Fachhochschule Nordwestschweiz
Hochschule für Technik

Institute for Sensors and Electronics (FHNW/ISE)

Handheld Emission Particle Counter (HEPaC)

Operation Manual

Document information

FHNW/ISE, 2020
Related device versions: v 1.0
Related firmware versions: ≥ 137
Document version: 1.04
Document Date: 2021-05-27

Document change log

Date	Change
2020-02-20	Initial version
2020-03-11	Safety information (page 2) – “do not measure with charger connected…”
2020-05-28	Additional changes for certification
2020-07-02	Additional changes for certification - Added version information displayed on screen during startup
2021-05-27	Extended error description

Abbreviations and definitions

DC	Diffusion charging, diffusion charger
d	diameter, number based geometrical average mobility diameter, geometrical standard deviation 1.4 …1.6
E	Efficiency
HV	High voltage
LED	Light-emitting diode
N	Number concentration

Safety information

General notes and warnings

This operation manual must be read completely before using the HEPaC. Incorrect use or handling and any consequences arising from this may damage the device or endanger personnel.
The manufacturer declines all liability resulting from incorrect use and handling.
During operation the evaporation tube is hot, do not touch.
Do not measure a vehicle with the charger connected to the HEPaC sensor unit!

Safety notes

Never operate the instrument at condensing conditions.
Do not blow into the instrument.
Do not open the HEPaC as you may damage it.
The HEPaC is a sensitive instrument made for measuring nanoparticles. Sampling too much coarse dust will eventually lead to deteriorating instrument performance.
Do not operate the HEPaC in an explosive atmosphere or in the presence of flammable gases or fumes.
Have your instrument recalibrated once a year.

Instrument specifications

Measurements and accuracy

Measured value:

Particle number concentration N

Concentration range :

N: 10^3 – $5 \cdot 10^6$ pt/cm^3

Efficiency E versus size:

23nm: E<50%
41nm: E>40%
80nm: 70% < E < 130%
200nm: E <150%
30nm Tetracontane (up to $10^5 cm^{-3}$) E < 5%

Time resolution: 1 s
Response Time: 5 s

Technical specifications

Inlet flow: 0.5 l/min
Environmental Operating Temperature: 5 – 30°C
Storage Temperature: -10 – 50°C
Sensor temperature: 55°C
Evaporation tube temperature: 195°C
Heat up time: ~ 20min
Relative Humidity: 10 % to 90%, non-condensing
Environmental pressure range: 860 – 1060 hPa
Mechanical environment: M2
Electromagnetic environment: E2
Battery: Rechargeable Li-Ion, 48Wh
Battery lifetime: ~ 3h (with a new battery)
Battery Charging voltage: 12V ± 2V
Max. charging current: 4.5A
BT wireless range: 3 - 30 m, depending on obstacles
Noise: < 60dB
Dimensions: 8.8 x 14.2 x 3.4 cm
Weight: 450 g

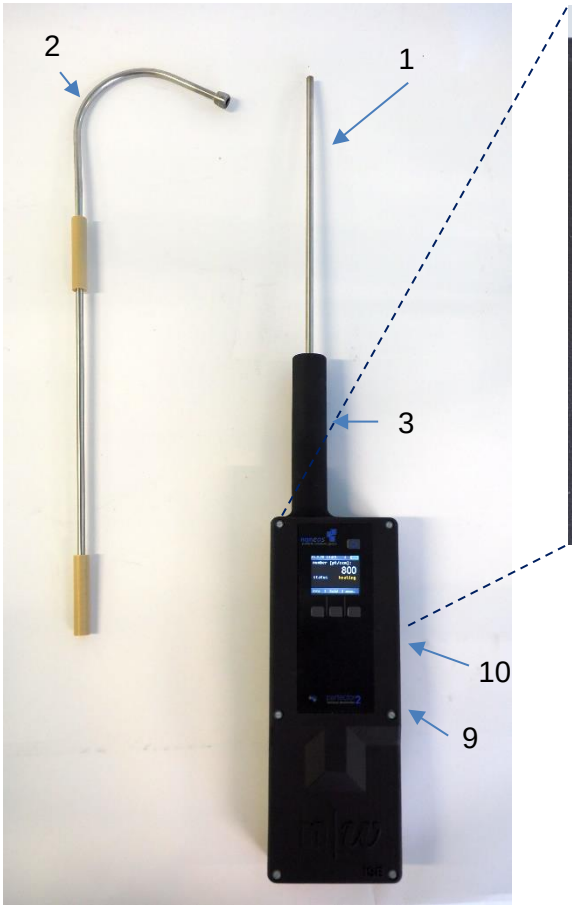
Storage and transport

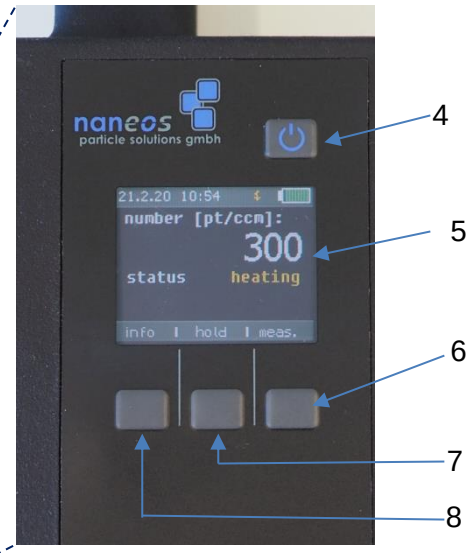
To avoid damage during storage and transport, please use original packaging.
Avoid locations with high/low temperatures and high humid conditions or places that can get wet.
Do not store the device with an empty battery.
Do not store the device in direct sunlight.

Getting started

Instrument description

The HEPaC is a hand-held, battery powered instrument based on the partector2 by naneos (naneos.ch) to measure the number concentration of nanoparticles. It displays the measured data on a graphical display. The device can communicate with devices supporting Bluetooth LE. Main application is the measurement of particles emitted by diesel engines according to the Swiss regulation for construction engines[1].
A Win10 Software package is supplied to monitor the measuring process on a PC/Tablet etc. and to produce the test report, but all the data processing is done in the HEPaC.





1 aerosol inlet
2. Sampling tube extensions
3 evaporation tube (caution hot)
4 power button
5 display
6 right key, start measurement
7 middle key, hold
8 left key, get info
9 12V connector
10 aerosol outlet

Figure 1: HEPaC main parts

Figure 1 shows a picture of the instrument, Figure 2 the internal setup. The sampled exhaust is first heated to a temperature of 195°C to evaporate volatile species. To avoid renucleation the whole sensor is heated up to 55°C. Particles are then charge by a unipolar diffusion charger (Corona charger). The ion current in the charger is measured and kept constant by a feedback control loop. The charge particles enter in to an electrostatic precipitator, operated pulsed. The charge pulses, leaving the precipitator enter into a stage, where the charge, induced by the charge pulses is measured. Min. and

[1] Verordnung 941.242 des EJPD über Abgasmessmittel für Verbrennungsmotoren

Max. voltage of the precipitator pulses allow to tune the efficiency as function of diameter. The flow is measured by the pressure drop over a nozzle and kept constant by controlling the pump. For more details on the sensor operation see[2]Sensors for ambient temperature and pressure allow to relate the measured signal to ambient conditions.

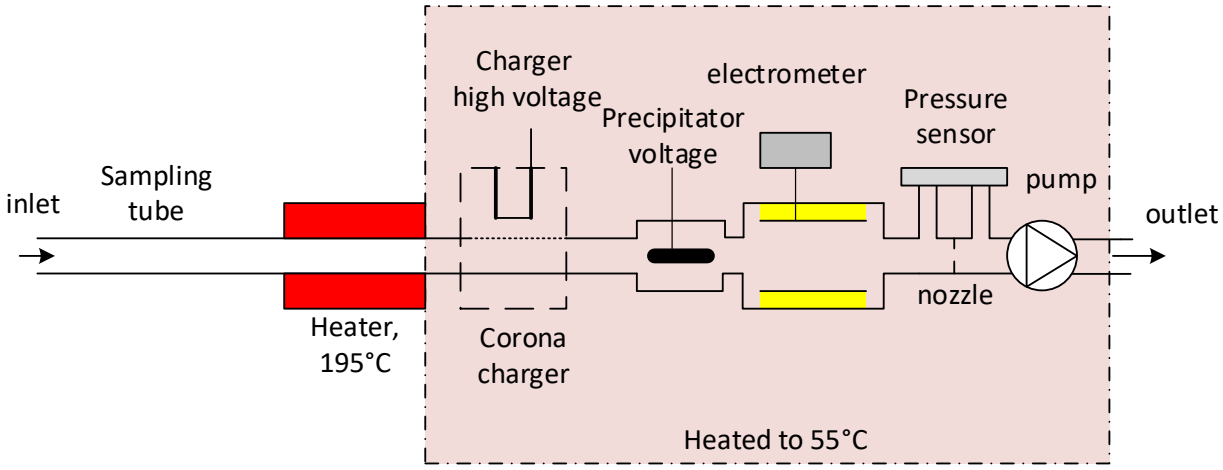


Figure 2: sensor flow chart

Aerosol inlet and outlet

The exhaust gas sampling tube is located at the top of the instrument. Before entering into the instrument, the exhaust passes through an evaporation tube. Depending on the location of the exhaust pipe extensions for the sampling tube may be used (see Figure 1). The internal pump provides a regulated air flow of about 0.5 l/min. A coarse wire mesh keeps coarse dirt and small insects out of the instrument.
The air exits the device via slits at the right side of the housing. The shape of the slits prevents the outlet to be closed by a finger.

Supplying power

To charge the HEPaC battery or to operate it for periods longer than the battery lifetime, connect it to the 12V±2V power supply.
While charging, the battery symbol will blink in white.
The HEPaC supports fast charging (~4.5A charging current).

Legal measurements have to be done battery operated without external power supply (the measurement cannot be started, if a power supply is connected).

Turning the device on and off

To switch on the device, press the power button. To turn it off, press and hold the power button for two seconds and release it when the goodbye message appears.
During startup the version of the firmware and measurement engine is displayed on screen. Additionally the ambient temperature used for ambient correction is displayed on screen.

[2] M.Fierz, D.Meier, P.Steigmeier and H. Burtscher: Aerosol Measurements by induced currents. Aerosol Science and Technology, 48, 350-357, 2014.

Keypad functions & symbols

In Figure 3, you can see the display screens:

Figure 3: menu screens

Home screen

On the home screen you can see the number concentration, date and time and the charge state of the battery. If no key is pressed for more than one minute, the display will be dimmed to prolong battery life. By pressing any key, the display turns on to full brightness again.

The lightning symbol indicates that the high voltage in the charger is on and working properly.

The exclamation mark indicates that an error occurred at some point during a measurement

Right key ‘meas.’ Starts the official measurement cycle

Middle key ‘hold’: shows a 10sec average particle number concentration. The color of the displayed value turns to blue as long as ‘hold’ is active. It is released by pressing the key once more.

Left key ‘Info’ leads to the ‘info’ screen

Info screen

The info screen displays device specific system information:

Serial:	serial number of the device
Minutes:	total operating time in minutes
kPtmin:	particle concentration value integrated over time
Pulses:	number of high voltage charging pulses
Calib:	calibration factor for the particle number count
Date:	date of calibration

Pressing the “status” soft button brings you to the status screens. Pressing the “config” soft button brings you to the configuration screen.

Status screens
The status screens show the most important device data. You can switch between the individual status screens by pressing “next”.

Ambient

P	air pressure [hPa]
RH	internal relative humidity [%]
T	internal temperature [°C]
Alt	calculated height above sea level [m]

Note: Altitude is calculated for average pressure. It may be off by several 100 meters if ambient air pressure is very high or low due to a high- or low-pressure area passing through.

corr	current ambient pressure and temperature compensation [%]

High voltage

HV	charger corona voltage [V]
Idiff	charger diffusion current [nA]
DV	deposition voltage [V]

Electrometers

EM1	signal of electrometer 1 [mV]
EM2	signal of electrometer 2 [mV]
A1	electrometer 1 amplitude [mV]
A2	electrometer 2 amplitude [mV]

Miscellany

Batt	battery voltage [V]
Error	displays the current error status (0 = no error)
Flow	approximate flow through device [lpm]

ThermoController

Ts_pt	sensor set temperature
Ts_pr	evaporation tube set temperature
T_pt	sensor measured temperature
T_Pr	evaporation tube measured temperature

PWM_pt heating power sensor
PWM_pr heating power, evaporation tube

Charger

Vbat	battery voltage
Vin	Input voltage
Ichrg	charging current
Fault	error

Config screens
Time and Date: the internal clock of the HEPaC has an accuracy of about 1s per day. It does not change to daylight saving time and back automatically. Therefore, you may need to set the clock from time to time.

Data rate
For certification purposes the sensor can store the measurement data with 10Hz to an internal memory. It is also possible to store the measurement data with 1Hz.

Meas.mode (= measurement mode)
There are two operation modes:

1. “always” (= always on)
    - In this mode the sensor does not switch off the pump and the internal high voltage. This mode is used during the calibration/certification process.

2. “interm.” (= intermittent)
    - In this mode the sensor switches the pump and the internal high voltage off after x seconds after measurement. The sensor will switch on the pump and high voltage automatically when a new measurement is started (e.g. by pressing the ‘meas.’-button

Press the “next” soft button until you are on the field you want to modify, then use the “up” and “down” soft buttons to change the field’s value.

Error messages
If an error occurred, the HEPaC sensor will show ‘ERROR’ on the home screen. The PC software will show a detailed error message. Those errors are described in the PC software section of this document.

Recommendations
If a high concentration (> 3mio) has been measured, it is recommended to turn the sensor off and on again. During startup the sensor performs a selfcleaning procedure."

We recommend connecting the battery charger during heating up to increase the measurement time before having to recharge the battery

PC Software
Introduction
The PC software is used to generate the official measurement reports (in all supported languages). It also displays the status and real time values of the sensor. The software communicates via a Bluetooth LE USB dongle with the sensor.
The PC software will be preinstalled on a tablet/laptop and will start automatically after boot. For installation procedure, please contact us.

The user interface of the software consists of a toolbar and a main window:

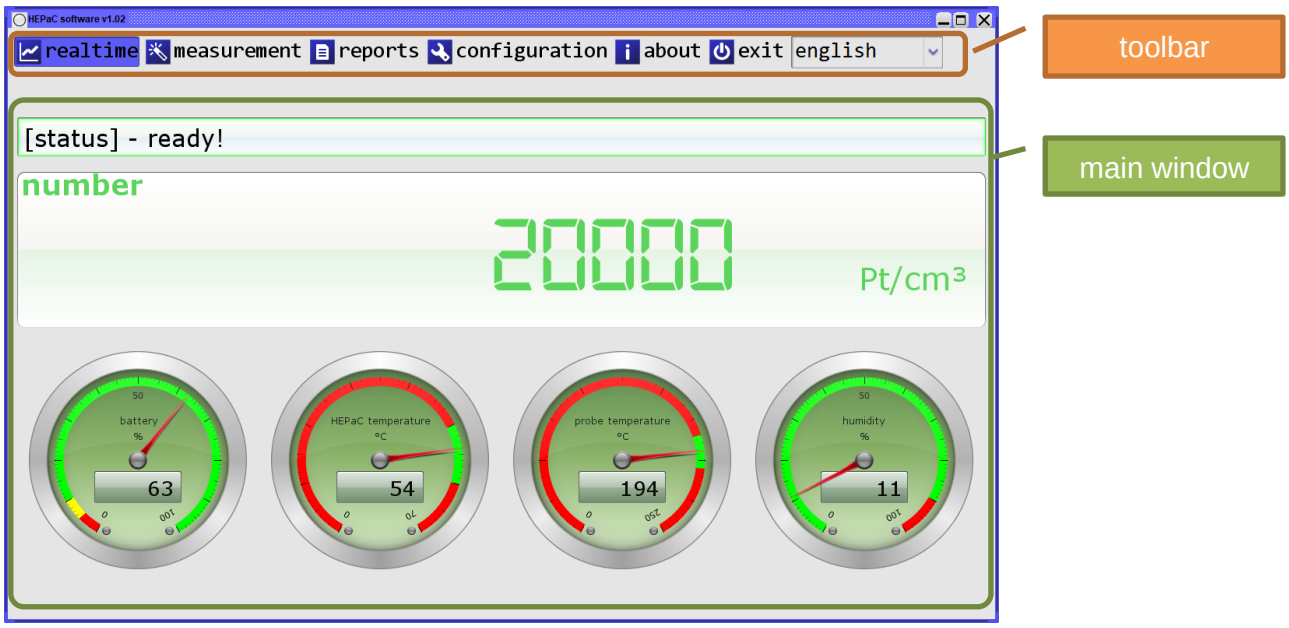

HEPaC software v1.02
realtime
measurement
reports
configuration
about
exit
english
toolbar
[status] - ready!
number
20000
Pt/cm³
main window
battery
%
63
HEPaC temperature
°C
54
probe temperature
°C
194
humidity
%
11

Figure 4

Realtime
Displays the real time data of the sensor:

- sensor status
- particle number concentration [Pt/cm³]
- battery status [%]
- temperatures of the sensor and evaporation tube (probe) [°C]
- aerosol humidity (@ sensor temperature) [°C]

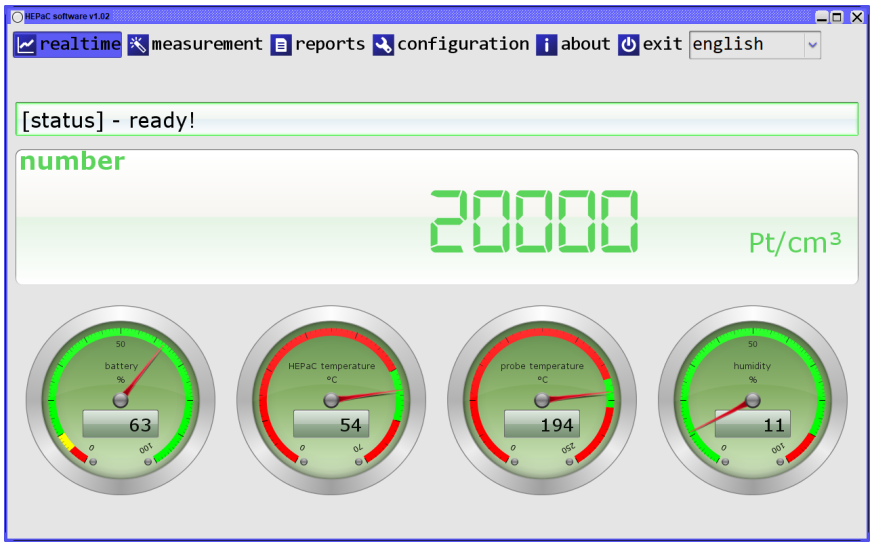


Figure 5

Measurement
Shows information about the measurement cycle.

- device status
- ‘meas. name’ (= measurement name)
- current particle number concentration
- ‘start measurement’ button to start a measurement (but you can also use the ‘meas.’ button on the HEPaC sensor)
- measurement progress

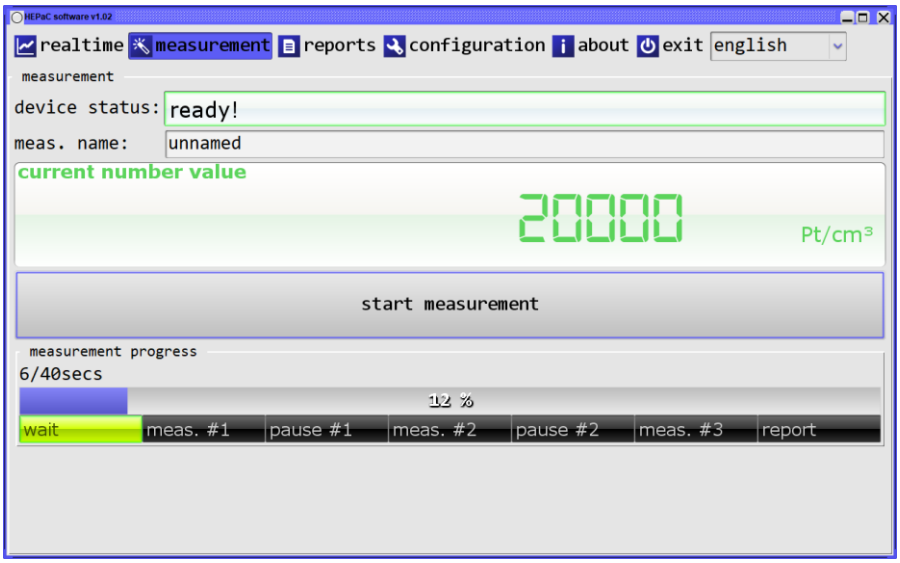


Figure 6

To change the name of a measurement, click on ‘unnamed’. A virtual keyboard will be displayed. To finish the input, click on ‘EXE’.

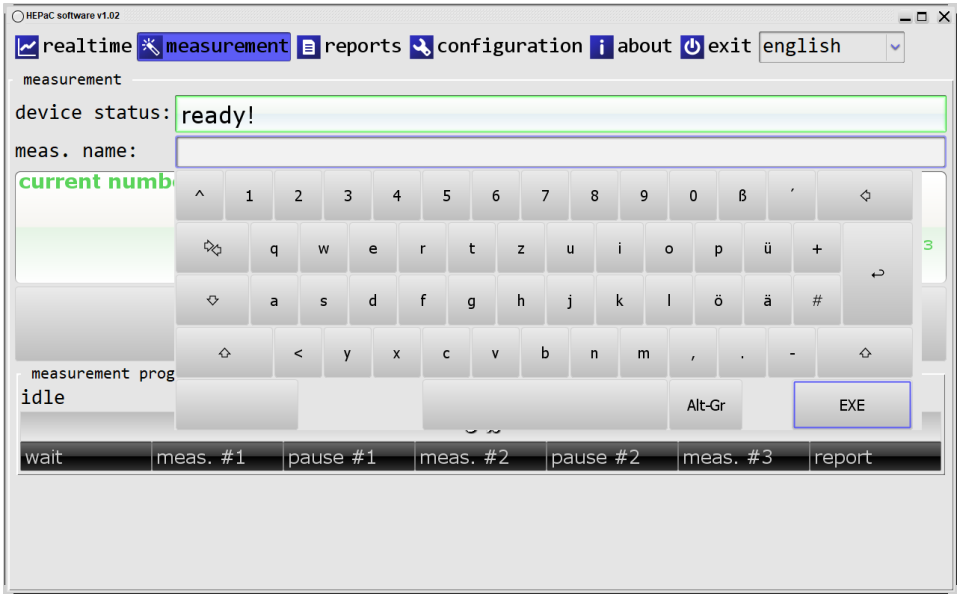


Figure 7

Reports
Displays the acquired reports. To scroll the report, drag with mouse or use scrollbars. The reports are stored as protected PDF in the subfolder ‘Desktop --> HEPaC software --> HEPaC --> reports’. The report name contains date and time of the test and the test name.

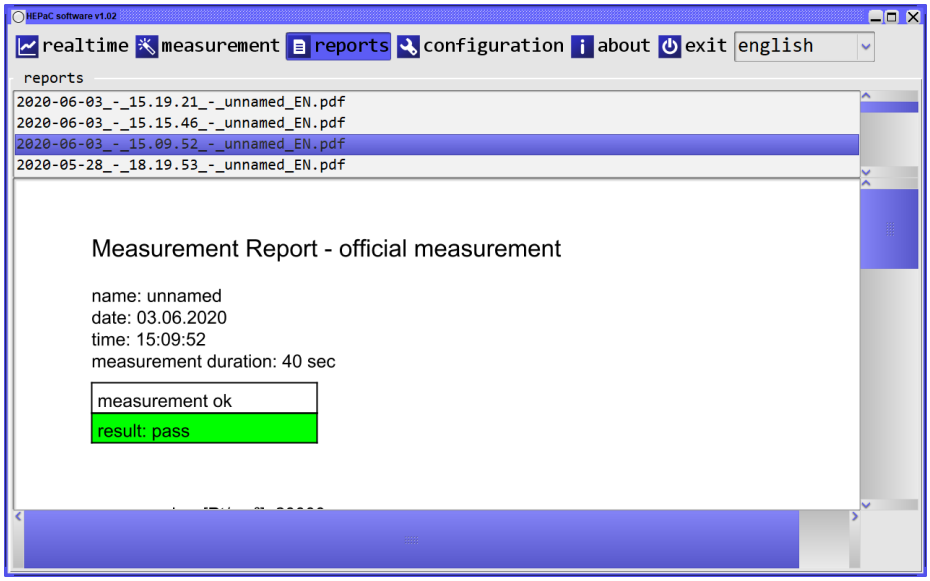


Figure 8

The report language can be chosen (toolbar, right), English, German, French and Italian are available.

Figure 9 shows two examples of reports, one for a valid measurement, on where an error occurred.

Measurement Report - official measurement

name: unnamed
date: 03.06.2020
time: 15:09:52
measurement duration: 40 sec

measurement ok
result: pass

avrg. number [Pt/cm³]: 20000

HEPaC status:
- no HEPaC errors occured

measurement status:
- battery: ok (3.3V)
- rel. humidity: ok (max 15%)
- HEPaC temperature: ok (54°C)
- probe temperature: ok (194°C)

software version: 1.0
HEPaC serial number: 8111
last calibration: 20.5.2020

variable	measurement #1	measurement #2	measurement #3
average number [Pt/cm³]	20'000	18'000	22'000
max number [Pt/cm³]	22'000	20'000	24'000
min number [Pt/cm³]	18'000	16'000	20'000
max humidity [%]	14	14	14

Measurement Report - official measurement

name: unnamed
date: 03.06.2020
time: 15:19:21
measurement duration: 40 sec

measurement ERROR
result: INVALID!

avrg. number [Pt/cm³]: >5000000

HEPaC status:
- HEPaC ERROR: particle concentration too high! (EM overflow)

measurement status:
- battery: ok (3.3V)
- rel. humidity: ok (max 15%)
- HEPaC temperature: ok (54°C)
- probe temperature: ok (194°C)

software version: 1.0
HEPaC serial number: 8111
last calibration: 20.5.2020

variable	measurement #1	measurement #2	measurement #3
average number [Pt/cm³]	2'000'000	>5'000'000	>5'000'000
max number [Pt/cm³]	2'400'000	>5'000'000	>5'000'000
min number [Pt/cm³]	1'800'000	4'000'000	4'000'000
max humidity [%]	14	14	14

Figure 9: Measurement report, left: valid measurement, right: error, particle concentration too high, out of range

Configuration
In this window you can change the configuration of the HEPaC software. We advise you not to change any parameter, only after we instructed you to do so. After changing a parameter, do not forget to press the save button and restart the application.

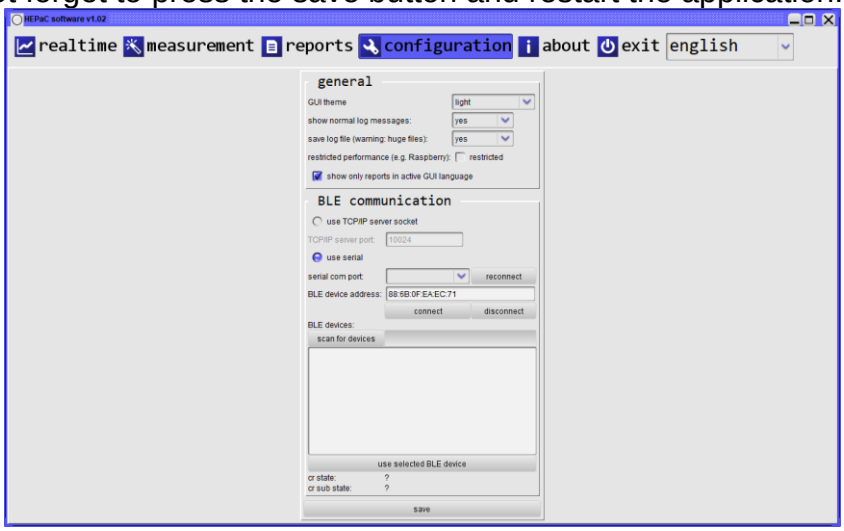


Figure 10

About
Information about the HEPaC software.

Figure 11

Exit
Here you are able to close the software.

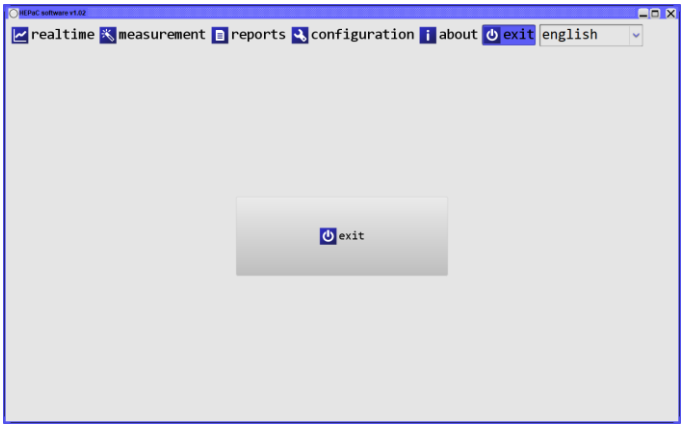


Figure 12

Warning and error messages

Introduction

See “german”

Warnings and error messages of the JAVA software

“ERROR: no HEPaC data available”
“ERROR: HEPaC temperature is too high”
“WARNING: HEPaC temperature is too low”
“ERROR: probe temperature is too high”
“WARNING: probe temperature is too low”
“ERROR: humidity is too low”
“ERROR: humidity is too high”
“ERROR: battery is empty”
“WARNING: battery is low”
“ERROR: HEPaC reports error”

“HEPaC ERROR: diffusion current did not reach low level”
“HEPaC ERROR: diffusion current did not reach high level (Pt/ccm³ too high?)”
“HEPaC ERROR: relative humidity too high”
“HEPaC ERROR: offset too high”
“HEPaC ERROR: corona voltage too low”
“HEPaC ERROR: buffer overflow”
“HEPaC ERROR: generic”
“HEPaC ERROR: deposition voltage too low”
“HEPaC ERROR: particle concentration too high! (EM overflow)”
“HEPaC ERROR: selftest error”
“HEPaC ERROR: flow error”
“HEPaC ERROR: heater error”
“HEPaC ERROR: EM 2 gain”
“HEPaC ERROR: pump current”
“HEPaC ERROR: flow sensor not responding”
“HEPaC ERROR: EEPROM”

“INFO: power supply connected”
“INFO: power saving active”
“INFO: HEPaC not ready yet. Please wait...”

Maintenance

All critical parameters (temperature, pressure, corona voltage, diffusion current, flow, electrometer offset) are measured. If they are not in the specified rage an error message is given and the legal measurement cannot be started. The device also has a self-cleaning procedure integrated, which is activated after turning on the instrument. It is recommended to use this function after measuring unusually high concentrations (e.g. vehicles without filter).
No other maintenance by the user is required. In case an error occurs contact the manufacturer.
Maintenance interval is one year. This is done by the manufacturer and includes:

- Cleaning of the sensor
- Testing the proper operation of all sensors (and replacing/recalibrating them if needed)

- Testing the calibration of the instrument, recalibration is needed.

Contact:
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