Label, 7/8" x 2", 25 G Sensitivity, Resettable | 1 |
| POWER-OPTION | POWER CORD (OPTION by Country/Voltage) | 1 |