

iPM

Turnkey Instruments Ltd

Operating Instructions

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The following associated documentation is available from www.i-PM.eu

- **Installation Instructions**
- **Installing the Power Portal**
- **Connecting to AirQWeb**

Please visit to the iGAS page at the website and refer to the iGAS documentation for the installation instructions. Please contact Turnkey if you need more help **techsupport@turnkey-instruments.com**

PREAMBLE

i-PM operates automatically under the control of AirQWeb and associated programs and Apps. The instrument is supplied pre-configured so that it will start operating automatically as soon as it is switched on. The Power Portal is a WiFi 'hotspot' and provides internet access via a 4G cellular modem.

i-PM is factory set as follows:

- Measurements are in SI units
- Reporting interval is 1 minute
- Connection to AirQWeb using a 3G/4G Power Portal is enabled
- Report Pushing is not enabled

Visit www.i-PM.eu to find more information.

The rest of this document gives deeper knowledge of the instrument to allow the operator to change its operating mode to suit their application. These changes can be made using AirQWeb or other programs and Apps. All sampling measurements must be stopped before any of the instrument's settings can be changed.

Operation of the instrument is controlled by the state of its **Feature Flags** and its **Instrument Settings**. Its operational state is indicated by the **Instrument Information** table, **Fault Flag** states and **Diagnostic & Housekeeping Readings**.

Please see Appendix of this document for full lists of the Feature Flags, Instrument Settings, Fault Flags and Diagnostic readings.

If you intend not to use the i-PM instrument for several days, disconnect the battery by setting the **Power** rocker switch to **O**. Return the switch to **1** when you wish to start using the instrument again. You may also momentarily click this switch if, for whatever reason, you need to reboot the instrument.

SAMPLING

Sampling is the process by which the instrument measures and stores readings from the iPHOT laser diffraction photometer. New readings from iPHOT are available every 1 second. Each **sample** consists of a series of readings averaged over successive time intervals known as the **Reporting Interval**. The series of reports, which make up the sample, is known as the time series. The reported readings are the average value of the 1 second iPHOT readings over the reporting interval. Average readings over the duration of the sample are also recorded.

Sampling may be started and stopped automatically as defined by the **Feature Flags**. Automatic samples are generally aligned with 1 minute boundaries. The instrument is set to synchronize its time with an internet NTP time server.

The shortest reporting interval is one second, the longest 50 minutes. You cannot push reports of less than 60 seconds duration. The recommended reporting intervals are between 1 minute and 15 minutes, these give the best compromise between memory use and time resolution. The shortest sampling period is one report interval, the maximum many days.

The instrument's memory can hold up to 100 samples each consisting of many reports. A sample is identified by its **Sample Number**. When the memory is cleared

the sample number is reset to 0. The total number of samples measured by the instrument over its life is the **Sample Total** and can only be reset by Turnkey.

SAMPLE CONTROL FEATURE FLAGS

If *Automatic Start* is set, sampling will automatically start on the next 1 minute boundary after the instrument is switched on. If *Timed Sample* is set the sample will last for the **Duration** number of reports (specified in the **Instrument Settings**) and, if *Automatic Start* is set too, another sample of the same duration will start immediately. This process will carry on till the memory fills when a *Memory Full* Fault Flag will end the current sample and prevent another restarting.

If *Circular Buffer* is set, the last sample (i.e. the one just finished) will be overwritten if the Instrument Settings **Sample Stack** value equals 0, if it equals 1 the last but 1 will be overwritten and so on. Hence it is possible to create a stack of samples that will overwrite forever. For example, if the Sample Stack value equal 28, the last 28 samples will always be available in memory. By default, the sample stack is set to 9.

If *New Sample Daily* is set a new sample will start at precisely midnight but only if *Automatic Start* is set. This can be combined with the *Circular Buffer* flag and the value of the **Sample Stack** to create a rotating, N-day, sample block.

POWER MANAGEMENT AND SLEEPING

i-PM requires an external 12 Volt power supply to operate and sample. The instrument is fitted with a, small, 560 mAh, 4.2 Volt, single cell Lithium battery. The latter allows sampling to be terminated in an orderly fashion if the external power is lost. It also allows stored results to be uploaded and settings changed in the absence of external power.

If the 12 Volt power drops below 7 Volts, measurements will stop and the current sample will be terminated and the *No 12V supply* Fault Flag will be set. If the battery drops below 3.6 Volts the instrument will go into a low power sleep to conserve

energy (regardless of the state of the *AllowToSleep* flag). The *Dead Battery* flag will only be cleared when the battery voltage has recovered to > 3.6 Volt

The *Low Battery* Fault Flag is set when the battery voltage drops below 3.8 Volt, this should never happen while the 12 Volt supply is connected.

When the 12 Volt supply is connected, the red LED on the front panel will be on while the battery is charging. It will flash if the battery has become disconnected.

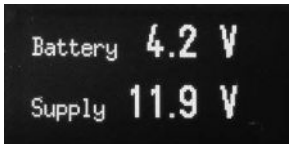
The battery is not required for data storage and the instrument uses flash memory to store the results. Data retention is more than 100 years.

When you have finished using the instrument, it is good practice to set the rocker switch to the O position. This disconnects the battery. Sampling cannot start unless 12 Volt power is present and the rocker switch is in the I position.

GETTING STARTED WITH i-PM

Please refer to the latest versions of the associated documentation for instructions on how to install i-PM, the Power Portal, and connect to AirQWeb. All the latest documentation can be found at www.i-PM.eu .

To turn the instrument on, switch the **Power Switch** rocker to **1**, after a short delay (2-3 seconds) the display will briefly show the battery and supply voltages.



The instrument will only start if the battery voltage is greater than 3.6 Volts and the supply greater than 7 Volts. You must connect the +12 Volt power supply from the Power Portal or similar and wait until the battery is sufficiently charged. The red light will appear when external 12 Volt power is connected and the battery is charging.

It will continue awakening every 100 seconds until the battery and supply voltages are both good. A full recharge may take 3 to 4 hours.

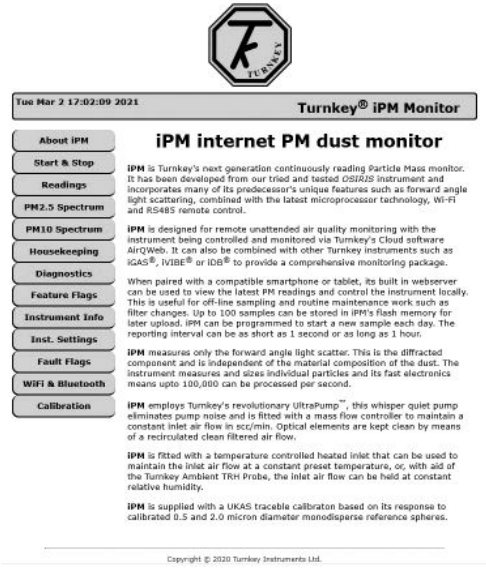
On later versions, the battery will read 5.6V when the 12V supply is connected iPM WILL HAVE BEEN PRESET TO USE THE POWER PORTAL HOTSPOT

Assuming the battery and supply are good, i-PM will then attempt to connect as a station of your WiFi network. It will only do so if the *Use WiFi network* flag is set. If you hold the OK button at startup it will force the iPM to create a local WiFi access point or hotspot instead. Similarly, clicking OK during the WiFi network search will cause the search to be abandoned and a hotspot created and the WiFi Hotspot flag to be set.



On first use, or with a new network, you must use this hotspot to tell i-PM your WiFi SSID and password. To do this, search for the i-PM hotspot with your Android or Apple device. It will be called iPM-xx, where xx are the last 2 characters of the ID on the front panel, and connect using the password XXXX (for security, please contact techsupport@turnkey-instruments.com).

Then, in your browser, navigate to 192.168.4.1 and the following page should appear:

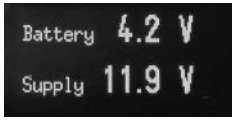


Then, using the buttons on the left, select the ***WiFi & Bluetooth*** page



Select the ***Connect iPM as a station*** checkbox, enter your network's SSID and Password into their edit boxes and click ***SAVE***. The SSID can have 31 characters, the password is AES encrypted and can have a maximum of 15 characters. The plaintext password is never saved in i-PM, only its ciphertext.

Reboot the instrument by toggling the rocker switch. The following sequence should appear on the display.









A valid IP address should have been assigned by your router, you can also see it in the refreshed ***WiFi & Bluetooth*** page above.

The iPM microsite is available via the hotspot or the network and is useful when setting up the instrument in the field and changing the filter. Please consult the factory before changing any of the instrument's flags and settings.

POWER SUPPLY

Applying 12 Volt from the Power Portal should automatically establish an internet connection between i-PM and AirQWeb. Please refer to ***Connecting i-PM to AirQWeb*** from www.i-PM.eu for more instructions.

To connect a third party power supply use a 6 pin Bulgin Micro-Buccaneer cable socket PX0410/06S/4550 with socket contacts. It should be wired as follows:

Pin 1	RS485-B
Pin 2	RS485-A
Pin 3	+12 Volts
Pin 4	+ 12 Volts
Pin 5	0 Volt & chassis
Pin 6	0 Volt & chassis

The 12 Volt DC supply can range between 9 Volts and 15 Volts and should be stable and free from noise and spikes, it must be able to source 1.5 Amperes continuously to drive the Inlet Heater. Verify the inlet reaches the set temperature if using less than 12 Volts.

The RS485 circuit has a 470R load resistor.

POWER ISOLATOR SWITCH

The **Power Isolator Switch** is intended to isolate the battery if the i-PM is not to be used for a long period of time. Only turn the switch to 0 when sampling has FINISHED and results have been stored. Operating the switch when sampling will lose the current sample results and may corrupt previous samples too. Wait till the i-PM has finished sampling, and preferably, gone to sleep before operating the switch.

Please contact techsupport@turnkey-instruments.com if you experience any difficulties.

APPENDIX

FEATURE FLAGS (shown as *underlined italics* in the text)

The operation of iPM is controlled by Feature Flags which may be set or cleared by the operator. They are normally set automatically by AirQWeb. The basic set of Feature Flags is as follows, preset factory defaults are shown ticked ✓ and should not be changed without consultation:

Feature Flag Name		Explanation / Description
iPM	✓	Measure PM concentrations
Auto Start	✓	Automatically start sampling whenever power is on and battery condition is OK. Sampling starts on 1 minute boundary. Will be cleared if sampling stopped manually
Daily sample	✓	New sample starts at midnight each day, the Auto Start feature must be on. Will terminate active sample at midnight
Timed sample		Each sampling period terminates after a set number of reports, specified in the Instrument Settings table (IS)
Stop if fault	✓	Stops sampling if a fatal fault occurs
i-PM Auto Zero		Not used
Save spectrum		Not used
Mean spectrum		Not used
Circular Buffer	✓	Use circular buffers to record stacked samples, number of stacked samples saved before overwrite is specified in the Instrument Settings Table (IS)
Save iPM	✓	Save the iPM readings in the dataset
Save housekeep		Save the Housekeeping readings in the dataset
Save diagnostic		Save the Diagnostic readings in the dataset
Allow to sleep	✓	Allow to fall asleep after about 5 minutes if not sampling and no communications
I need 12 Volts	✓	A 12 Volt supply is always needed by iPM
I expect COMMS		If there have been no communications for more than 20 minutes, sampling will stop and iPM will return to standby for 4 minutes and then to sleep. It will awake and reboot after 100 seconds and await communications for 4 minutes. If none it will return to sleep and the cycle repeats. When communications are received a sample will start if AutoStart is set. Communications are any of RS485, WFi, Oked PUSH or OK click.
WiFi reconnect		Automatically set if iPM is trying to reconnect to your WiFi
Fake readings		For test purposes only
Inlet heat ON	✓	Turns on the heater element, it draws about 800mA at 12 Volt. Temperature is held at set point

Feature Flag Name		Explanation / Description
RH control ON		Requires an ambient T & RH. Temperature is adjusted to hold inlet flow RH at set point
Flow control ON	✓	Automatic volumetric flow control is enabled
User Time Server	✓	Clock is set from Internet time server
Use WiFi network	✓	Connect as station of your WiFi network, needs your SSD and password. Will repeatedly try to reconnect if the WiFi connection is lost. The password is stored as Ciphertext. Factory set to use Power Portal hotspot
WiFi Hotspot	✓	Create a WiFi hotspot to connect your smart device. Allows your network SSID and password to be entered and saved. Clicking OK during reboot will create a hotspot regardless of the state of this flag
Advertise		Not implemented
Publish AdCode 0		Not implemented
Enable PUSH		PUSH reports to remote secure server
PUSH my GPS		Add GPS location to PUSH
Pre-shared key		Not implemented
Ambient Pressure	✓	Measure ambient atmospheric pressure and case temperature
Ambient T & RH		Measure ambient T & RH. A T&RH Probe is required
iPM sample flow	✓	Measure iPM sample flow rate
Command Echo		For test purposes only
Divert U1 to U0		For test purposes only

INSTRUMENT INFORMATION (show in **bold font** in the text)

The Instrument Information table (II) provides additional information about the instrument. It is read only and cannot be modified by the user. Some of the values are automatically uploaded from the iPM photometer. Not all of the Instrument Information is listed below.

Information Table (II)	Explanation / Description
Serial Number	Instrument serial number
Instrument type	iPM Monitor
Manufacturer	Turnkey UK
Software Version	Software version programmed into instrument
Description	PM Particle Mass
Description	Diffracted laser
Time Server	'europe' is locale of default time server
Manufacture Date	Date iPM was manufactured
Oscillator tune	Usually 0, ±127
Time zone GMT ±	Your time zone relative to GMT
Cal. detail	As iPHOT
Cal. Cert No	As iPHOT
Cal. info	TKI-SCC
Cal. due by	Date next calibration is due
iPM zero flow	Zero offset of flow sensor, set to 0.0
iPHOT /s to /cc	Uploaded from iPHOT. Normally 0.25
iPHOT supply V	Uploaded from iPHOT, ~6 Volts or thereabouts
iPHOT offset mV	Uploaded from iPHOT, ~ 860mV
My key	Not used
User PIN	Not used
Fake Particle	For testing purposes, normally 1000
iPHOT Serial No	Uploaded from iPHOT
iPHOT Cal date	Uploaded from iPHOT
iPHOT Cal info	Uploaded from iPHOT
iPHOT Cal Cert	Uploaded from iPHOT

INSTRUMENT SETTINGS (show in **bold font** in the text)

These settings control the instrument's reporting and sampling. They are normally controlled automatically by AirQWeb. Not all of the Instrument Settings are listed below.

Instruction Setting	Explanation / Description
Sample Total	Running count of total number of samples taken by the instrument over its life. Never normally reset
Sample Number	Next sample number, is reset to 0 when memory is cleared. Increments by 1 every time a sample is completed. Range is 0 to 99. Sample 0 is always the first sample
Reporting interval (sec)	Time interval when new results are reported. AirQWeb normally sets this to 1 minutes (60 secs)
Inlet T set (C)	Inlet temperature set point, normally 50 C. Inet heating must be on
Inlet RH set (%)	Inlet humidity set point, normally 30% RH. Requires Ambient T&RH probe. Inlet temperature is adjusted to maintain constant inlet humidity
Flow (scc/min)	The set point sample flow for iPM, normally 600 scc/m
Autozero (sec)	Not used
Spectrum (sec)	Integration time for particle spectra, normally 20 sec
Start time	If sampling, start timestamp of current sample. If not, start timestamp of last sample
Stop time	If sampling, timestamp of first report. If not, stop timestamp of last sample
GPS	GPS latitude, longitude and altitude
User calibration	User scale factor for each size fraction, normally 1.0
User zero	User offset or zero for each size fraction, normally 0.0
ID#	ID index number, normally 1
Sample Stack	Number of samples in the stack before loopback if ***Circular Buffer*** Feature Flag is selected. Default is 10
Report Number	Number of reports in the current sample, or last sample if not sampling
Duration (rpt)	Number of reports in a sample before it auto-stops, only if Timed Sample Feature Flag is selected. If AutoStart is set, will restart a new sample. If Circular Buffer is set will accumulate a circular buffer of samples. Sample Stack sets the number of contiguous samples in the buffer
Company	Company name string, up to 16 bytes
Location	Location name string, up to 16 bytes
Notes	Notes about the sample, up to 16 bytes
Operator	Name of the operator, up to 16 bytes

Instruction Setting	Explanation / Description
Site detail	Details of the site, up to 16 bytes
Bluetooth	Bluetooth device address
Idle Pushes (s)	Interval between pushes if not sampling, default 60 secs
Handshake (s)	Max handshake time with push server, default 10 secs
Watchdog (s)	Strobe interval for watchdog timer, default is 20 secs
iPM Mask	Not used, default 11111111
Housekeep Mask	Not used, default 11111111
Diagnostic Mask	Not used, default 11111111
iPHOT hours	Number of hours the photometer has been used
iPM filter (mg)	Mass in milligrams of dust accumulated on filter, change filter if mass > 4mg. See changing filter (below)
iPHOT changed	Date iPHOT was fitted
iPM filter at	Date iPM filter was changed
iPM Pump Volts	Between 5 and 11 Volts. Typically 7 volts, flow error if more than 10 Volts
Pump frequency	Diagnostic pump frequency, ~25kHz
PushOked	Number of OKed pushes in this idle or sample session
Push retry.fail	Number of retries and number of fails in this session

FAULT FLAGS (shown as *underlined italics* in the text)

These flags indicate the faults or errors the instrument has encountered. Many of these are managed automatically by AirQWeb.

Fault Flag	Explanation / Description
Directory FULL	100 samples have been stored. Sampling is stopped and cannot restart. Upload and clear memory
Memory FULL	The IPM memory is full. Sampling has stopped. Upload and clear memory. Depending on length of samples, may occur before 100 samples have been saved
Flow Error	Set when pump voltage is <5 Volts or > 10.5 Volts
Dead battery	Battery voltage < 3.5Volts. Sampling will have been stopped and cannot re-start until 12 Volt connected
I'm too hot!	The laser temperature is >70C. Sampling is stopped
Fatal Error	One of the above faults has occurred, sampling is stopped until fault condition clears
Memory 90% full	Memory is at 90 % capacity, stop sampling and clear memory
Low battery	The battery voltage is < 3.8 Volts
Cal. < 50 day	Calibration is due in less than 50 days. Have instrument recalibrated
E Cal. OVERDUE	Calibration is now overdue. Soon the instrument will be disconnected from AirQWeb server. Have instrument recalibrated as soon as possible
iPHOT error	Communications error between iPM and iPHOT
No 12V supply	12 Volt supply has disappeared. Sampling will stop
Pump Volts >90%	Pump volts > 90 % of maximum, check filter
Pump Volts > 95%	Pump volts > 95% of maximum, check filter
No WiFi	WiFi connection lost, will try to reconnect automatically
PUSH failed	PUSH not OKed. Will try again
I've lost COMMs	Communications have been lost

Note if a flow error occurs you must restart the instrument by sending a start command via AirQWeb or smart device. It will not restart automatically. Sending the start command will set the pump to mid-voltage and try sampling again. If it fails repeatedly a maintenance visit is required.

Some faults such as over temperature may clear themselves and the instrument will restart if auto-start is set.

Fault Flags are saved at sleep or power down and reloaded at awakening.

CHANGING THE FILTER

The calibration filter is designed to collect dust particles for calibration purposes and to protect the pump and photometer. It is located on the front of the instrument directly beneath the sample inlet and held in place by three countersunk M4 screws.

The recommend filter type is Whatman GF/B 25mm fibre glass circle. Change the filter when the accumulated mass (see Instrument Settings) exceeds 4 mg or if it becomes so clogged the requisite flow of 600 cc/min cannot be achieved.
The command S430 resets the accumulated filter mass to zero, the command S4A sets the filter change date to now.

To change the filter, remove the 3 screws securing the filter cap to the front panel. The cap contains the filter circle secured by an O-ring. Check the O-ring is in good condition when replacing the filter. Check too the smaller O-ring for the exhaust port on the panel. Proper sealing cannot be obtained unless both O-rings are fitted. Make sure the small O-ring is aligned with the exhaust port in the panel before refitting the filter cap. The threaded lugs make sure the filter is aligned correctly.

Never run the instrument without the calibration filter. There is a high capacity secondary filter in the pump which protects the pump and photometer but this will eventually become clogged too, necessitating replacement.

NOTES

- Clicking OK while iPM is searching for a WiFi network will abort the search and turn off the *Use WiFi Network* feature flag and turn on the *WiFi HotSpot* flag. You must re-set and save the use network flag when you are ready to use it, see note on HotSpot security below.
- The small single cell Lithium battery inside iPM allows the instrument enter its standby mode, be setup and have results uploaded in the absence of 12 Volt power.
- If 12 Volt power is lost the iPM will stop sampling, save the sample file and return to standby until power is restored. However, since the microprocessor and WiFi reman operative, the Lithium battery will be exhausted after about 4 hours in standby.
- If the *Allow To Slee*p feature flag is set, the instrument will fall asleep after 20 minutes in standby. It will awaken every 100 seconds and immediately return to sleep if the 12 Volts has not been restored. This increases the battery life to many days. The battery and supply voltages are momentarily shown on the display every 100 seconds. Note the instrument will wait for a 100 second wakeup before restarting after 12V has been restored.
- You can awake the iPM from sleep at any time by clicking OK. It will stay awake for 20 minutes after the last communication unless power is restored. Communications are any of RS485, WFi, Oked PUSH or OK click.
- If the *I expect COMMS* feature flag is set, the instrument will go to standby and awakening sleep until communications are restored.
- In the unlikely event of the internal battery being exhausted, the instrument can be restored by simply reconnecting the 12 Volt supply. It may take several 100 second wakeup cycles before the battery recovers sufficient energy to safely reboot the instrument.
- Sending a stop sampling command will clear the AutoStart feature flag.
- Feature flags are saved at the end of each sample and at sleep or power down. They are reloaded on awakening.

SECURITY

The WiFi HotSpot is only protected by a weak password. After the iPM WiFi network has been setup, you might want to consider turning off the ***WiFi Hotspot*** feature flag. This will stop un-authorised access to your instrument via a smartphone.

For maintenance, you can re-enable again by clicking OK at power on. Remember to re-enable the WiFi network afterwards.

The SSID password and PUSH token are only stored in iPM memory as Ciphertext, never as Plaintext

NOTES

Please visit i-PM.eu to access other iGAS, iDUST, and i-PM documentation

If you need assistance, please contact:

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Revision History
Original, 21 Mar 2021
Corrections and Notes added, 20 Sept 21
Minor updates, April 22

Turnkey Instruments Ltd