Ambient Air Analyzers

APDA-372 / APDA-372 E

FINE-DUST MONITORING SYSTEM

Instruction Manual

Version: HE0050419, valid as of firmware version 100449

APDA-372 / APDA-372 E Fine-Dust Monitoring System Instruction Manual

Preface

These instructions describe the operation for the Fine-Dust Monitoring Systems, APDA-372 and APDA-372 E. Be certain to read this manual before using the product in order to ensure that the device is operated properly and safely. You should also save the manual in a reliable manner so that it is readily available whenever required. The product specifications and the appearance as well as the contents of this manual may be altered without advance notification.

Warranty and responsibility

The product delivered to you is covered by a warranty from HORIBA for the period of one (1) year. In the event of malfunctions or damage during this time period for which HORIBA is responsible, the necessary repairs or the replacement of parts will be carried out by HORIBA at no charge. The warranty does not cover the following:

- Any malfunction due to improper operation;
- Any malfunction due to repairs or modifications by any party not authorized by HORIBA;
- Any malfunction due to use in an unsuitable environment;
- Any malfunction due to disregard of the instructions contained in this manual;
- Any malfunction due to use in a manner that is not described in this manual;
- Any malfunction due to natural catastrophes, accidents or mishaps that are not HORIBA's responsibility;
- A deterioration in appearance due to corrosion, rust, and so on;
- Consumables and the replacement of consumables;
- Products of other companies.

HORIBA is not liable for damage resulting from malfunctions of the product, any deletion of data or other uses of this product.

Trademarks

Other brands, company names, brand names or registered trademarks are the property of the respective company.

CE conformity declaration

The APDA-372 / APDA-372 E complies with the regulations of the European directives:

Directive:	
EMC directive	89/336/EC
Low voltage directive	73/23/EC
Standards:	
EMC directive	EN61326-1: 2006 Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements
Low voltage directive	EN61010-1: 2010 Safety regulations for electrical equipment for measurement, control and laboratory use Part 1: General requirements

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IMPORTANT – Please take note!

- Please check the device for externally discernible transport damage immediately after unpacking. If damage can be ascertained, the device must not be put into service under any circumstances for safety reasons. If this is the case, please contact the manufacturer.

- Only put the APDA-372 / APDA-372 E into service after thoroughly studying the operating instructions!

- The manufacturer is not liable for damage that is caused by improper commissioning, use, cleaning, operating errors or the measurement of aerosols for which the gas state and gas composition are not included in the device's specifications.

- The device must only be operated at atmospheric ambient pressure and at temperatures of +5 °C to +40 °C at the operating site.
  The manufacturer does not assume any functional guarantee for operation under other ambient conditions, e.g. in corrosive or explosive environments, in strong electrical or electromagnetic fields, in areas with ionizing radiation or in areas exposed to shock and vibration.

- **To switch off the APDA-372 control unit, the "shut down" button must be pressed, after which the APDA-372 then switches itself off automatically. The mains switch must only be switched off after the operating system has shut down, otherwise a loss of data is possible!**

- **The APDA-372 is set to a fixed mains voltage by the manufacturer in accordance with the order. Please check to be sure the mains voltage specified on the type plate matches the mains voltage at the intended work site.**

- Only use original spare parts! Please contact the manufacturer if these are needed.

- The measurement procedure employed by the APDA-372 system is not gravimetric, but instead uses an equivalence method. Consequently, an exact match with gravimetric analysis cannot be guaranteed in every case.

- The measuring system must be calibrated regularly using the gravimetric reference method for PM10 and PM2.5 in accordance with DIN EN 12341: 2014 at the installation site.

Caution: Aerosols can be injurious to health depending on the type. They should therefore not be inhaled. With hazardous materials, corresponding protective clothing (respirator mask) should be used. Please observe the respective guidelines and accident prevention regulations.

- General information on optical particle counters, such as the resolving power, counting efficiency and detection limit, can be found in the VDI Guideline 3489, Sheet 3.

- **The APDA-372 is shipped in the state in which it was subjected to the TÜV equivalence test. This also applies for the device version APDA-372 E. If corrections are to be made to this state, please take section 3.5 into account.**

1. Installation and initial commissioning

1.1. Verify the mains voltage

The device is set to a fixed mains voltage by the manufacturer in accordance with the order. Please check to be sure the mains voltage specified on the type plate matches the mains voltage at the intended work site. The manufacturer is not liable for damage resulting from operation with an incorrect mains voltage!

1.2. Verify the completeness of the delivery

When the APDA-372 is transported by a carrier, the APDA-372 system is dismantled into its components. The system must be reassembled once again before initial commissioning. The following parts must be present:

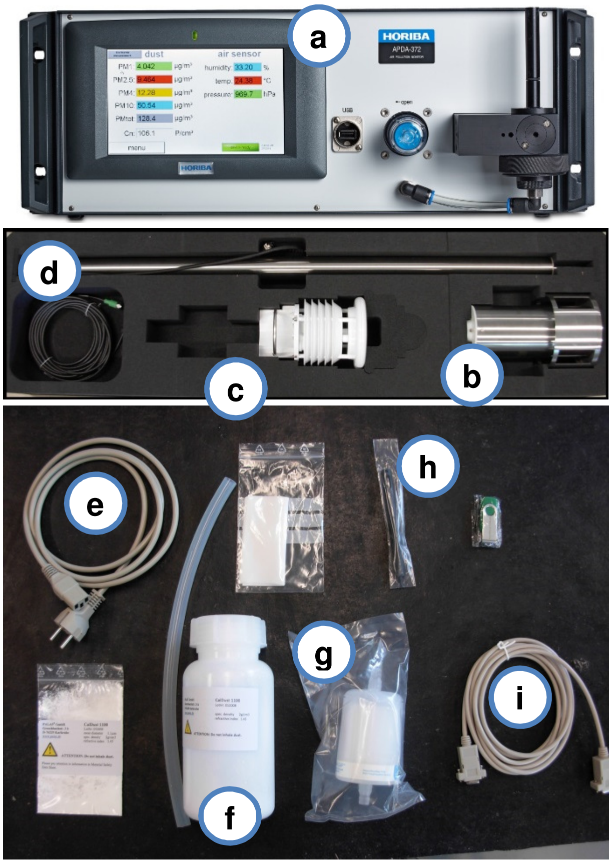


Figure 1: Components of an APDA-372 system

The following components and documentation should be present for all versions
(The letters in parentheses refer to the items in Figure 1).

- APDA-372 control unit **(a)**
- Aerosol inlet tube
- Power cord **(e)**
- Plastic hose, approx. 30 cm, for calibration and verification
- Bottle of MonoDust 1500 for calibration and verification **(f)**
- Refill packet of MonoDust 1500
- Cleaning kit consisting of optical cloths
- Zero filter (g)
- Printed instruction manual for APDA-372 Fine-Dust Monitoring System
- Printed description of APDA-372 firmware
- Printed instruction manual for PDAnalyze
- Instruction manual for weather station WS300-UMB or WS600-UMB
- Printed calibration certificate
- CD or USB flash drive with PDAnalyze analysis software
- Serial cable (null modem) **(i)**
- Pointer for touchscreen **(h)**

The following additional components are also included in the scope of delivery:

All versions:

- Weather station WS300-UMB **(c)** – or WS600-UMB instead as an option
- Sampling tube with IADS **(d)**
- Connector, sampling head to sampling tube
- Sigma-2 sampling head **(b)**
- Mounting for the sampling tube on the housing

APDA-372 E only:

- External aerosol sensor unit with connecting lines

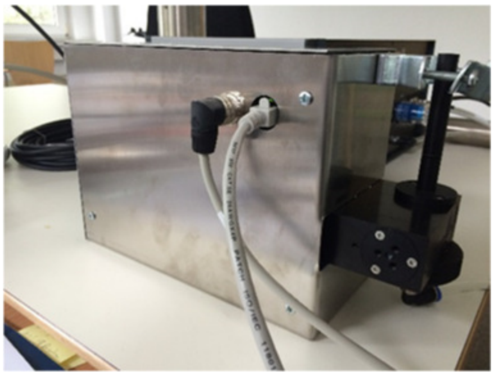


Figure 2: External aerosol sensor unit APDA-372 E

1.3. Device overview

1.3.1. Front view of the APDA-372 control unit

Figure 3: Front of the APDA-372 control unit

The APDA-372 device is operated via a touchscreen (for more on this, see the separate APDA-372 firmware instruction manual which includes detailed information on the user interface).

The data can be read out via the USB port and then processed further with the separate PDAnalyze software (included in the scope of delivery) on an external PC. In addition, it is also possible to transmit the data via an RS-232 or Ethernet connection using one of the communication protocol options.

1.3.2. Rear view of the APDA-372 control unit

Figure 4: Back of the APDA-372 control unit

The control unit is switched on and off using the mains switch. The device has two fuses, T 2 A / 250 V, which are located on the back.

The LED switches on with the mains switch. The operating hours counter runs as long as the device is on. The light source has a service life (MTTF) of >20,000 operating hours. The LED in the APDA-372 is operated at 20% of capacity with a controlled, lower temperature, which considerably prolongs the service life.

1.3.3. Connections on the back of the control unit

Figure 5: Connections on the back of the APDA-372 control unit

The following connections are located on the right-hand side of the back.

- **Network** port, for connecting the APDA-372 system to a network, for example, for online service support and transmitting software updates.
- **USB port**, for example, for connecting a printer, keyboard, mouse or USB flash drive to the APDA-372 control unit.
- Modbus via **RS-232** connection for remote queries of the measured values and external control of the measuring instrument (WebAccess).
- **Connection for the weather station, WS300-UMB or WS600-UMB,** for recording the:
  - ➔ Temperature
  - ➔ Humidity
  - ➔ Pressure
  - ➔ Wind speed (WS600-UMB only)
  - ➔ Wind direction (WS600-UMB only)
  - ➔ Amount of precipitation (WS600-UMB only)
  - ➔ Type of precipitation (WS600-UMB only)
- **Input for external sensors** for recording the temperature and the relative humidity
- **Input for external sensor** for recording the barometric pressure
- **Connection for the humidity compensation module, IADS** (Intelligent Aerosol Drying System)

1.3.4. APDA-372 E – External aerosol sensor unit

With the APDA-372 E, the entire aerosol sensor unit is separate from the control unit and is installed in a separate housing, which easily enables flexible installation in a measuring station. The connection between the control unit and the sensor unit is accomplished via a total of 3 connections:

- Connection cable for data transfer (LAN cable)
- Connection cable for the power supply / temperature measurement of the LED
- Hose connection for the sampling flow

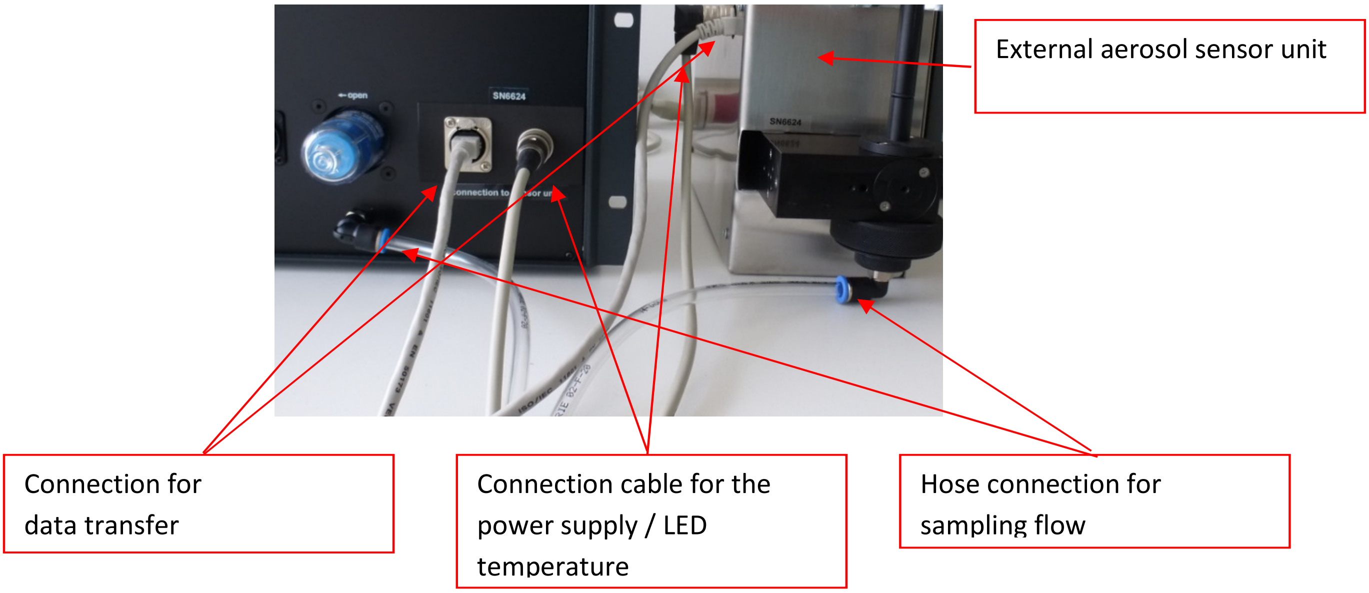


Figure 6: Connection of the external aerosol sensor unit

The standard length of the connection lines is 3 m (other lengths possible on request).

The other aspects of installation / connection of the measuring system are the same as for the APDA-372.

The APDA-372 E measuring system can be converted back to the APDA-372 measuring system, meaning the external sensor can also be reinstalled in the control unit.

1.4. First measurement

Switch the device on (I/0 switch on the back of the APDA-372 control unit).
The measurement process begins automatically when the device is switched on. The measured data are also automatically stored in the internal memory. The initial screen appears after the device has started (see figure 6).

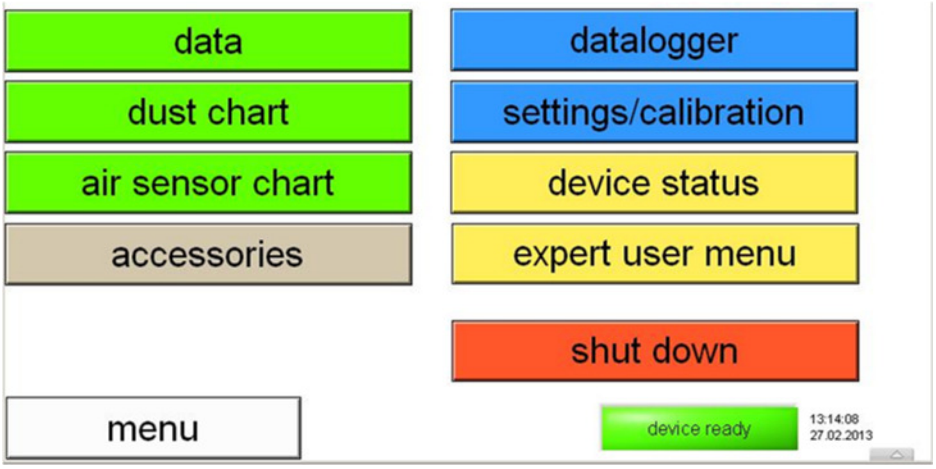


Figure 7: Initial screen

It is now possible to navigate between the individual display options using the touchscreen.

Figure 7 shows an overview of the following as an example:

Dust values

- PM1
- PM2,5
- PM4
- PM10
- PM total (total mass concentration)
- Cn: Particle concentration in P/cm3

Air sensors: (Weather station data)

- Relative humidity
- Temperature
- Barometric air pressure

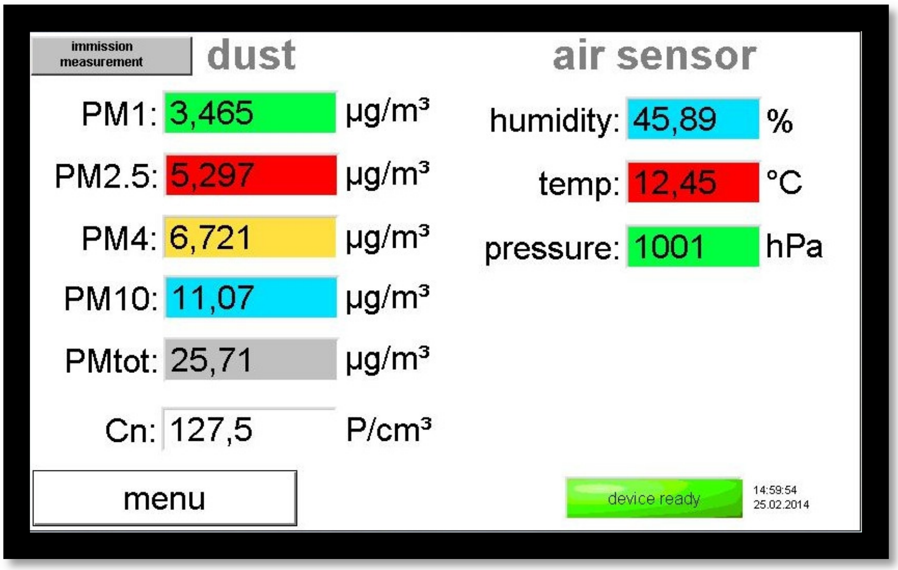


Figure 8: Data overview, e.g. PM values

More detailed information can be found in the separate instruction manual for the APDA-372 firmware. Please note: The value "NaN" (no number) appears briefly after the device is switched on and before the first measurement or during calibration or maintenance.

2. Integrating the measuring system in the measuring station

2.1. General

The measuring systems APDA-372 and APDA-372 E are designed for setup in a temperature controlled environment (climate-controlled measuring station or the like). The measuring system can be installed in an equipment rack or on a table top.

This section describes the special measures for installing and connecting the APDA-372 control unit at the installation site. Any possible measures required for a roof penetration for the sampling tube or for installing the weather station are dependent on the installation situation and are not described in this instruction manual. They must be determined according to the individual case.

When mounting the sampling tube / sampling head at the installation site, the relevant regulatory or legal requirements (e.g. according to Directive 2008/50/EC Annex III) concerning inlet height, flow exposure, distances to sources, etc., must be taken into account.

2.2. Positioning and connection of the APDA-372 control unit

Position the control unit in such a way that the opening of the sampling inlet tube is directly below the sampling tube (see Figure 9). To do so, you must previously have raised the sampling tube. Then, carefully (!) move the sampling tube over the sampling inlet tube as shown in Figure 10. The sampling tube should be as vertical as possible; it may be necessary to change the position of the control unit accordingly.

Then connect the cables from the weather station and the IADS (sampling tube) with the connections provided and labeled for this purpose (The exact location may deviate from that shown in Figure 9 depending on the model). Also connect the mains cable (and, as needed, a network cable as well), but do not switch the APDA-372 yet!

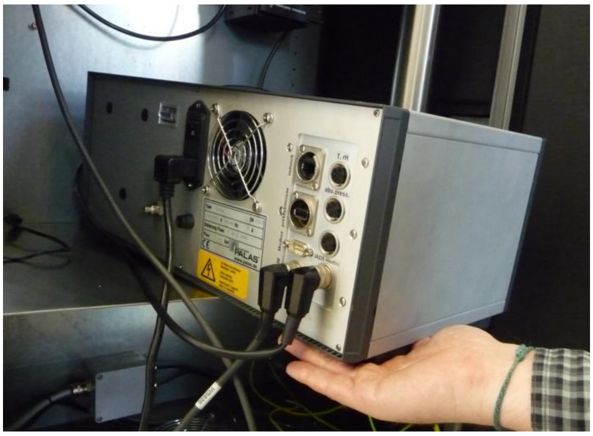


Figure 9: Connecting the weather station and IADS with the connections on the back

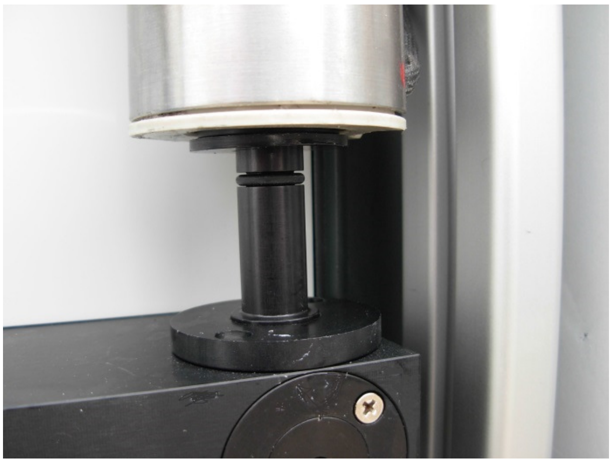


Figure 10: Connecting the sampling tube with the sampling inlet tube and the control unit

Continue with this step until the sampling tube directly touches the sensor unit, meaning there should no longer be any gap. Figure 11 shows the correct position on the right.

Figure 11: Incorrect position of sampling tube shown on left, correct position on right

Then carefully fasten the clamps of the mount located somewhat higher:

Figure 12: Internal mounting of the sampling tube

APDA-372 E only:

Use the connection lines to connect the APDA-372 control unit to the external aerosol sensor as described in section 1.3.4.

2.3. Installing the Sigma-2 sampling head

Slide the Sigma-2 sampling head onto the connecting piece to the sampling tube (it should have full contact with the sampling tube) and then secure the sampling head with the 2 mm Allen head screw (see Figure 13).

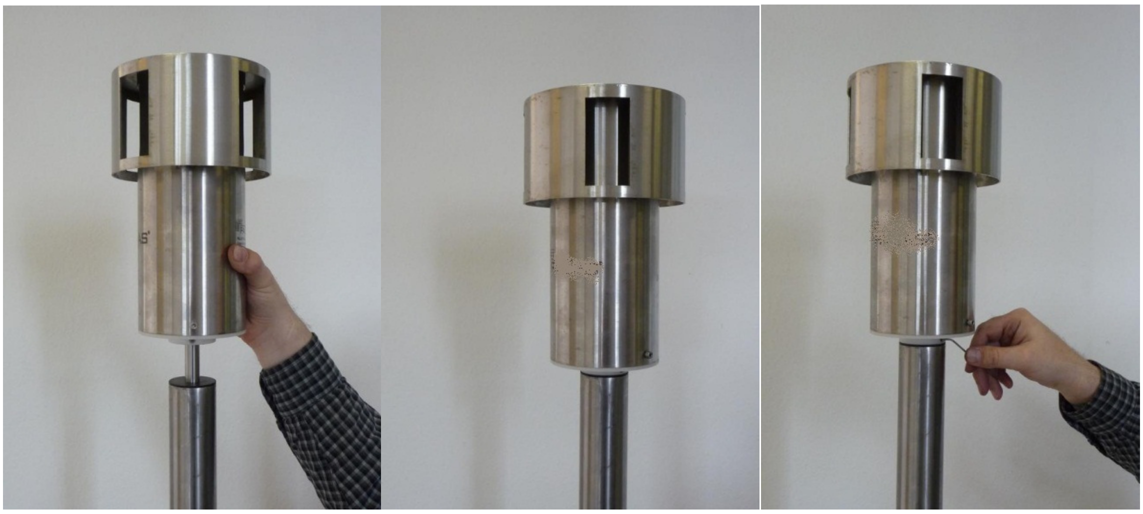


Figure 13: Installing the Sigma-2 sampling head

2.4. Switching on the measuring system

Switch on the mains switch on the back of the APDA-372 control unit. After launching the Windows operating system and the APDA-372 Start-up Manager, you will see the screen with the various different PM fractions, the particle number concentration and the ambient conditions (temperature, relative humidity, air pressure). For the initial PM fraction values, you will need to wait about 4 minutes due to the averaging.

3. Notes on the system

3.1. As-delivered condition of the measuring system

The as-delivered condition of the APDA-372 is the same as the condition of the measuring system during the qualification test with the following default settings:

No.	Parameter	Default setting
1	Evaluation algorithm	PM_ENVIRO_0011
2	Operating mode on start-up	Auto
3	Integration time (time basis for PM moving average)	900 s
4	IADS mode on start-up	1 (remove volatile / moisture compensation)
5	Slope factor for PM fractions	1
6	Offset factor for PM fractions	0
7	Temperature compensation factor	0.17 (APDA-372) or 0.19 (APDA-372 E)
8	Password for “Expert User Menu”	-1
9	Coincidence correction	Not active
10	Velocity correction	Not active

3.2. The promo.ini file

The promo.ini file contains important settings for die APDA-372 user interface. A detailed presentation of the entries in the promo.ini file follows below. Please bear in mind that almost all changes will have a strong influence on the firmware, meaning that changes should be kept to an absolute minimum and should only be made when the effects can be clearly isolated.

Explanation:
Please note: Entries which do not apply for the APDA-372 are struck through

[system]	
type=Fidas 200	Instrument model, note that Fidas® 200 S / Fidas® 200 E are also displayed as Fidas® 200
ser#=XXXX	Serial number of instrument [DO NOT CHANGE!]
password=yxcvbXXXX	Password for internal use [DO NOT CHANGE!]
user_device#=	Customized user identifier (3 characters)
[plugin]	
~~Promo 3000_enabled=no~~	
Fidas 100_enabled=yes	Plugins (top level user interface), that are enabled resp. disabled
Fidas 200/210_enabled=yes	[DO NOT CHANGE!]
Fidas 300/310_enabled=yes	
~~Fidas mobile_enabled=no~~	
~~Nanoco 100_enabled=no~~	
~~Nephel 100_enabled=no~~	
stop_enabled=yes	
start_enabled=yes	
[my-palas.com]	Automatically connect after every start-up to the Palas® website for data upload and remote
my-palas.com_autostart=no	control - Requirement: Instrument is registered on Palas® website

[Fidas]	
velocity_calibrated=9.3 m/s	Setting "Velocity_Average", determined at installation site according to chapter 5.5
PM10_slope=1.000	Entry of slope and offset factors for PM fractions possible
PM10_intercept=0	(e.g. from TÜV-report 936/21226418)
PM4_slope=1.000	
PM4_intercept=0	
PM2.5_slope=1.000	
PM2.5_intercept=0	
PM1_slope=1.000	
PM1_intercept=0	
PMtotal_slope=1.000	
PMtotal_intercept=0	
PM_alternative=yes	Display of alternative PM-values under "accessories" is active
~~PM_volatile=no~~	
textfile=yes	Data logging as text file is active
textfile_interval=60s	Interval for data logging as text file
PM_autoadjust=no	[DO NOT CHANGE!]
~~gravimetric_correction_factor=1.00~~	
IADS_modus=1	Operating mode of IADS
dust_type=2	[DO NOT CHANGE!]
sensor_selection=2	[DO NOT CHANGE!]
automated_cleaning=no	Automatic cleaning not active
alarm_threshold=99999 µg/m^3	Limit value for PM fraction, that triggers the digital alarm (digital out)
alarm_value=PM10	Setting of PM fraction, that triggers the alarm
alarm_email_address=""	E-mail adress, to which a notification is sent in case of error message
password_service=-1	Password for "Expert User Mode"
calibration_IADS_restrict=yes	Enabling of calibration only, if nominal temperature is reached
calibration_temperature=50	Nominal temperature IADS for calibration (35°C or 50°C)
~~[Promo3000]~~	
~~interval=300~~	
~~sensor1=15.000000~~	
~~sensor2=33.000000~~	
[hardware]	
weatherstation_connected=yes	Weather station is connected
weatherstation_comport=4	COM-port of connected weather station
weatherstation_scale_T=1	Entry of slope and offset factors possible for adjustment of weather station
weatherstation_scale_p=1	from comparison with transfer standard
weatherstation_scale_h=1	
weatherstation_offset_T=0	
weatherstation_offset_p=0	
weatherstation_offset_h=0	
weatherstation_equation= x_corr=scale*x+offset	Applied equation for calibration of weather station
~~GPS_connected=no~~	GPS is currently not supported
~~GPS_comport=8~~	GPS is currently not supported
discmini_connected=no	DISCmini is not connected
discmini_comport=81	COM-port of DISCmini
discmini_interval=300s	Time basis for reported data from DISCmini
~~[UF-CPC]~~	
~~liquid_pump_impulsinterval=45 s~~	
~~liquid_pump_impulsamplitude=0.5 V~~	
[settings]	
sensor_selection=2	[DO NOT CHANGE!]
PM_interval=900s	Time basis for moving average of PM fractions (according to TUV test 900s)
IP_UDP_broadcast=127.0.0.1	UDP adress for data transmission
PLC_interface=1	Selected communication protocol upon start-up (see below legend)
temperature_compensation=yes	LED temperature control [DO NOT CHANGE!]
temperature_slope=0.17	Setting 0.17 for APDA-372 and 0.19 for APDA-372 E [DO NOT CHANGE!]
velocity_correction=yes	Dynamic border zone correction [DO NOT CHANGE!]
velocity_calibration_enabled=no	[DO NOT CHANGE!]
flow_calibration_enabled=yes	Calibration of flow rate is possible (button under "sensor calibration")
~~server_IP_accesslist=+*~~	
RSBaudRate=9600	Baud rate for data transmission
BayerHessen_DA_commmand=60>60,61>61,62>62,63>63,64>64,65>	Mapping of addresses for Bayern-Hessen protocol

Selected communication protocol upon start-up

0	Modbus
1	Bayern/Hessen
2	UDP ASCII
3	UDP single particle data stream
4	Modbus with UDP
5	Serial ASCII

3.3. Activating the coincidence correction

In the as-delivered condition of the APDA-372, the default setting is that the coincidence correction is **not** activated. This is the same setting that is used in the type approval testing.
If the APDA-372 is used at installation sites at which significantly high concentrations can occur, and if the APDA-372 measures a coincidence value of greater than 10%, it may be necessary to activate the coincidence correction in order to significantly broaden the original concentration range of 0 to 10,000 µg/m³. The following steps explain how the coincidence correction can be activated.

After starting the APDA-372, you will find yourself in the main menu (Figure 14):

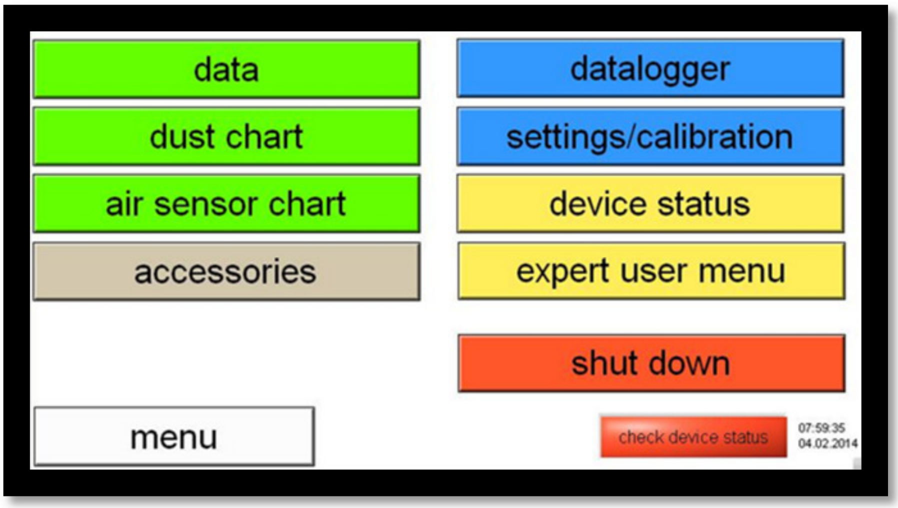


Figure 14: Main menu

Go to the Expert User menu by clicking on the “expert user menu” button, then enter “1” followed by “-” and click on “accept” (Figure 15):

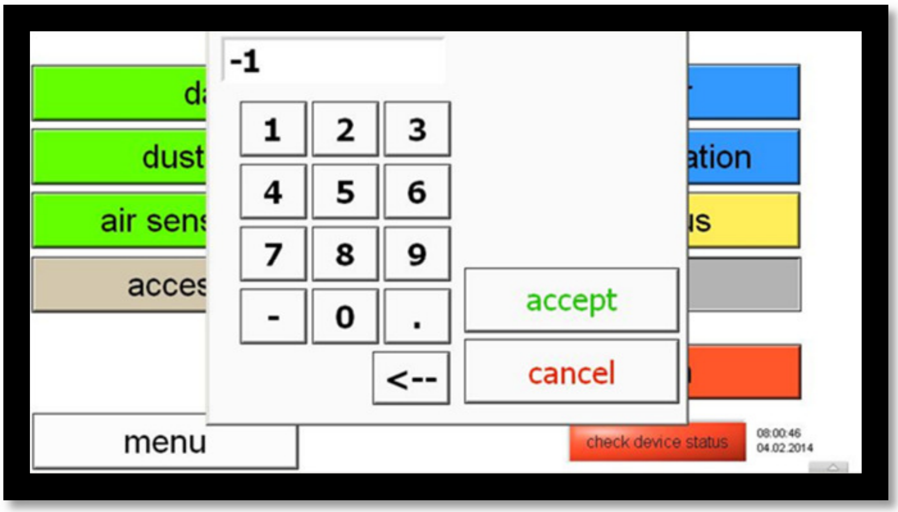


Figure 15: Password entry for accessing the Expert User menu

You are now in the Expert User menu (Figure 16). You can return to the APDA-372 main menu from here by clicking on the green APDA-372 bar at the top left. Please click on "system" to continue:

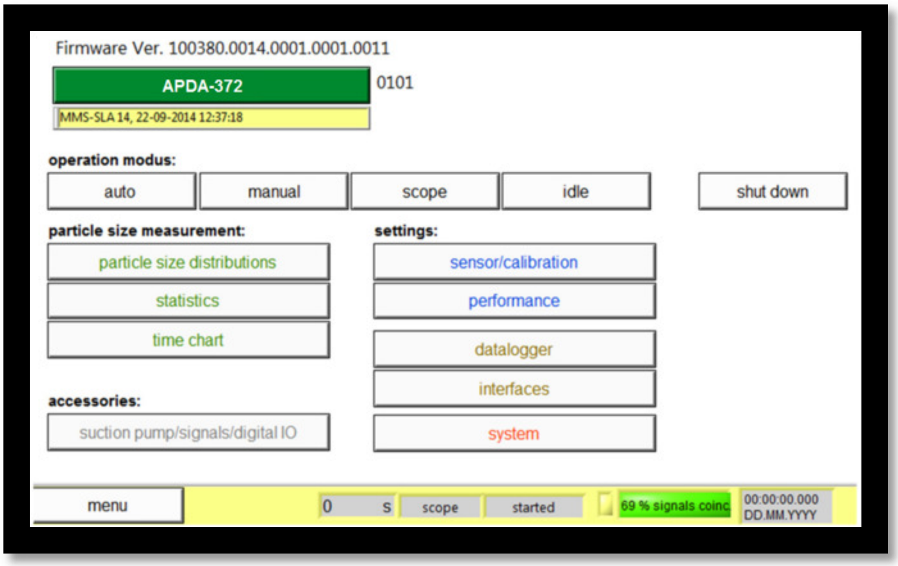


Figure 16: Expert user menu

You are now in the "System" screen (Figure 17). Continue by clicking the "advanced system settings" button:

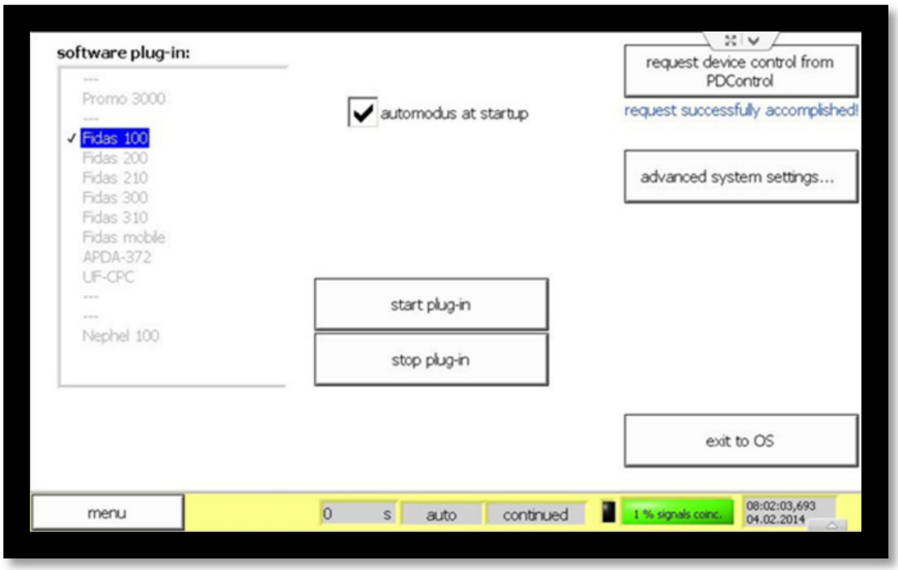


Figure 17: System menu

You are now in the "advanced system settings" screen (Figure 18). Now connect a USB keyboard and make sure that it is recognized by the system (typically indicated by an audible ringtone). Then press "c" on this keyboard. This opens a hidden calibration screen with various different tabs.

Caution:

Please do not change anything other than what is described below. Otherwise you run the risk that your device will no longer function properly!

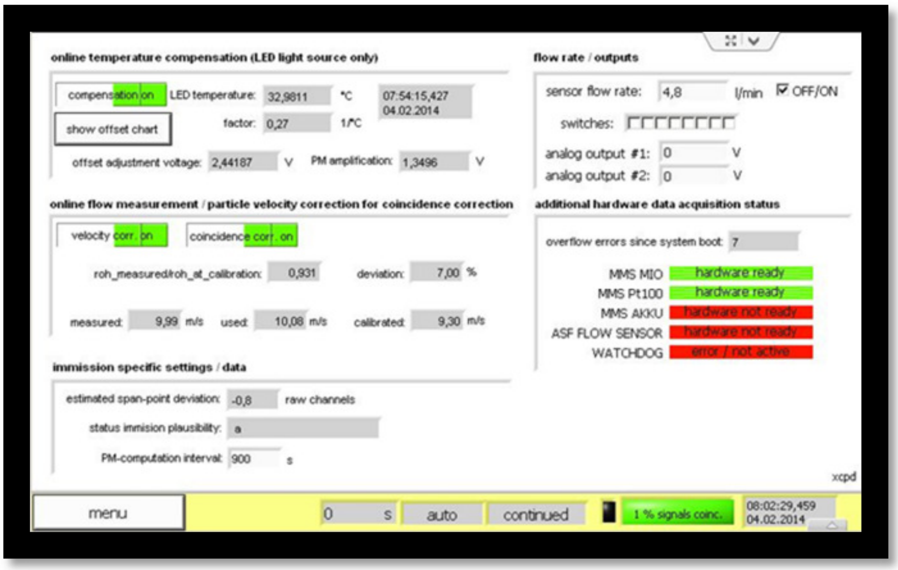


Figure 18: Advanced system settings

You are now in the hidden calibration screen. Go to the "statistics" tab and activate "coincidence correction T-aperture" (C factor + T shape). Then click "save for selected settings only" followed by "close" (Figure 19).

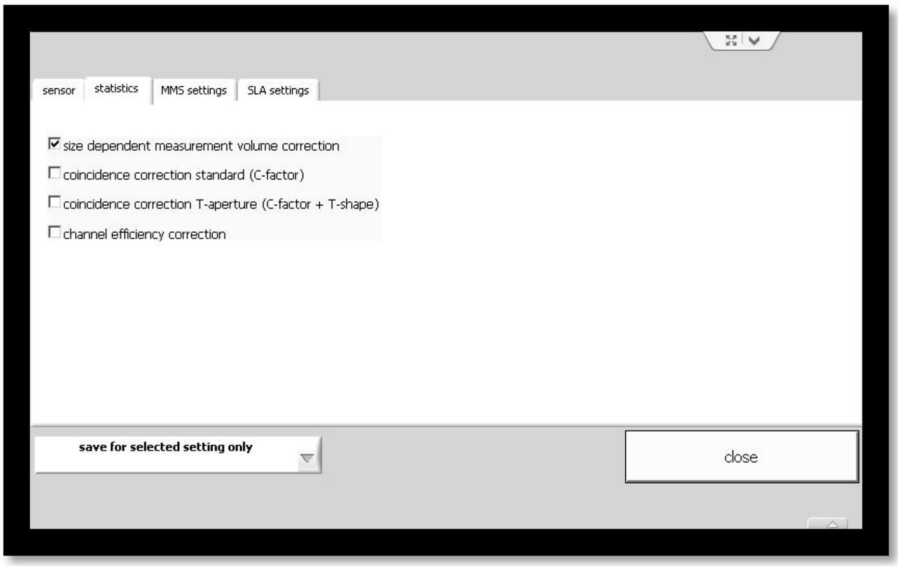


Figure 19: Statistics tab

3.4. Changing the moving-average time basis for APDA-372 measurements

The PM values are measured on the basis of a moving average with a time basis of 900 s. This is the same time basis that was also used for the TÜV equivalence and type approval testing. If you change the time basis, then please be aware that the configuration will then deviate from the certified status and no information is available on the effects of such a change, meaning that neither the correlation nor the gravimetric analysis will remain valid.

Caution:

A change of this value is undertaken at the user's own risk.

Nevertheless, under certain circumstances, changing the time basis can be advantageous. The following steps explain how to change the time basis:

- After starting the APDA-372, you will find yourself in the main menu (see Figure 14):
- Go to the Expert User menu by clicking on the "expert user menu" button, then enter "1" followed by "-" and click on "accept" (see Figure 15).
- You are now in the Expert User menu (Figure 16). You can return to the APDA-372 main menu from here by clicking on the green APDA-372 bar at the top left. Please click on "system" to continue:
- You are now in the "system" screen (see Figure 17). Continue by clicking "exit to OS" to obtain access to the Windows operating system.
- On the Windows Desktop you will see an icon and a folder. You can use the "Shortcut to startupmanager" icon to reboot the APDA-372 user interface. Please click the "startup" folder (see Figure 20)

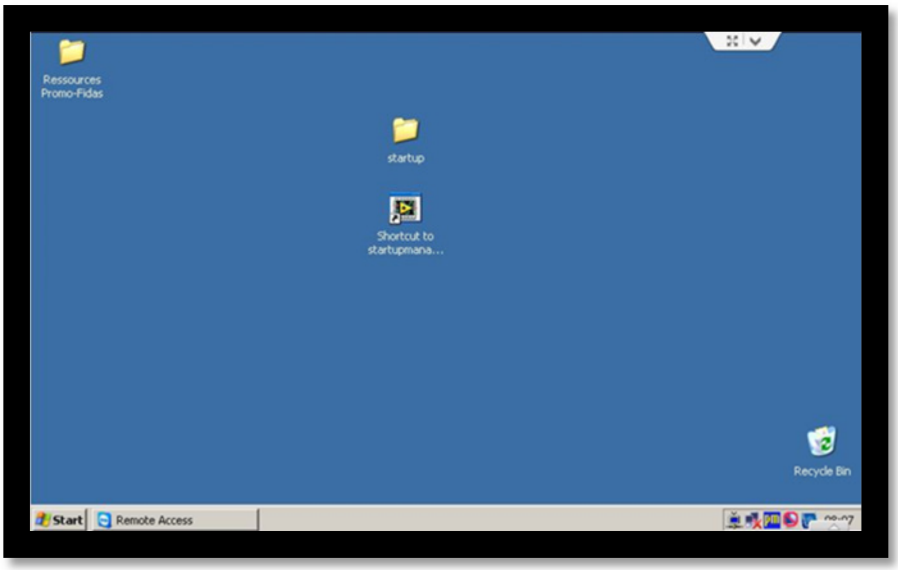


Figure 20: Windows desktop

- You are now in the “startup” folder; please click the FIDAS folder (see Figure 21).

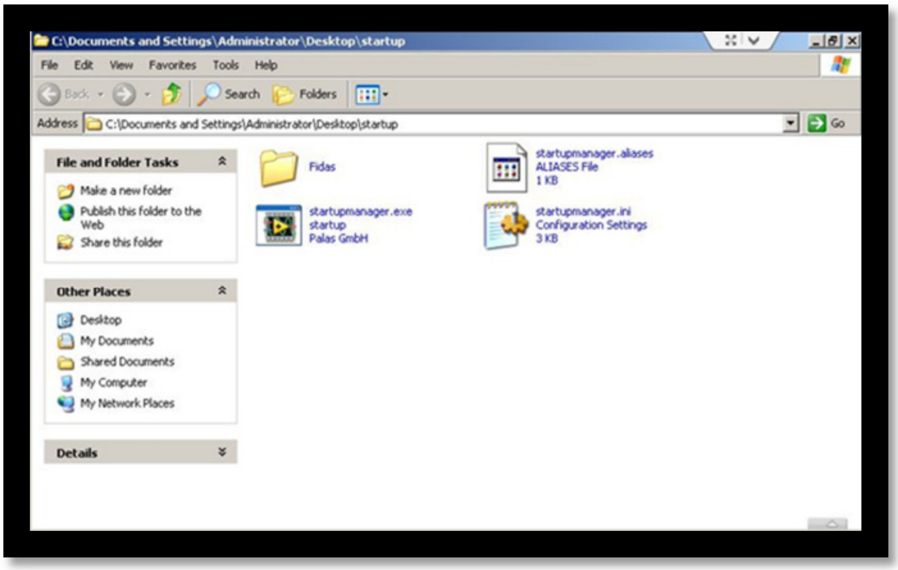


Figure 21: Startup folder

Various different files can be seen in this folder (scroll downwards to see the second half; see Figure 22).

File	Purpose
“_palassupport.exe”	Teamviewer module for remote support and remote control
“counter-win32.100###.exe”	APDA-372 user interface firmware; the highest number is the most current version
“DATA_auto_5048_...”	APDA-372 files
“promo.ini”	APDA-372 *.ini file with permanent settings

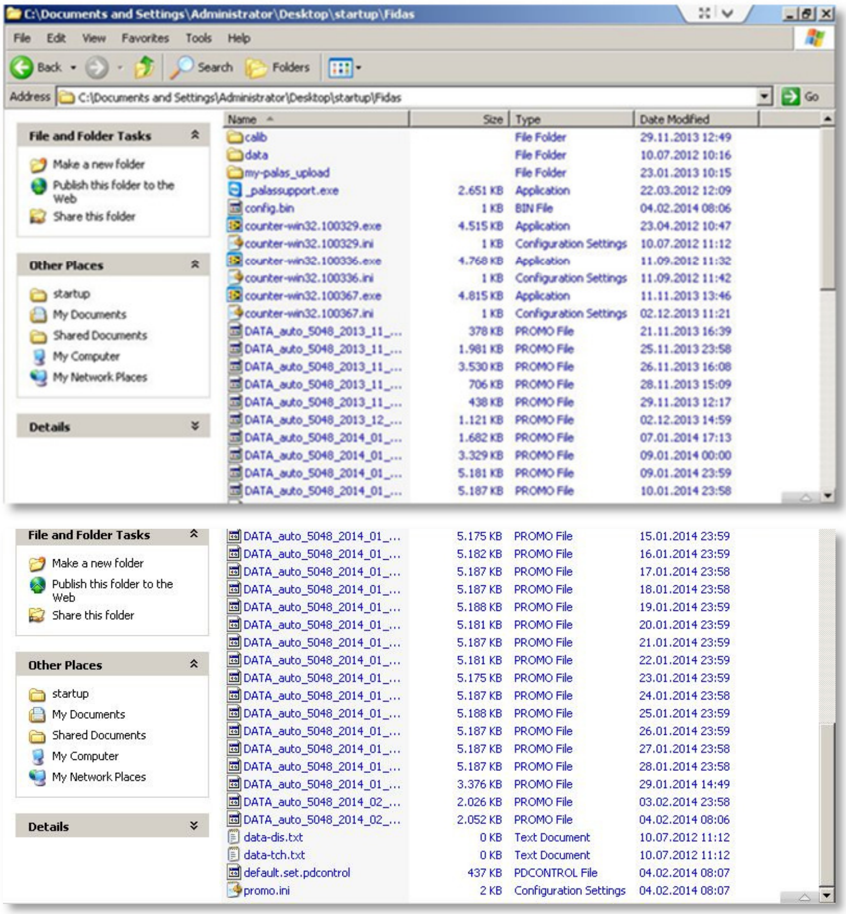


Figure 22: Fidas folder

Please open the “promo.ini” file. For the APDA-372, it should appear as follows (see Figure 23):

```
[system]
type=Fidas 200
ser#=XXXX
password=yxcvbXXXX
user_device#=

[plugin]
Promo 3000_enabled=no
Fidas 100_enabled=yes
Fidas 200/210_enabled=yes
Fidas 300/310_enabled=yes
Fidas mobile_enabled=no
Nanoco 100_enabled=no
Nephel 100_enabled=no
stop_enabled=yes
start_enabled=yes

[my-palas.com]
my-palas.com_autostart=no
```

```
[Fidas]
velocity_calibrated=9.3 m/s
PM10_slope=1.000
PM10_intercept=0
PM4_slope=1.000
PM4_intercept=0
PM2.5_slope=1.000
PM2.5_intercept=0
PM1_slope=1.000
PM1_intercept=0
PMtotal_slope=1.000
PMtotal_intercept=0
PM_alternative=yes
PM_volatile=no
textfile=yes
textfile_interval=60s
PM_autoadjust=no
gravimetric_correction_factor=1.00
IADS_modus=1
dust_type=2
sensor_selection=2
automated_cleaning=no
alarm_threshold=99999 µg/m³
alarm_value=PM10
alarm_email_address=""
password_service=-1
calibration_IADS_restrict=yes
calibration_temperature=50

[Promo3000]
interval=300
sensor1=15.000000
sensor2=33.000000

[hardware]
weatherstation_connected=yes
weatherstation_comport=4
weatherstation_scale_T=1
weatherstation_scale_p=1
weatherstation_scale_h=1
weatherstation_offset_T=0
weatherstation_offset_p=0
weatherstation_offset_h=0
weatherstation_equation=  x_corr=scale*x+offset
GPS_connected=no
GPS_comport=8
discmini_connected=no
discmini_comport=81
discmini_interval=300s

[UF-CPC]
liquid_pump_impulsinterval=45 s
liquid_pump_impulsamplitude=0.5 V

[settings]
sensor_selection=2
PM_interval=900s
IP_UDP_broadcast=127.0.0.1
PLC_interface=1
temperature_compensation=yes
temperature_slope=0.17
velocity_correction=yes
velocity_calibration_enabled=no
flow_calibration_enabled=yes
server_IP-accesslist=+*
RSBaudRate=9600
BayerHessen_DA_commmand=60>60,61>61,62>62,63>63,64>64,65>65
```

Time basis for moving average of PM fractions
Recommended and TUV-approved setting: 900 s

Figure 23: The promo.ini file

The second half can be viewed by scrolling downwards. Please check the time basis and, if necessary, set the time basis for the moving average value to 900 seconds (i.e. 15 minutes). Save and close the “promo.ini” file and restart the APDA-372 user interface.

3.5. Corrections used for the algorithm, e.g. TÜV correction for PM2.5 and PM10

Based on the TÜV Rheinland report concerning the type approval testing of the APDA-372 measurement system for the components PM10 and PM2.5, Report Number: 936/21226418/C, it has been determined that the measurement uncertainty for PM10 and PM2.5 obtained from the comparison of the APDA-372 with the gravimetric reference method is improved when the measured values of the APDA-372 are corrected using the determined slopes and axis intercepts. The following correction parameters were determined in the context of the equivalence test:

PM2.5:	Slope: 1.076	Axis intercept: -0.339
PM10:	Slope: 1.058	Axis intercept: -1.505

The inverse values shown below are used to implement the correction. This means
Correction = 1/slope *y – axis intercept/slope

PM2.5:	cSlope: 0.929	cAxis intercept: -0.315
PM10:	cSlope: 0.945	cAxis intercept: -1.422

If this correction for measurements with the APDA-372 is to be used, it must be entered in the promo.ini file. The same procedure applies for other corrections, such as of a location correlation that has been determined with respect to a gravimetric measurement system.

Example: To be able to use the aforementioned TÜV Rheinland correction, the promo.ini must contain the following data:

```
Promo.ini:
[Fidas]
PMtotal_slope=1
PMtotal_intercept=0
PM10_slope=0.945
PM10_intercept=1.422
PM4_slope=1
PM4_intercept=0
PM2.5_slope=0.929
PM2.5_intercept=0.315
PM1_slope=1
PM1_intercept=0
```

3.6. System monitoring functions

The APDA-372 measuring system is delivered with the system monitoring activated. If the firmware is not running or has crashed, the system is restarted automatically after 255 seconds. However, this also means that access to the Windows operating system is limited to 255 seconds if the access is initiated via the following path: “expert user menu” -> “system” -> “exit to OS”.

To obtain access to the Windows operating system without the time limitation, please select “Ver.exe” while starting the APDA-372 Start-up Manager.

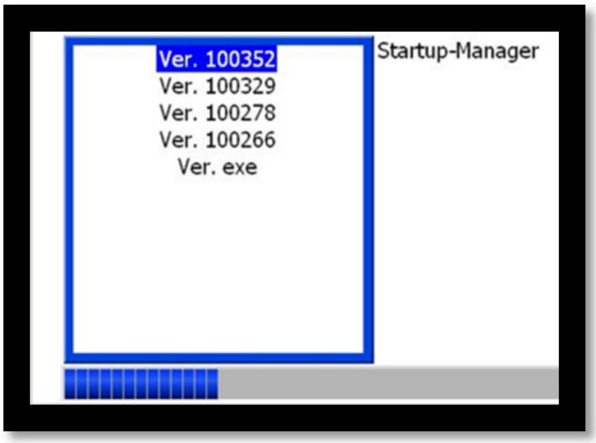


Figure 24: Startup-Manager

3.7. System modifications and installation of additional software under Windows

All devices are delivered with a file-based write filter (FBWF). The purpose of this protection is to prevent a deterioration of the Windows operating system and to protect against any possible installation of malware. This filter ensures preservation of the original state of the operating system.

Any modifications to the operating system or any newly installed file is not saved permanently, but instead, the original state is restored the next time the system is launched. This includes, for example, the setting of the Windows system clock and the date.

The only exception is for data that are saved on the desktop. The APDA-372 data and system files are also saved on the desktop and can be modified at any time, and new files can be added.

To be able to save permanent system modifications, please activate the batch file in the following folder on the desktop: "/startup/Fidas". After rebooting the Windows operating system, the modifications will be saved permanently (e.g. system clock and date). We recommend running the batch file after all desired modifications in order to reactivate the write protection. This requires a reboot of the system; the protection is only active again after this.

Please note:

It is possible to run the system without the FWBF being active, however, we recommend activating the FBWF.

4. Maintenance

We recommend a periodic inspection of the correct operation of the APDA-372 according to the following table and section 5. Apart from this, the device only needs to be serviced if one of the error bits is triggered (see **Figure 25**).

Test	Test interval	Section in the manual
Calibration/verification	1 month or 3 months	5 – 5.8
Clean the optical sensor	1 year or if the photomultiplier voltage during calibration of the optical sensor is > 15% above the calibration value after the last cleaning or the as-delivered condition	5.10
Clean / replace the exhaust filter of the internal pump (part no. 1000106819)	1 year or if the power required for the exhaust pump is >50%	5.11
Check/cleaning of the Sigma-2 head	3 months	5.12
Replacement of the O-ring seals (part no. 1000106822)	1 year or if leakage is ascertained	5.13
Replacement of the pump assembly (part no. 1300010121)	If there is a failure or the pump power required is > 80%	5.14

Table 1 Overview of maintenance tasks

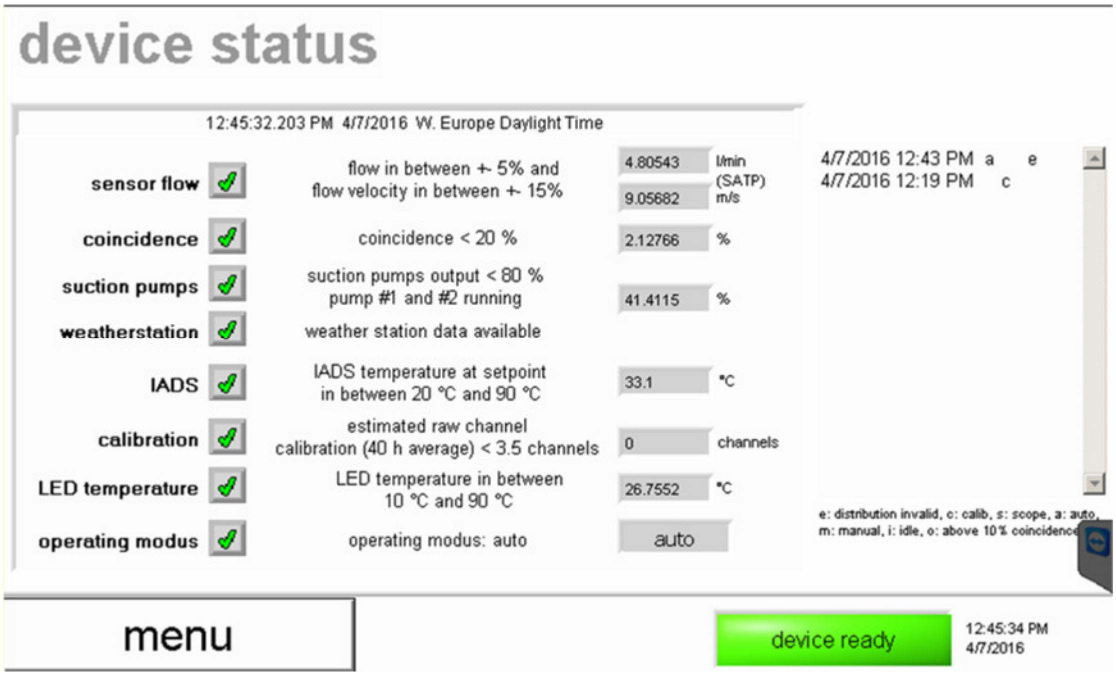


Figure 25: Status overview

Various items of sensor information are shown here which are required for correct operation of the APDA-372. This information is also saved along with every data record in the form of a status/error byte.

This specifically includes:

Sensor flow

The APDA-372 regulates the volumetric flow rate at 4.8 l/min by means of a control circuit with mass flow meters and inclusion of the values measured for temperature and air pressure. This volumetric flow rate is then standardized for “standard atmospheric temperature and pressure” (SATP), that is, with reference to 25 °C and 1013 hPa.

An error is displayed if the volumetric flow rate deviates from the setpoint value by more than 5%.

The second value indicates the velocity (flow velocity) of the particles through the optical detection volume. An error is displayed if the velocity of the particles deviates from the setpoint value by more than 15%. The setpoint value corresponds to the velocity entered in the promo.ini file which is determined at the installation site in accordance with section 5.5. An error message indicates a possible leak after the sensor.

IMPORTANT:

The result of the velocity measurement has **no** influence on the calculation of the PM values, but is instead only used as an indicator for the leak tightness.

Coincidence

Detection of more than one particle in the optical detection volume. An error is output if this occurs with a frequency of greater than 20%.

Suction pumps

The volumetric flow in the APDA-372 is generated by two pumps that are connected in parallel. If one pump fails, the other can assume its role; the power consumption is then accordingly higher, which leads to an error. If both pumps should age uniformly, an error is also triggered when 80% is exceeded. It is important to note that the device still continues to measure correctly, however, the user must see to it that the pumps are replaced soon.

Weather station

This indicates that a weather station is correctly connected and is transmitting values.

IADS

This indicates that the IADS is correctly connected and the temperature corresponds to the prescribed regulation point.

Calibration

This monitors the calibration online. If the average over 40 hours deviates by more than 3.5 raw data channels , an error is set.

Note: In individual cases, this value might be out of tolerance for brief periods while the device is nonetheless still operating properly. Need for action (i.e. a field calibration using calibration dust) only arises if this is a longer-term trend (>40 hours).

LED temperature

The LED light source is subject to temperature control. If a problem arises in this control circuit, this error bit is set.

Operating mode

The operating mode should be set to “auto” because otherwise it is possible that the data will not be saved correctly or the device will not restart again on its own after a power outage.

5. Calibration/verification of the APDA-372

The device should always be calibrated before a measurement campaign. The calibration should be checked at regular intervals while a measurement campaign is running (see Table 2).

The device must be in operation for at least one hour before the calibration so that it is in a thermally stable condition. The ambient temperature for this must be between 10 °C and 40 °C.

Please note:

If the device is calibrated using MonoDust, the calibration is only valid if it is conducted at a temperature in the range of from +10 °C to +40 °C!

The device must be switched to the calibration mode for the calibration. To do so, select "settings/calibration" in the main menu of the APDA-372 firmware. In the next screen select "activate calib mode". Return to the main menu.

The complete calibration consists of five individual steps:

1.) Leak test
2.) Flow rate test / calibration
3.) Check of the particle sensor offset
4.) Check of the particle sensor zero point
5.) Check of the average particle velocity
6.) Check / calibration of the particle sensor sensitivity
7.) Check of the MonoDust particle velocity
8.) Save the data

The steps are described individually below:

5.1. Leak test

5.1.1 In the main menu, select the "expert user menu" (password "-1"). In the next screen, select "suction pumps/signals/digital IO".

5.1.2 In the "suction pumps/signals/digital IO" screen, you will see the current gas volume flow ("sensor flow rate"). Use the "suction pump" sliding switch to switch the pump off. "Sensor flow rate" now shows the zero value of the flow rate sensor. Write down this value ("Offset").

5.1.3 Disassemble the sampling head. Loosen the mount of the IADS tube and raise it about 20 cm to gain access to the aerosol inlet of the APDA-372 sensor. Secure the IADS in this position. Close off the aerosol inlet with a cap / plug / clamped off piece of hose or your thumb. As an ALTERNATIVE, if you do not want to disassemble the IADS, you can disconnect the short piece of hose between the filter holder (under the sensor) and the inlet on the Fidas front panel (under the blue filter) by pulling it out of the connection on the filter holder. Block the inlet of the hose.

5.1.4 Switch the pump back on. The pump now evacuates the sampling system. The output power of the pump control will rise to 100% and the working noise will be significantly louder – this is normal. Wait until the flow rate that is displayed has reached its minimum and write down the value (as "APDA-372 control unit gross leakage"). If the value is not stable, write down the lowest value read. Switch off the pump once again.

5.1.5 Calculate the net leakage:

"APDA-372 control unit net leakage" =
"APDA-372 control unit gross leakage" – "Offset".

The result should be < 0.08 l/min. If this value is exceeded, check the filter holder under the sensor as well as the transparent protective cover of the blue filter on the front panel of the control unit for damage to the ring seal and for a firm seat. If you are authorized to perform internal repairs on an APDA-372 and the APDA-372 is no longer under warranty, you can open the device to look for possible causes for the internal leakage, such as loose/damaged/hardened sections of hose, and repair them inasmuch as possible. Repeat the leak test until the result is acceptable – otherwise, contact your APDA-372 supplier.

5.1.6 Reconnect the IADS, but leave the Sigma-2 head aside (or reconnect the piece of hose between the filter holder and the aerosol inlet on the front). Close off the IADS inlet with a cap / plug / clamped off piece of hose.

5.1.7 Repeat the procedure described in 5.1.4, except that the value your write down this time is now the "APDA-372 system gross leakage".

5.1.8. Calculate the net leakage:

"APDA-372 system net leakage" =
"APDA-372 system gross leakage" – "Offset".

The result should be < 0.5 l/min. If this value is exceeded, check the IADS for damaged ring seals and correct seating of the aerosol inlet of the APDA-372 sensor. Also check whether the IADS inlet is really closed off tightly. Repeat the leak test until the result is acceptable – otherwise, contact your APDA-372 supplier.

5.1.9 Put the Sigma-2 head back in place and switch the pump on once again.

5.2. Flow rate test / calibration

Checking and possibly calibrating the flow rate must only be carried out after a successful leak test.

5.2.1 Connect a suitable flow rate measuring instrument with a low level of pressure loss to the IADS input (remove the Sigma-2 head).

Important:

Because the flow rate references SATP (standard ambient temperature and pressure), please be certain that your flow rate is referenced to the same temperature (25 °C) and the same pressure (1013 hPa). If this is not the case, this must first be corrected manually before the measured flow rate is entered in the firmware!

5.2.2 In the main menu, select the "expert user menu" (password "-1"). In the next screen, select "suction pumps/signals/digital IO".

5.2.3 In the "suction pumps/signals/digital IO" screen, you will see the current gas volume flow ("sensor flow rate"). Under normal operating conditions, this value is approximately 4.8 l/min. Compare the value with the display of your flow rate measuring instrument. The gas volume flow according to the display of your flow rate measuring instrument must be 4.8 ±0.15 l/min. If the value read is in this range, you can disconnect the flow rate measuring instrument and reinstall the Sigma-2 head. Otherwise, continue with step 5.2.4.

5.2.4 Access to the setting of the flow rate control can be obtained as follows: Go back to the “expert user menu” -> select “sensor/calibration” -> in the next screen select “sensor calibration” -> in the next screen, select “calibrate flow sensor offset” -> enter the value that your flow rate measuring instrument displays (observe the decimal separator!) and select “accept”.

5.2.5 After the calibration, check the flow rate once again according to 5.2.3.

Please note:

If the “calibrate flow sensor offset” is not visible, the following changes must be made in the promo.ini file in the [settings] area:

flow_calibration_enabled=yes

5.3. Check of the particle sensor offset

The check of the particle sensor offset is only a monitoring measurement – contact your APDA-372 supplier if the measured values lie outside of the specified range.

5.3.1 In the main menu, select the “expert user menu” (password “-1”). In the next screen, select “sensor/calibration” -> in the next screen select “sensor calibration” -> in the next screen, select “adjust offset” -> the procedure begins automatically.

Observe the offset value displayed at the top right, which changes continuously while the offset adjustment voltage is varied. The minimum value displayed as the curve passes through its lowest point should be less than 0.2 mV. Once the measurement has been completed, the value for the offset compensation voltage is calculated and the display in the field below the graph is updated. The value should be between 2 and 3 V.

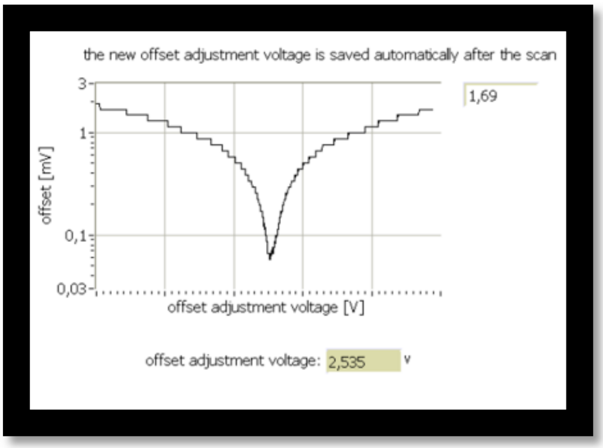


Figure 26: Screen display during the automatic offset adjustment

5.4. Check of the particle sensor zero point

Checking and possibly calibrating the particle sensor zero point must only be carried out after a successful leak test (5.1) and sensor offset (5.3).

5.4.1 In the main menu, select “data”. The value initially displayed on the screen (“Cn”) is the currently detected particle number concentration (moving average over 10 s).

5.4.2 Remove the Sigma-2 head and attach an HEPA filter to the IADS inlet. This filter removes all of the particles that are normally detected from the intake air. Observe the Cn value. It should go to zero within one minute and remain there as long as the HEPA filter is attached. If this is the case, the HEPA filter can be removed again.

If the value is not zero, check to see if the filter is perhaps not seated tightly or there is electronic interference (interference sources). If the problem continues, please contact your APDA-372 supplier.

If you wish to check the zero point of the PM values in [µg/m³], then the HEPA filter must remain connected over the entire period of the integration time that is set (default setting: 900 s).

5.5. Check of the average particle velocity

The check of the average particle velocity is typically only performed when the device is installed. It must be carried out only after a successful leak test, sensor offset and sensor zero point. IMPORTANT: The result has **no** influence on the calculation of the PM values, but is instead only used for the internal leak tightness test (see section 4)!

5.5.1 In the main menu, select the “expert user menu” (password “-1”). In the next screen, select “sensor/calibration” -> in the next screen select “sensor calibration” -> in the next screen, various values are displayed to the right of the “raw data distribution” graph. The fifth entry shows the “velocity (average)”. Write down this value and return to the overview screen of the “expert user” menu.

5.5.2 In the “expert user” screen, select “system”. In the next screen, select “exit to OS” to exit the Fidas® firmware and gain access to the operating system.

5.5.3 Navigate to the “promo.ini” file. Open the file and scroll to the entry “velocity_calibrated”. Replace the value there with the value noted previously in 5.5.1, “velocity (average)”. Save and close the “promo.ini” file.

5.5.4 Restart the APDA-372 firmware.

5.6. Check / calibration of the particle sensor sensitivity

The check / calibration of the particle sensor sensitivity must be carried out only after a successful leak test, sensor offset and sensor zero point.

5.6.1 In the main menu, select “settings/calibration”. Once you select “sensor calibration” in the following screen, the system prepares the check / calibration of the particle sensor sensitivity by heating the IADS up to 50 °C (in older systems, possibly 35 °C). This ensures that the volumetric flow rate and the gas dynamics are always the same during the calibration, and the test dust used is subject to a certain conditioning.

The IADS temperature must remain within ±1 °C of the setpoint value for 120 s before the calibration can be continued. Usually, this will mean a wait of 10 minutes.

5.6.2 Remove the Sigma-2 head while the IADS heats up. Attach a hose to the IADS inlet. Its length should ideally be sufficient to allow you to be present in front of the device during the check of the amplification. For a Fidas® that is installed in a measurement container, you may need a hose that is several meters in length. Take care to ensure that the hose is not kinked anywhere.

5.6.3 Once the IADS temperature has stabilized in the vicinity of the setpoint value, you can select "continue calibration" and the calibration screen will be displayed.

5.6.4 Take a closed bottle of MonoDust 1500 and shake it lightly or tap on the bottom of the bottle to release dust particles. Open the bottle and hold the end of the hose connected to the IADS near the bottle, but do not put the end of the hose into the bottle. Squeeze the bottle together slightly a few times to exchange a little air between the inside of the bottle and the environment. The APDA-372 will draw in particle-laden air and the "raw data distribution" graph will display a signal peak. The firmware will recognize the location of the peak and display the numerical value as "measured peak at …". Write down this value.

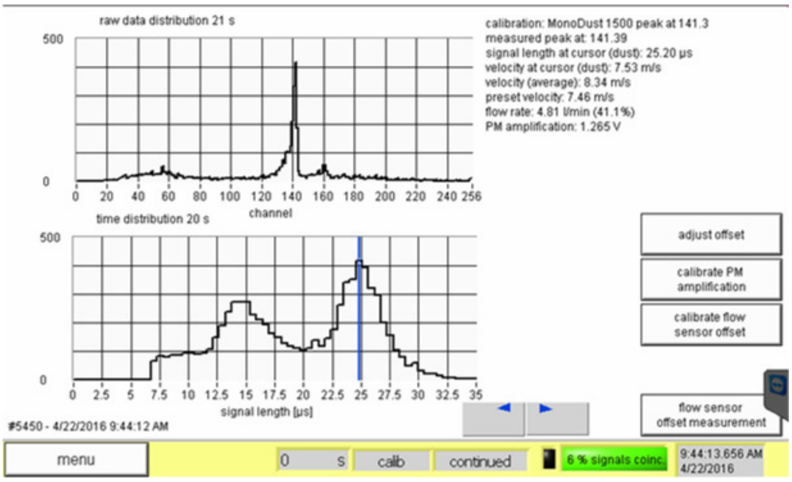


Figure 27: Screen display during the calibration

(Graphic above: Raw data distribution of channel 0 to 256 with maximum at 141.39)

5.6.5 The target channel of the MonoDust 1500 test dust is known exactly through comparative measurements with the PSL standard, is indicated in the enclosed test certificate and on the bottle, and is also indicated on the top line in the calibration screen through firmware version 100448 (see Figure 27). As of firmware version 100449, the top line of the calibration screen no longer contains the specified target channel, but instead only the text "see bottle".

If the MonoDust signal peak is detected in the **target channel ±0.5** (in Figure 27 141.3±0.5), no further measures are required.

If the deviation lies between 0.5 and 1.5 channels, adjust the voltage of the photomultiplier:

Select “calibrate PM amplification” and change the value that is displayed. Increase the voltage if the signal peak was detected below the target value and decrease it in the reverse case. For a rough guideline: 1 channel of deviation – adjust the PM voltage by 0.01 volts. Repeat the measurement with MonoDust 1500 after adjusting the PM voltage. Repeat the measurement with MonoDust 1500 and the adjustment of the PM voltage until the signal peak is detected in the target channel ± 0.5. If the MonoDust 1500 signal peak lies more than 1.5 channels below the value of the last calibration (provided this took place no longer than 1 month previously), the first thing to do is clean the sensor (see section 5.10). Cleaning is also required if the PM voltage is more than 15% above the calibration value after the last cleaning or the as-delivered condition. Switch off the device before cleaning the sensor – when switched on, the sensor reacts very sensitively to too much light. After cleaning, check the leak tightness once again (section 5.1.) and then continue at 5.6.1.

In the event of substantial deviation (> 10 channels) between the measured position of the MonoDust 1500 signal peak and the target value, contact your APDA-372 supplier.

An evaluation of the effect of a shift of the peak in the raw data channel with respect to the mass concentration was carried out in the context of the type approval testing by TÜV Rheinland using CalDust 1100 (setpoint, 130) (see excerpt from Report 936/21226418/C) – The evaluation procedure remains unchanged by the use of MonoDust 1500 instead of CalDust 1100:

Table 3: Matrix on the influence of a peak shift on the mass concentration

	PM2,5		PM10	
channel shift	slope	offset	slope	offset
-3	1,086	0,03889	1,0877	0,0331
-2	1,056	0,025	1,057	0,012
-1	1,029	0,0122	1,028	0,048
0	1	0	1	0
1	0,973	-0,00785	0,976	-0,0047
2	0,945	-0,0197	0,947	0,038
3	0,918	-0,031	0,9224	0,083

For instance, if there is a shift by -3 channels, the actual PM values bear relation to the hypothetically determined PM values in the following way:

$PM_{2.5}$_actual=1.086*$PM_{2.5}$_hypothetical+0.03889
PM_{10}_actual=1.0877*PM_{10}_hypothetical+0.0331.

A shift by -3 channels results in the particle size being determined too small. As a consequence, the $PM_{2.5}$ value is measured too low by the factor 1.086.

For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for PM_{10} were defined. The concentration value to be expected depending on the peak shift was then calculated according to the following matrix

Figure 28: Excerpt from TÜV Rheinland Report 936/21226418/C

5.7. Check of the velocity with MonoDust particles

In addition to the signal amplitude for each individual particle, the sensor also measures the signal length for each individual particle. This signal length is directly proportional to the velocity of the particle in the sensor because the height of the optical measurement volume is known. If the velocity of the particles in the sensor is not correct, the flow rate in the sensor is also not correct, or the flow configuration in the sensor is disturbed.

IMPORTANT:

For the regular inspection of the particle sensor sensitivity using MonoDust 1500, only a check of the channel position for the MonoDust signal peak according to section 5.6 is of relevance for evaluating the correct functioning of the measuring system. **A check of the average particle velocity using MonoDust 1500 is not relevant for the determination of the measured value** and therefore does not need to be monitored. The particle velocity only serves as an indicator for possible disturbances in the flow (e.g. leakage) and is monitored continuously by default as a parameter under the status item "sensor flow" (see section 4).

The check of the velocity with MonoDust particles must be carried out only after a successful leak test, sensor offset and sensor zero point.

The testing requires a conditioned IADS (50 °C or 35 °C), meaning that the test is ideally conducted in combination with the testing of the particle sensor sensitivity.

5.7.1 Follow the instructions in sections 5.6.1 through 5.6.4 and Figure 27 of this manual. Please consult the signal length distribution graph (Figure 27 lower graph) while the APDA-372 aerosol is analyzed using MonoDust particles. The two modes for the velocity distribution should be clearly distinguishable, and the peak value of the second mode (graph, right maximum) should be stable and unambiguously readable.

5.7.2 Use the buttons shown on the screen with the blue left and right arrows to move the vertical blue line in the signal length distribution graph to the position of the peak value of the second mode. The signal length marked in this manner will be converted to a velocity ("velocity at cursor") which is displayed to the right of the "raw data distribution" graph along with additional information. Write down this value.
Important: This procedure is merely intended to simplify the reading of the signal length in the second mode of the velocity distribution – the position of the blue line has no influence on the evaluation of the measurement data (except for "velocity at cursor").
Compare the velocity value with the value that is listed in the APDA-372 calibration certificate (measurement performed at either 35 or 50 °C, depending on what is indicated on the certificate). The deviation should be less than ±0.5 m/s.

5.8. Saving the data

It is recommended that the firmware be closed after the calibration (via the "expert user" menu) and an external back-up copy of the files "promo.ini" and "default.set.pdcontrol" be created (e.g. on a USB flash drive). Then restart the APDA-372 (using the corresponding command from the Windows® "Start" menu, NOT using the On/Off switch!).

Test	Test interval	Tested parameter	Limit values	Comment
Leak test	3 months	Flow rate	< 0.08 l/min (control unit) < 0.5 l/min (overall system) (excluding the pump offset)	by sealing off the intake
Flow rate test	3 months	Flow rate	4.8 l/min ± 0.15 l/min relative to 25 °C and 1013 hPa (Standard Ambient Temperature and Pressure - SATP)	With a suitable transfer standard (volume flow measuring instrument)
Particle sensor offset	3 months	Offset (minimum)	< 0.2 mV	Fully automatic
		Offset adjustment voltage	> 2 V; < 3V	Fully automatic
Particle sensor zero point	1 year	C_N or PM values	C_N : 0 PM: ≤ 1 µg/m³	With HEPA filter on the inlet
Particle sensor sensitivity	1 month	Measured peak	Setpoint ± 0.5 According to the test certificate included in delivery / MonoDust 1500 marking	With MonoDust 1500 test dust
Velocity of the MonoDust particles	3 months	Velocity (MonoDust)	± 0.5 m/s from the factory value According to the APDA-372 test certificate	With MonoDust 1500 test dust by marking the right maximum

Table 2: Summary: Operational procedure for calibration

5.9. Removal of the gravimetric filter / filter replacement

To remove the gravimetric filter, the gravimetric filter holder on the bottom of the aerosol sensor must be removed.

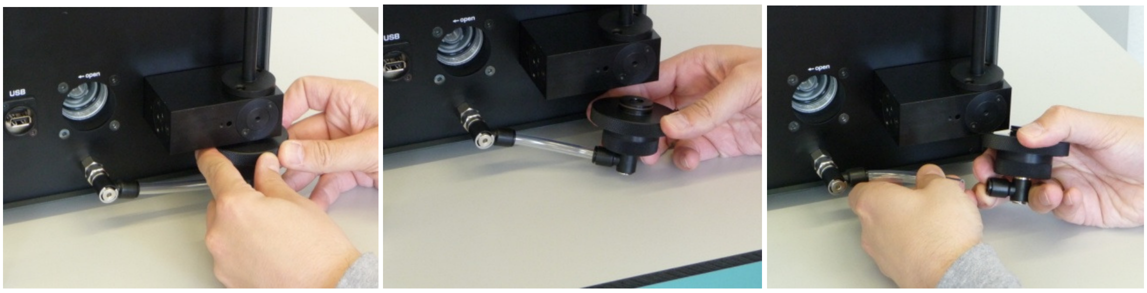


Figure 29: (A-C) Removing the filter holder

The filter holder (Figure 29A) can easily be pulled off downwards (Figure 29B). Afterward, the plug-on connection of the exhaust hose can be removed. To do so, press the plug-on connection towards the back and at the same time, pull off the hose with the other hand (Figure 29C). The filter holder can now be opened by rotating it to the left.

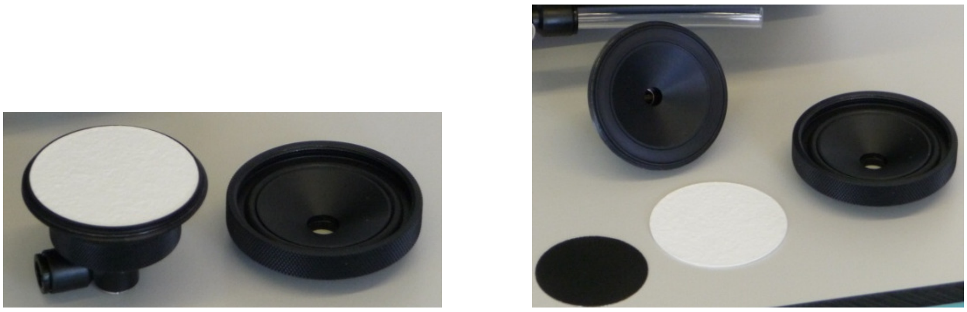


Figure 30: (A and B) filter holder assembly

The filter holder consists of an upper and lower part which are secured to each other by a screw connection (see Figure 30 A&B). The lower part also contains a supporting grid on which the gravimetric filter rests.

5.10. Cleaning the APDA-372

Cleaning of the optical sensor is required if the photomultiplier voltage during calibration of the optical sensor lies more than 15% above the calibration value after the last cleaning or the as-delivered condition.

5.10.1. Cleaning the APDA-372 with IADS

When using an IADS humidity compensation module, it must first be removed from the aerosol inlet of the sensor so that the APDA-372 control unit with the integrated aerosol sensor can be moved aside.

Figure 31: Connection of the sensor inlet with IADS humidity compensation module

The adapter for connecting the IADS humidity compensation module on the aerosol inlet must be pushed downwards. Afterwards, the IADS humidity compensation module can be pushed all the way upwards so that the inlet of the aerosol sensor is freely accessible.

5.10.2. For all APDA-372 systems

To clean the internal optical lenses of the sensor requires that the filter holder be removed from the sensor outlet and the plug-on connection between the filter holder and the inlet of the exhaust pump also be removed.

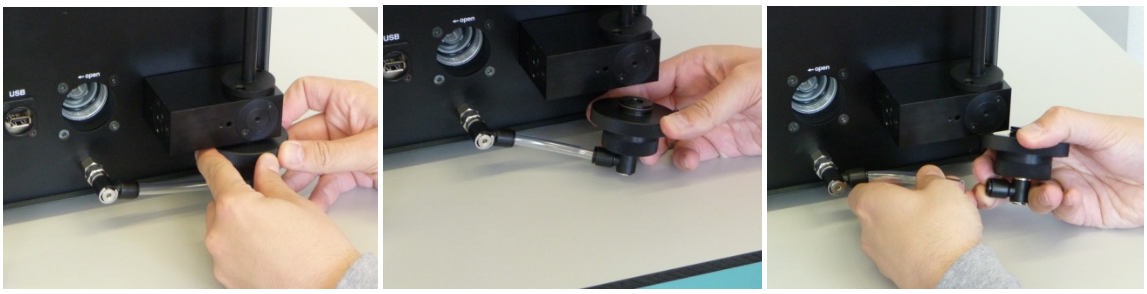


Figure 32: (A-C) Removing the filter

The filter holder (Figure 32A) can easily be pulled off downwards (Figure 32B). Afterward, the plug-on connection of the exhaust hose can be removed. To do so, press the plug-on connection towards the back and at the same time, pull off the hose with the other hand (Figure 32C). Afterwards, the two M3 Phillips head screws must be unscrewed with a suitable screwdriver.

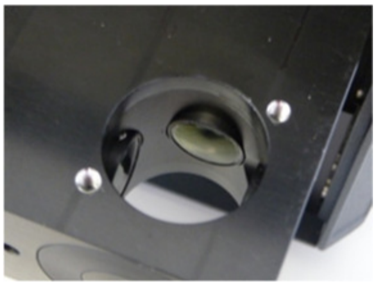
Figure 33: Unscrewing the M3 Phillips head screws

Figure 34: Removing the aerosol guide tube

Caution:

When removing the aerosol guide tube, care must be taken to ensure that the inner optical lenses of the aerosol sensor are not scratched or damaged by the aerosol tube!

Now the two optical lenses in the inside of the aerosol inlet can be cleaned. This must be done with an optical cloth only (included in the scope of delivery).



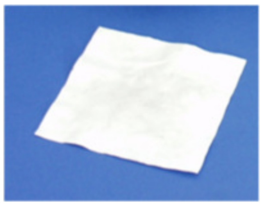


Figure 35: Optical cloth

Figure 36: Optical lenses in the inside of the aerosol sensor

Caution:

Do not touch the lenses with your fingers!

Clean only with optical cloths!

The aerosol guide tube can be cleaned with compressed air.

5.11.Cleaning the exhaust filter of the internal pump

The filter must be cleaned or replaced if the power required by the exhaust pump is greater than 50%. The protective cover of the exhaust filter (Figure 37) of the internal pump can be released and pulled off easily by rotating it to the left. The filter itself can also be removed by rotating it to the left (Figure 39).

Figure 37: Removing the protective cover

Figure 38: Filter without protective cover

The filter can either be blown out with compressed air or be replaced if too heavily contaminated.

Figure 39: Removing the filter

Figure 40: Filter and protective cover after removal

Proceed in the reverse order for installation.

5.12.Cleaning the Sigma-2 head

For monitoring purposes, the Sigma-2 head should be inspected for coarse dirt and cleaned as needed every three months (in connection with the calibration).

5.13. Replacing the O-ring seal

If a leak test or a visual inspection reveals that an O-ring seal must be replaced, we recommend only using the O-ring seals that HORIBA supplies. HORIBA offers a “set of O-ring seals for the APDA-372” as a spare part item. This set consists of the following O-ring seals:

Figure 41: Set of O-ring seals for the APDA-372

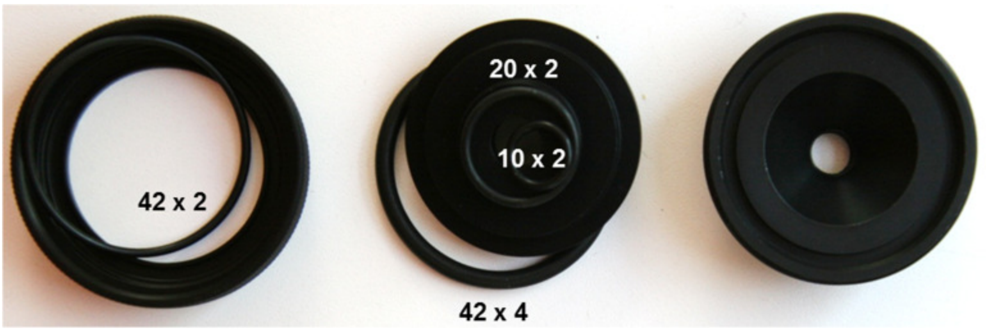


Figure 42: Absolute filter holder

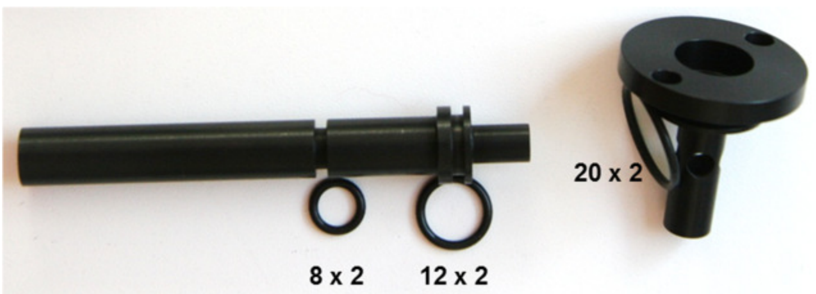


Figure 43: Aerosol inlet, sensor inlet

5.14. Servicing of the pump assembly

The volumetric flow in the APDA-372 is generated by two pumps (= pump assembly) that are connected in parallel. The pumps used require no maintenance during operation. The pump performance is monitored continuously (also see section 4). Replacement of the pump assembly is only necessary when the pump power required increases to > 80% (status warning). Generally, the pump assembly service life is at least two years.

6. Particle detection with the APDA-372 system

The APDA-372 is an optical aerosol spectrometer which uses the principle of light scattering according to Lorenz Mie to determine the size of individual particles.

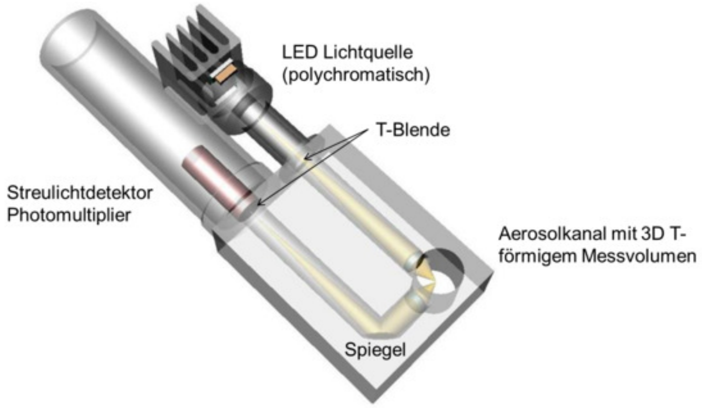


Figure 44: Sensor setup of the APDA-372 measurement system

The particles move through an optically restricted measurement volume that is illuminated homogeneously with polychromatic light.

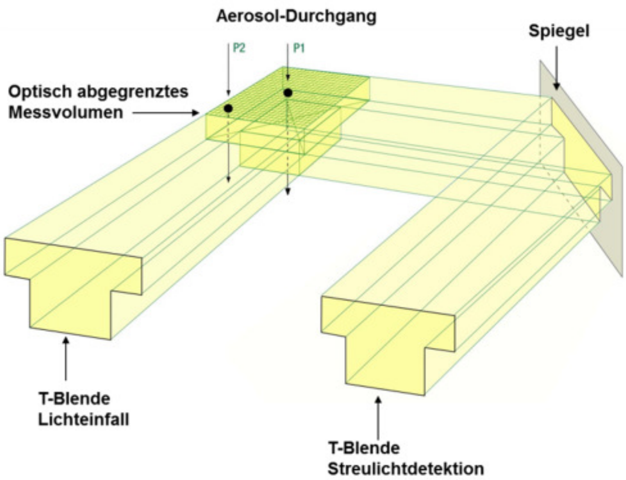


Figure 45: Depiction of the T-aperture

Using a polychromatic light source (LED) in combination with 90° scattered light detection, a very precisely defined calibration curve is obtained with no unambiguities in the Mie range. This allows the use of a very high size resolution.

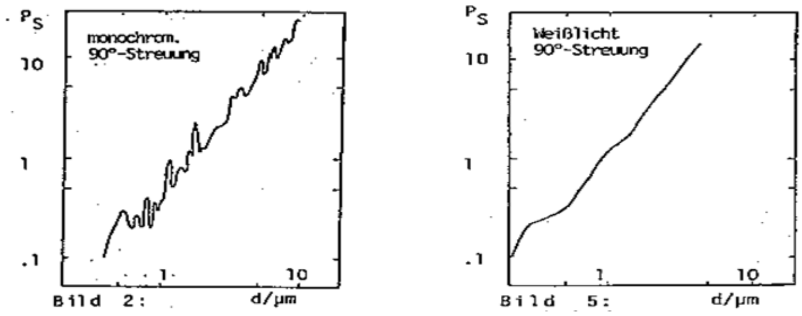


Figure 46: Calibration curve for 90° scattered light detection

With a monochromatic light source (left) and with a polychromatic light source (right)

For each individual particle, a scattered light pulse is generated that is recorded at an angle of from 85° to 95°. The particle number emission is measured based on the number of scattered light pulses. The amplitude (height) of the scattered light pulse is a measure of the particle diameter. Moreover, the signal length is also measured.

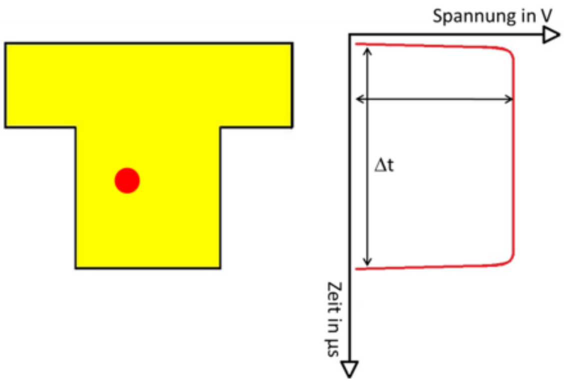


Figure 47: Measurement of the scattered light signal on the individual particle.

The amplitude and the signal length are measured.

Use of the special T-aperture optics with simultaneous measurement of the signal length allows elimination of border zone errors. When particles at the edge of the measuring range are only partially illuminated, this is referred to as a border zone error. This partial illumination results in particles being classified as smaller than they actually are (see Figure 48, red curve). Using the T-aperture allows a distinction to be made between the particles that can only fly through the arm of the T (shorter signal length) and those which can also pass through the middle section of the T (longer signal length). The latter are sure to be fully illuminated in the upper part. This means there are no border zone errors with the APDA-372 (Figure 48, blue curve).

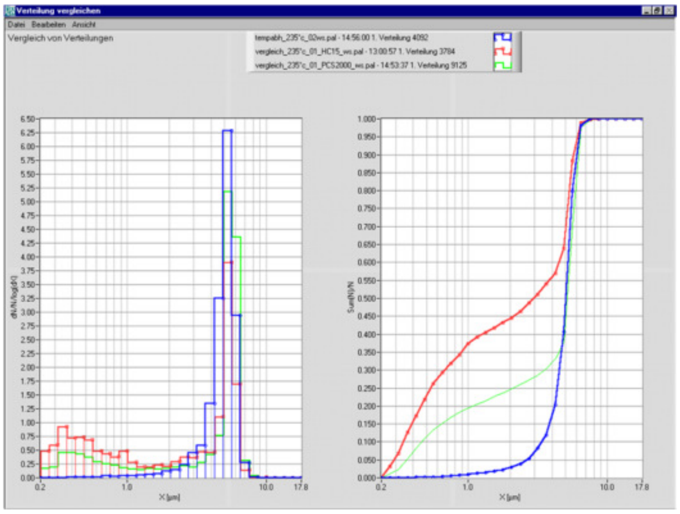


Figure 48: Comparison of an optical scattered light spectrometer with

a simple rectangular aperture (HC15, red) with an optical scattered light spectrometer with a T-aperture (welas®, blue) when monodisperse 5 µm particles are introduced

Measurement of the signal length also makes detection of coincidence possible (more than one particle in the optical detection volume), because the signal length is greater in this case. Using a correction factor determined and verified by Dr. Umhauer and Prof. Dr. Sachweh, this then allows the coincidence to be corrected online.

Using improved optics, a higher light density achieved through a new white-light LED as a light source and improved signal analysis electronics (logarithmic A/D converter), it was possible to reduce the lower detection limit to 180 nm. This allows smaller particles, especially those which are found in high concentrations in the vicinity of streets, to be taken into account a good deal better (Figure 49).

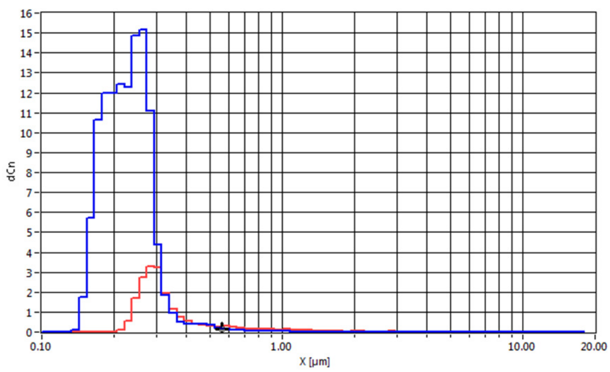


Figure 49: Measurement in the vicinity of streets with the APDA-372

(Size range from 0.18 µm, blue curve) compared with a different optical measurement system (size range from 0.25 µm, red curve)

6.1. Special properties of the APDA-372 system

The APDA-372 system is characterized by the following properties:

Using the techniques presented

- unambiguous calibration curve (polychromatic light and 90° scattered light detection)
- no border zone error (patented T-aperture technology)
- coincidence detection and coincidence correction (digital individual particle analysis)

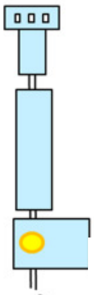
the following decisive advantages are achieved

- very good size resolution (high number of raw data channels)
- very good size classification accuracy
- exact concentration determination

In summary, it can be stated that:
The mass concentration can only be determined reliably with a very good size resolution and very good size classification accuracy as well as with precise concentration determination.

6.2. Overview of the individual measuring steps

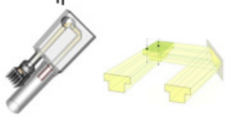
Particles of different sizes



Representative „suction" of particles in ambient air with Sigma-2

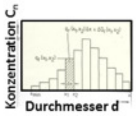
Drying of particles with IADS (Intelligent Aerosol Drying System)

Measurement of scattered light intensity with white light and 90° scattered light at the single particle

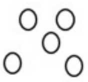


Filtration of border zone and coincidence signals

Determination of optical particle size by allocation of the scattered light signal to the particle diameter via an unambiguous calibration curve based on Latex



Classification of measured particles into size classes in form of a histogram



Detection of fog by analyzing the distribution form,
eliminating the mass of fog droplets

n_{Umwelt}

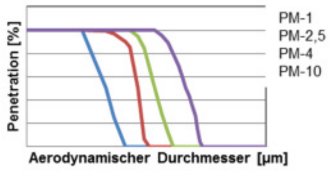
Conversion of particle size distribution based on the Latex diameter to a distribution based on a representative refractive index for the environment

Conversion of particle size distribution based on the

optical diameter to a

distribution based on the aerodynamic diameter

Analysis of the distribution form, determination of density parameters depending on the distribution form



Transfer of the separation behavior of the individual

PM sampling inlets to the size distribution depending on the density parameters

$$PM = \frac{\sum N(d) \cdot \frac{1}{6} \cdot \pi \cdot d^3 \cdot \rho(d)}{V}$$

Calculation of the particle mass by using a size depended transformation function depending on the form of the distribution

PM value

The APDA-372 uses the measured particle size information to calculate the following dust values:

- PM-1[µg/m^3]: Dust fractions smaller than $d_{50,Aero}$ = 1 µm in accordance with the US EPA
- PM-2.5 [µg/m^3]: Dust fractions smaller than $d_{50,Aero}$ = 2.5 µm in accordance with the US EPA
- PM-4 [µg/m^3]: Dust fractions smaller than $d_{50,Aero}$ = 4 µm
- PM-10 [µg/m^3]: Dust fractions smaller than $d_{50,Aero}$ = 10 µm in accordance with the US EPA
- PM-thoracic [µg/m^3]: Dust fractions that can enter the bronchi
- PM-alveolar [µg/m^3]: Dust fractions than can enter the alveoli
- PM-respirable [µg/m^3]: Total respirable dust fraction
- PM-total [µg/m^3]: Total measured dust

The dust fractions mentioned above are calculated using the penetration curves for standardized sampling heads to EN-481 (PM-respirable, PM-thoracic and PM-alveolar) as well as of the US EPA (PM-1, PM-2.5, PM10).

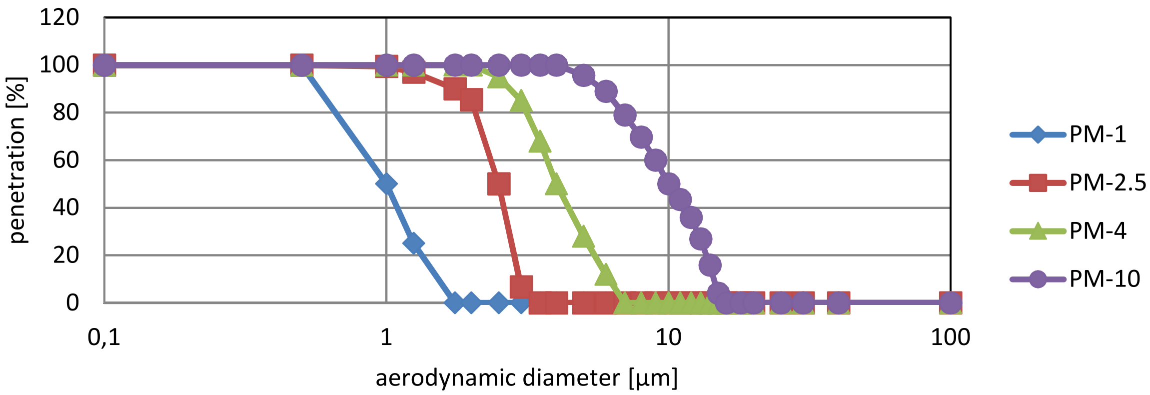


Figure 50: Penetration curves used

for PM-1, PM-2.5, PM-4, PM-10 (US EPA)

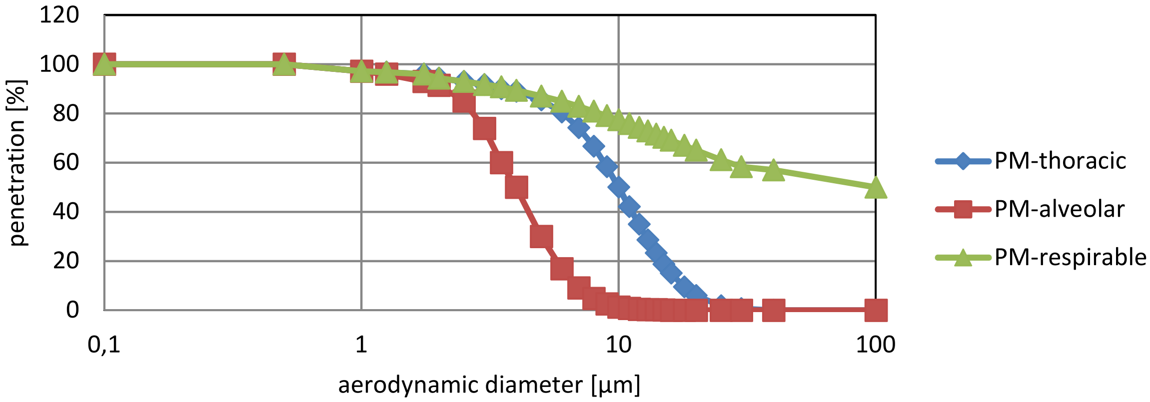


Figure 51: Penetration curves used

for dust measurements at workplaces in the health-care sector (EN-481)

Aerodynamic diameter [µm]	PM-1 [%]	PM-2.5 [%]	PM-4 [%]	PM-10 [%]	PM-thoracic [%]	PM-alveolar [%]	PM-respirable [%]
0.1	100	100	100	100	100	100	100
0.5	100	100	100	100	100	100	100
1	50	99.5	100	100	97.1	97.1	97.1
1.25	25	97	100	100	96.8	96	96.8
1.75	0	90	100	100	96	93	96
2	0	85.5	100	100	94.3	91.4	94.3
2.5	0	50	95	100	93	85	93

3	0	6.7	85	100	91.7	73.9	91.7
3.5	0	0	68	100	90	60	90.8
4	0	0	50	100	89	50	89.3
5	0	0	28	95.7	85.4	30	87
6	0	0	12	89	80.5	16.8	84.9
7	0	0	0	79	74.2	9	82.9
8	0	0	0	69.7	66.6	4.8	80.9
9	0	0	0	60	58.3	2.5	79.1
10	0	0	0	50	50	1.3	77.4
11	0	0	0	43.5	42.1	0.7	75.8
12	0	0	0	36	34.9	0.4	74.3
13	0	0	0	26.9	28.6	0.2	72.9
14	0	0	0	15.9	23.2	0.2	71.6
15	0	0	0	4.1	18.7	0.1	70.3
16	0	0	0	0	15	0	69.1
18	0	0	0	0	9.5	0	67
20	0	0	0	0	5.9	0	65.1
25	0	0	0	0	1.8	0	61.2
30	0	0	0	0	0.6	0	58.3
40	0	0	0	0	0	0	57
100	0	0	0	0	0	0	50

Table 3: Penetrations used for determining the dust mass concentration

The dust fractions mentioned above are based on the aerodynamic diameter. The aerodynamic diameter can be calculated as follows:

$$x_{aerodynamic} = x \cdot \sqrt{\frac{\rho_{particle}}{1\frac{g}{cm^3} \cdot \chi}}.$$

Generally, the density of the particles $\rho_{particle}$ lies between 0.7 and 3 g/cm³, and the shape factor χ between 1 and 1.5. For the calculation of the PM values, the APDA-372 assumes a density of 1.5 g/cm³ and a shape factor of 1. These values are suitable for most aerosols. However, the APDA-372 is equipped with a gravimetric filter system which can be used for the measurement of the correction factor C. This system also takes into account the influence of the refractive index on the measured PM values. Using the factor C, the PM values are corrected as follows:

$$PM_{corrected} = C \cdot PM.$$

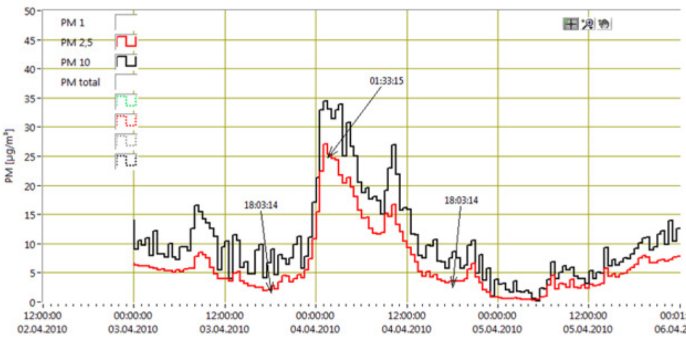
6.3. Additional advantages

In addition to the PM fractions, which are output continuously and simultaneously, the data on the measured particle number concentration and particle size distribution are available with a high level of time and size resolution (up to 32 size classes per decade). This additional information can be used to carry out a "source apportionment" or to assess the health relevance (larger particles penetrate more deeply into the human respiratory tract).

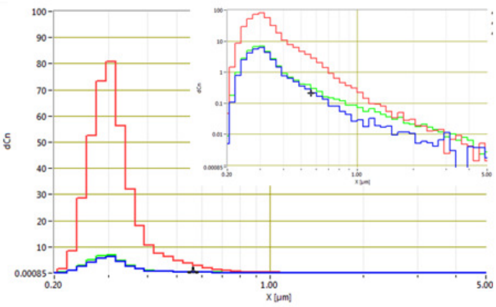
Figure 52 shows an example from Vienna around Easter time. The time history of the PM fractions evidenced a sudden and substantial increase, which then slowly subsided.

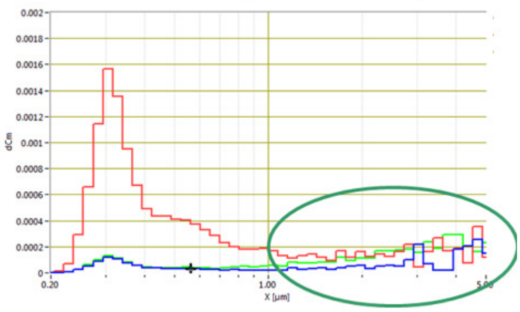
An investigation of this phenomenon in consideration of the particle size distribution revealed that this was caused by a massive increase in the number concentration of very small particles such as are typical of a combustion process. In fact, in many cities of Germany and Austria, a significant increase in particulate pollution is measurable in the night from Saturday to Easter Sunday. This is caused by Easter fires – a custom from ancient times which serves to drive away the winter. The combustion aerosols which are thereby created contain a high percentage of small particles. In order to be able to model the dispersion behavior of fine dust, both the particle size distribution and a high time resolution are important (whereby a time resolution of one second is technically feasible with the APDA-372 system), since the physical properties of the particles are decisive for a prediction of the dispersion. For example, the diameter can be used to derive the sinking velocity, and the number concentration to derive the coagulation behavior.

Easter fire
A tradition from olden times, which is used to frighten away and to burn winter



Chronological sequence of PM concentrations in the night to Easter Sunday in Vienna





Number size distribution (left) and mass size distribution (right) of the combustion aerosol of Easter fire.
Blue – 3.4.2010 6:03 pm, red – 4.4.2010 1:33 pm, green – 4.4.2010 06:03 pm

Figure 52: Additional information based on particle size distributions during an increase of the PM concentrations

6.4. Definition of terms

- Classification accuracy

How exact is the measurement of the testing aerosol? Does the determined particle size distribution meet the actual particle size distribution of the testing aerosol?

- Resolution capacity

How exact is the resolution of the device? Does the optical particle counter even determine the difference between very close particle sizes?

- Ambiguity

Does the optical particle counter determine unambiguously the particle sizes within the range of wave length of the laser light?
There even 180° white light forward scattering delivers ambiguous results.

- Border zone error

Does the device consider the tolerances in the border zones caused by the Gaussian distribution of laser light?

- Counting efficiency

How many particles of the testing aerosol are really measured at a known concentration?

- Coincidence error

How do you assure that the light impulse is caused by only one particle?

6.5. Effects of the device parameters

- Border zone errors

The particle size spectrum is measured with a fine fraction that is too high. The broader the particle size spectrum, the greater the border zone errors.

- Coincidence errors

The particle size spectrum is measured too coarsely while the particle concentration is measured too finely. Per definition, a 10% coincidence is allowed during a measurement.

- Counting efficiency

A lower counting efficiency causes a shift of the particle size distribution in the direction of coarser particles because the fine fraction is underrated. With a high counting efficiency, the coarse fraction is correspondingly underrated. The quantity is determined incorrectly. If measurements are made using several particle counters, the difference in counting efficiency between the counters used must be known. Only then can the results be compared!

- Classification accuracy

In correlation measurements, e.g. with impactors, the correlation factor becomes better the better this device parameter is.

Devices with good classification accuracy over the entire measurement range deliver reliable distributions.

- Resolution capacity

In correlation measurements, e.g. with impactors, the correlation factor becomes better the better this device parameter is. Devices with a high resolving power can also measure tightly grouped bimodal and trimodal distributions.

7. Ensuring correct measuring conditions

The measurement result, i.e. the particle size distribution of the individual measurements that is determined, can deviate significantly from the actually present values in the aerosol flow under unfavorable measuring conditions.

Therefore, pay attention to:
- Representative sampling
- Minimal particle losses due to the aerosol transport
- No coincidence errors

As a matter of principle, the APDA-372 system can only measure and display what it has registered in its optical measurement volume. This means that the sampling flow of the aerosol must be guided there in as unadulterated a manner as possible.

Towards this end, the following points should be observed:
- Short hoses for the aerosol
- Metal tubes should be used whenever feasible and under no circumstances should there be longer plastic hoses (strong particle deposition due to electrostatic charging)
- Vertical aerosol guidance because large particles (greater than 5 µm) settle out or the aerosol looses its original mixture.

In principle and for all counting scattered light measurement methods, only one individual particle may be present in the optically delimited measuring volume of the aerosol sensor at any one time, since the scattered light of the individual particle is evaluated to determine the particle size.

If more than one particle is present in the measurement volume, these particles are registered as one particle, which means the particle is measured as too large and the number measured is too small.

If the APDA-372 is used at installation sites at which significantly high concentrations can occur, and if the Fidas® measures a coincidence value of greater than 10%, it may be necessary to activate the coincidence correction in order to significantly broaden the original concentration range of 0 to 10,000 µg/m^3 (also see section 3.3).

8. Technical data of the APDA-372 system:

Measurement volume size, WxDxH	262 µm x 262 µm x 164 µm	
Maximum concentration for 10% coincidence errors	Sensor integrated in the control unit Max. concentration of up to 4,000 P/cm³	
Maximum concentration with coincidence detection and coincidence correction	20,000 P/cm³	
Maximum concentration (mass)	10,000 µg/m³	
Communication between the control unit and the evaluation computer	RS-232 (Bayern-Hessen, ASCII or Modbus) Ethernet (UDP ASCII, TeamViewer, etc.)	
Sample volumetric flow rate	4.8 l/min SATP	
Cleaning	The housings can be cleaned with non-aggressive detergent (e.g. dishwashing liquid) or spirits. Cleaning optical parts: see maintenance	
Mains connection: see rating plate! Supply voltage Mains fusing	230 V, +/-10% 2 pcs. T 2 A / 250 V	115 V, +/-10% 2 pcs. T 4 A / 130 V
Power consumption Network frequency	200 W 47-63 Hz	
Ambient conditions	Temperature range, 5 °C to 40 °C Acoustic emission of the device << 85 dBA	
Dimensions (HxWxD)	Control unit incl. built-in sensor: 185 mm x 450 mm x 320 mm	
Weight	Control unit incl. built-in sensor: 9.3 kg	

Technical data are subject to change.

APDA-372 / APDA-372 E
Fine-Dust Monitoring System
Appendix

9. Appendices:

9.1. Humidity compensation module, IADS

When the ambient humidity is high, water condenses on the particles and thereby falsifies the particle size. This effect is avoided by the use of the IADS humidity compensation module.

The temperature of the IADS is controlled in dependence on the ambient temperature and humidity (measured by the weather station). The minimum temperature is 23 °C. The humidity compensation is accomplished by means of a dynamic adaptation of the IADS temperature utilizing up to a maximum of 90 watts of heating power.

The IADS humidity compensation module is connected to the aerosol sensor of the APDA-372 system using an adapter. When cleaning the APDA-372 aerosol sensor, the adapter must be pushed down so that the IADS humidity compensation module can be pushed completely upwards and the aerosol inlet of the APDA-372 sensor is freely accessible.

The APDA-372 firmware controls the humidity compensation module (see the APDA-372 firmware instruction manual for more on this).

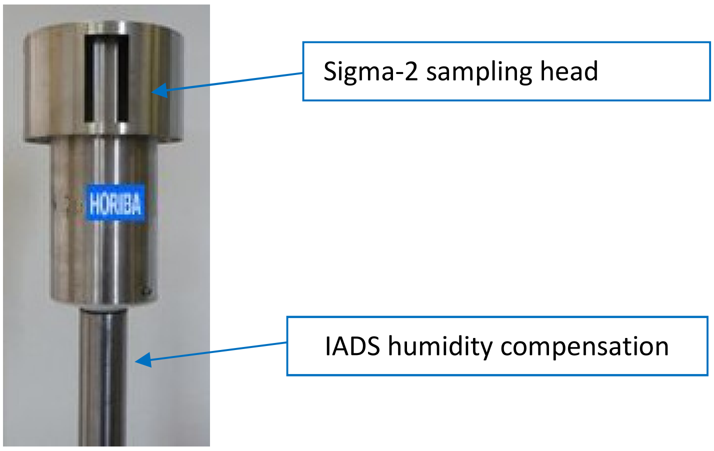


Figure 53: Sigma-2 sampling head

Figure 54: APDA-372 control unit, aerosol sensor with IADS

Important technical dimensions of the IADS:
Length: 1150 mm plus 80 mm narrow tube on which the Sigma-2 head is installed
Outer diameter 48.3 mm

Extended IADS
For installation of the APDA-372 in an existing container, HORIBA offers the option of using an extended IADS.

Figure 55: IADS extension with external tube

Length: 1.20 m to 2.10 m

9.2. Sigma-2 sampling head

Sigma-2 sampling head to VDI 2119-4 for measurements that are predominantly independent of the wind is simply pushed onto the inlet of the IADS and secured by means of the locking screw using an Allen key.

Figure 56: Sigma-2 sampling head

For monitoring purposes, the Sigma-2 head should be inspected for coarse dirt every three months (in connection with the calibration).

9.3. Compact weather station, WS300/WS600-UMB

Figure 57: Compact weather station, WS600-UMB

The WS300/WS600-UMB weather station is read out by the APDA-372 firmware (see the APDA-372 firmware instruction manual for more on this).

Special features:

- All in one
- Ventilated radiation protection
- Maintenance-free measurement
- Open communication protocol

Description of country variants: EU, USA, Canada

WS600-UMB Compact weather station for measuring air temperature, relative humidity, precipitation intensity, precipitation type, precipitation amount, air pressure, wind direction and wind speed. The relative humidity is recorded by means of a capacitive sensor and the air temperature by a precision NTC sensor element. The precipitation measurement is accomplished by means of a 24 GHz Doppler radar. The droplet velocity of each individual drop (rain/snow) is measured. The precipitation amount and intensity are determined based on the correlation of the droplet size and velocity. The type of precipitation (rain/snow) is determined based on the different falling velocities. A great advantage as compared to common tipping spoon and tipping scale methods is that the measurements are maintenance-free. The wind measurement is based on ultrasonic sensor technology. The measurement data are available in the form of a standard report (Lufft UMB protocol) for further processing.

WS300-UMB Compact weather station for measuring air temperature, relative humidity and air pressure. The relative humidity is recorded by means of a capacitive sensor and the air temperature by a precision NTC sensor element. The measurement data are available in the form of a standard report (Lufft UMB protocol) for further processing.

9.3.1. Technical data of the WS600-UMB

Dimensions	Ø approx. 150 mm, height approx. 345 mm
Weight	approx. 2.2 kg
Interface	RS-485, 2-wire, semi-duplex
Power supply	24 VDC ±10% <4 VA (without heating)
Permissible operating temperature	-50...60°C
Permissible rel. humidity	0...100% R.H.
Heater	40 VA at 24 VDC
Cable length	10 m

Temperature sensor

Principle	NTC
Measurement range	-50 .. 60 °C
Units	°C
Accuracy	±0.2 °C (-20...50 °C), otherwise ±0.5 °C (>-30°C)

Rel. humidity sensor:

Principle	Capacitive
Measurement range	0 .. 100% R.H.
Units	% R.H.
Accuracy	±2% R.H.

Air pressure sensor:

Principle	MEMS capacitive
Measurement range	300 .. 1200 hPa
Units	hPa
Accuracy	±1.5 hPa

Wind direction sensor:

Principle	Ultrasonic sound
Measurement range	0 .. 359.9 °
Units	°
Accuracy	±3 °

Wind speed sensor:

Principle	Ultrasonic sound
Measurement range	0 .. 60 m/s
Units	m/s
Accuracy	±0.3 m/s or 3% (0...35m/s)

Precipitation amount sensor:

Resolution	0.01 mm
Reproducibility	typ. > 90%
Droplet size measurement range	0.3...5 mm
Type of precipitation	Rain/snow

9.3.2. Technical data of the WS300-UMB

Dimensions	Ø approx. 150 mm, height approx. 223 mm
Weight	approx. 1 kg
Interface	RS-485, 2-wire, semi-duplex
Power supply	4…32VDC
Permissible operating temperature	-50...60°C
Permissible rel. humidity	0...100% R.H.
Cable length	10 m
Temperature sensor	
Principle	NTC
Measurement range	-50 .. 60 °C
Units	°C
Accuracy	±0.2 °C (-20...50 °C), otherwise ±0.5 °C (>-30°C)
Rel. humidity sensor:	
Principle	Capacitive
Measurement range	0 .. 100% R.H.
Units	% R.H.
Accuracy	±2% R.H.
Air pressure sensor:	
Principle	MEMS capacitive
Measurement range	300 .. 1200 hPa
Units	hPa
Accuracy	±1.5 hPa