the vision competence center

pdm

PDM4

HE350

5 µm/50cm²

PDM4 Optical Head

High End Series

Hardware V4

Software V3

Operation Manual

English

CE

Get a Grip on Surface Cleanliness

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Certification Listing

Serial Number:	Date of Certification:

Date of Certification:	Trace Number:
Expiration Date:	Inspector:

Date of Certification:	Trace Number:
Expiration Date:	Inspector:

Date of Certification:	Trace Number:
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Remarks

Remarks article 9 tab 3 EMC directive 2004/108/EG

The HE350 unit weighs 14.3 kilograms and should be lifted using both hands. Hold the bottom with fingers and stabilize the side with the hand. Do not hand-carry the unit for more than 20 meters to avoid damage and potential injury. Dropping the unit may result in both unit damage and personal injury.

Remarks article 9 tab 5 EMC directive 2004/108/EG

The HE550 employs intense illumination for particle measurement. Avoid looking directly into the light source at all times. Arrange the operator's workspace so that the direct view of the light source is obstructed either by the positioning of the HE550 or external shielding.

PDM4 HE550
Latest model of the Particle Deposition Monitor

Note: Lock the power cable using the locking nut on the cable.

Witness Plate
Borosilicate extra bright with unique serial number and QR-code

I/O
Interconnection socket with power inlet

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I. Hardware

The Particle Deposition Monitor (PDM) is designed to image particle deposition on a borosilicate disk using a scanning system. Calibrated images serve as the instrument's output. It is calibrated to capture only deposition on the disk's surface. The instrument's mechanical design is optimized to prevent thermal airflows above it. The system comprises of the PDM and monitoring software. The software analyses images from the instrument, providing measurements such as particle box size (length and width), particle surface area, and the number of particles within customizable size ranges.

I.1 Modes of Operation

The PDM has two modes:

Real time mode: In real-time mode, the PDM is positioned at the designated location. The system quantifies particle deposition at customizable intervals. Automation allows operation without a constant operator presence. Real-time intervals can vary in size, offering insight into average deposition with larger intervals and detecting abrupt changes in deposition rate with smaller intervals.

Witness plate mode: The reference value for a set of witness plates is measured before placement at the sample location. After a sufficient time, the plates are measured again. Calculating the difference between the initial and subsequent measurements yields the particle deposition rate. The second measurement can serve as a reference value for a third measurement, and so forth.

I.2 PDM Operation

The HE550 optical readout unit for particle deposition can scan 12cm diameter borosilicate disks. Measurements can be conducted directly from a PC to the unit or via the network. In a typical operation cycle, the operator loads the unit with the witness plate and initiates the initial measurement. The unit activates the illumination, scans the plate, and automatically stores the image data on the local or remote computer. The software processes the image, isolates each particle on the plate, and displays relevant parameters. After the second measurement, only information on new particles is displayed, along with the deposition rate.

I.3 Particle Sizing

Various methods can be employed to measure particles, and according to ISO 14644(-9:2022), manufacturers are permitted to define their own measuring system. The Particle Deposition Monitor (PDM) utilizes a measurement method commonly employed in machine vision. Airborne particle counters adopt a sizing equivalent to the polystyrene latex sphere (PSL) particle, aligning with their calibration method and sensor type.

The PDM employs an optical standard on a glass plate for calibration. This measuring system utilizes the flat projection of particles to extract dimensional information. When particles settle on a surface, they assume a mechanically stable state, presenting their largest area to the detection system, thereby revealing their longest dimension.

In the vision industry, the 'fitting box' length and width are employed, where the smallest rectangular fitting box is determined. This involves drawing a box around the particle to minimize the covered area. The length and width of the box are then designated as the particle's length and width, respectively. Importantly, the orientation of the box is not restricted to the axes of the Cartesian system.

In the illustration below, three distinct measurement methods are depicted. The first demonstrates the PSL method, where the diameter of the circle (red) defines the length of the particle. The second illustrates Feret's diameter, equating the length and width of the box (red) to the particle's dimensions. The third drawing employs the Flat Surface Longest Side (FSLS) method, where the length and width of the box (red) are also aligned with the particle's width and length, with the smallest possible box size. This method is used by the PDM.

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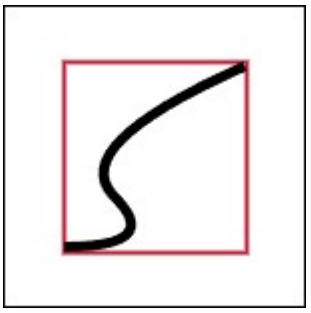
PSL Method



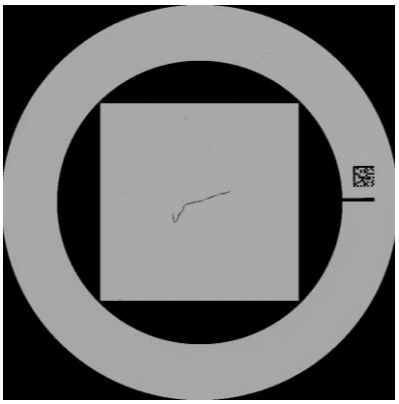
Feret's Method

FSLS Method

Note: Real-world particle sizes in airborne conditions may appear smaller than the same particles in deposition. Deposition equipment relying on reflection exhibits a PSL equivalent phenomenon.

Note: Fibers in contact with the surface may manifest as a dim fiber structure in the image. In the results, this could appear as multiple parts closely grouped as a cluster, particularly when the particle has excessive height to stay in focus of the camera. Airborne equipment may encounter challenges in registering fibers, while deposition equipment based on reflection may go into overflow mode.

I.4 Sampling Field



The optical measuring system scans a predefined donut-shaped field on the used witness plates, with a surface area of approximately 50cm^2, allowing for efficient and rapid scans. ISO 14644 permits the use of this shape. The field, starting approximately 2mm from the edge of the witness plate, encompasses an outer border with a width of approximately 15.9mm. A sample can be seen to the right.

I.5 Differences Between The PDM, PDM2, PDM3 and PDM4

The original optical readout unit, known as the PDM, had the type number HE850. It served as a high-end particle deposition monitor with an optical resolution better than 8 micrometers and a readout area close to 50 square centimeters. Utilizing a mechanical arrangement with a motor and gearbox, the gearbox is audibly noticeable, and white light is visible during a scan.

Distinguishing between the PDM and the PDM2, the difference lies in the disk support. In the second model, the support is reduced to three points, clearly visible on the turntable. The PDM2, being the second generation, features a silent motor, and the light used during a scan is blue and monochromatic. Internally, a large optical encoder samples the witness plate equidistantly, combined with a large rotating mass to ensure less rotational displacement noise. Additionally, the turntable is improved to reduce warp.

The PDM2 is compatible with next generations of the Vision Analysis software. For the PDM3, the optical resolution is improved to 5 micrometers, while the disk system remains unchanged. The VAS software was modified to manage the increased data from the PDM3 and now employs the mask method instead of the A, B method, as explained in the software section.

The new PDM4 boasts enhanced cooling for the lighting, a redesigned motor for the turntable, and a more compact form factor. Additionally, the VAS software has undergone significant updates to enhance user-friendliness. The latest version now features a database-centric design, facilitating improved organization of measurements and data.

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1.6 PDM Hardware Specifications.

Mechanical Specifications		Interconnections	
Height	29 cm	**TCP/IP**	8 Pin RJ45
Diameter	21 cm	**Ground Clip**	Trough the power unit
Weight	11 kg	**Speed**	~3.8s per revolution
Material	Aluminium Cabinet. Fully closed, no inside airflows present	**Power Inlet**	24 Volt, 5 Amp, Direct Current
Surface Finish	Anodized	**Optical Readout**	7 seconds
Turntable	RVS	**Processing Time**	Max. 15s. Average 5s.
ESD Common	Zero ohm to cabinet	**Real Time Cycle**	30s minimum

1.7 Equipment Parameters

Detectable Particle Size	>5µm <12 000µm
Measuring Surface	50cm^2
Sample Time	2 minutes
Optical Light Source	
Method	Contrast Imaging
Calibration	Annually, either remote or service call
Data Storage	Depends on laptop storage volume
Adapter	100-240V Adapter 18V 3Amp
Cooling	Internal air heat distribution over full body surface
Measuring Principle Size	Flat Surface Longest Side Method
Measuring Principle Particle Area	Enclosed In Contour*

Note*: For a detailed explanation on the measurement method, contact your sales representative. Upon request changes can be made to the measurement method.

1.8 Safety Instructions

- Do not stare directly into the light source.
- Only use the original power supply.
- Lift the PDM with 2 hands, beware of the weight.
- The witness plates, composed of borosilicate, can produce shards if broken. They are suitable for use in environments up to 150 °C without special requirements and can withstand temperatures up to 500 °C with slow heating and cooling processes. However, it is important to note that the laser print may incur damage at temperatures exceeding 200 °C.
- Do not allow the PDM to come into contact with moisture.
- Allow the PDM to acclimate for at least 10 minutes per °C.
- Under no circumstances should you lift the PDM by its 'neck' as this action will cause damage to the equipment.

1.9 Witness Plate Cleaning and Minimizing Measurement Errors

For the most precise results, it is essential to ensure the witness plate is thoroughly cleaned before use. The goal is to have fewer than 300 particles present during the initial measurement (mask), as a higher number may compromise precision. To achieve this, utilize a polyester cloth designed for cleanroom environments and apply a moderate amount of isopropanol. Clean the witness plate using broad strokes from the center outward. It is advisable to replace the cloth regularly or when it becomes evident that the cloth has begun to generate particles of its own. It is advised to avoid using paper cloth as it can generate new particles.

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When positioning the witness plate on the PDM, there is a slight allowance for movement. To ensure consistency, it is advised to place the witness plate in the same orientation for each measurement, followed by a gentle forward nudge to ensure its consistent position. It is crucial to adhere to this practice, as failure to do so may lead to results that are not representative of reality.

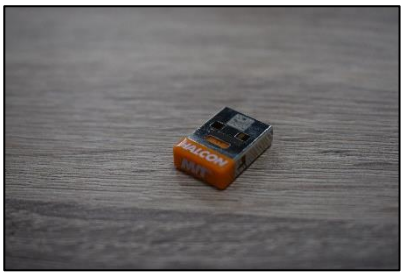
I.10 Connecting and Starting the PDM

1. Place the PDM on a firm surface. Connect the main adapter unit to the PDM and secure the connection by locking the Nut. See below for illustrations. And ESD connection is not usually required.
2. Start the PC with the VAS software installed.
3. Connect the PC to the ethernet cable and connect the ethernet cable to the USB-C adapter, and then to the PDM. If a server is used instead, contact your sales representative.
4. Check if the dongle is present. Launch the VAS software.
5. Check the interconnection tick in the upper right corner to see if the connection is active.
6. If a different device is required, right click the device image.
7. In case the interconnection is lost, click on the interconnection image to re-connect the device.

PDM I/O Interface

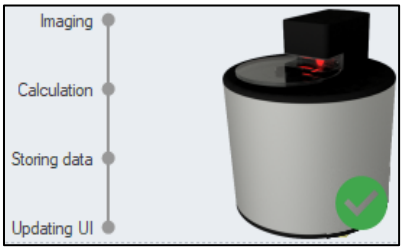
PDM Power Adapter

Power Cord Nut



VAS Software Dongle

Ethernet to USB-C Adapter



Active Interconnection

The enhanced VAS software for the PDM3 and PDM4 enables faster connections and includes improved features for maintaining the connection. To expedite on-screen results, the software is modified to generate a screen dump of the data, and the image is constructed a few moments later. For measurements demanding even quicker results, the option to switch off image construction is available.

I.11 Hardware Cleaning Regulations

The PDM can be cleaned using a polyester cloth to effectively remove any contaminants. If any impurities persist on the device, isopropanol can be applied to the cloth for thorough cleaning. It is crucial to refrain from cleaning the camera or lighting equipment as doing so may result in damage. If you suspect any issues with the camera or lighting equipment's functionality, please contact your sales representative for assistance.

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2. Vision Analysis Software

The Vision Analysis software (VAS) extracts information from the generated image and presents it in tables, values, and graphs. This condensation of information facilitates easy storage in a database. Subsequent actions related to the database form the foundation of the monitoring program. The VAS is Windows 10 and 11 compatible. The software version can be found at the top of the screen.

Minimal system requirements

Any system running the VAS software should at least possess the following hardware:

- 10th Generation Intel(R) Core (TM) i7-10510U Processor (8MB Cache, up
- to 4.9 GHz)
- 15.6-inch FHD (1920 x 1080) Anti-glare LED Backlit Non-touch Narrow
- Border WVA Display
- 24GB, onboard, DDR4, 2666MHz
- USB C port
- 256GB M.2 PCIe NVMe Solid State Drive
- 65-Watt AC Adapter
- Power Cord – European
- 42WHr, 3-Cell Battery (Integrated)
- 802.11ac 1x1 Wi-Fi and Bluetooth
- NVIDIA GeForce MX250 with 2GB GDDR5 graphics memory

System output:

- Channel Deposition Information
- Particle Area Coverage (PAC)
- Particle Deposition Rate (PDR)
- PAC witness plate zero measurement and mask measurement
- CSV

Monitoring features:

- Differential measurements (mask measurement)
- Continuous incremental (real time) (In later update)

Differential Measurements

This type of measurement yields the difference between the mask- and the following measurement.

Continuous incremental

This type of measurement makes use of the same mechanics as the previous, but automatically repeats measurements, giving the deposition parameters between each measurement.

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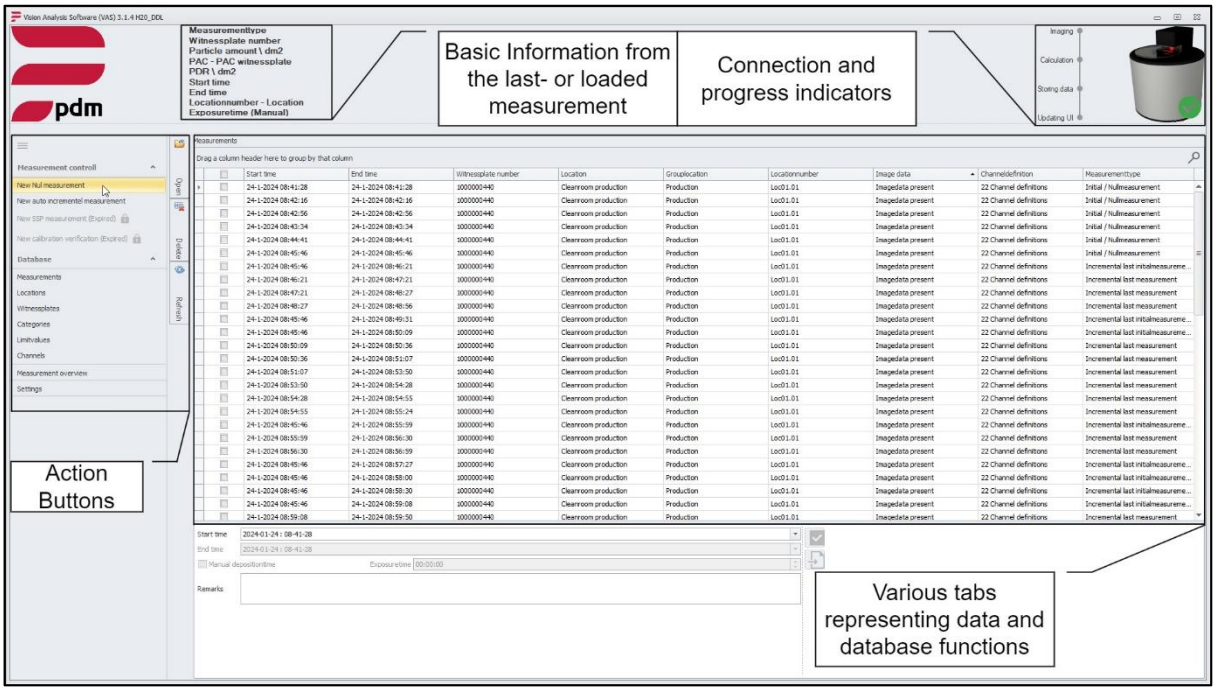
2.1 VAS Opening Page



The opening page allows access to all the features the VAS offers, including but not limited to:

- Interconnection icon and progress bar (top right corner)
- Measurement initialization (left side)
- Database functions (left side)
- A multitude of result formats in the various tabs and database functions (center of the page)
- Quick overview of the measurement data (top left)

The vertical bar in the upper right corner, progressing from top to bottom, denotes the measurement's status. Hovering the mouse over fields and tabs triggers tooltips for additional information.

2.2 General Description of Particle Deposition Measurements

Particle deposition occurs in a cleanroom, primarily influenced by particle sources such as people and operational equipment. When the cleanroom is at rest, particle deposition is minimal to non-existent. The assessment of particle deposition involves measuring the surface cleanliness of a witness plate before and after exposure, following the ISO 14644-9 approach.

At critical locations, data on particle deposition is essential for conducting risk assessments. Particle deposition varies at each location and is contingent on the activities within the cleanroom. The average particle deposition across different locations serves as an indicator of the overall operational quality of a cleanroom.

The Particle Deposition Rate (PDR) at a specific location is determined by the change in surface cleanliness, measured in the number of particles per dm^2 per hour. The time parameter corresponds to the operational duration of the cleanroom. The PDR can be expressed either as a particle size distribution for particles $> 5\mu m$ at chosen intervals (channels) like 20, 50, 100, 200, and 500 μm, or as a PDR number within the particle size range of interest. In certain industries, the total particle fallout during a project is essential. Therefore, it is also possible to determine the particle deposition in ppm coverage by particle, referred to as Particle Area Coverage (PAC).

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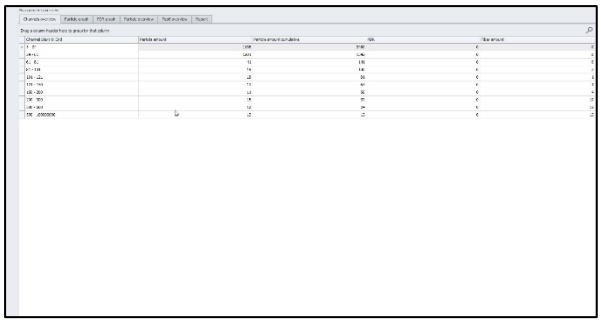
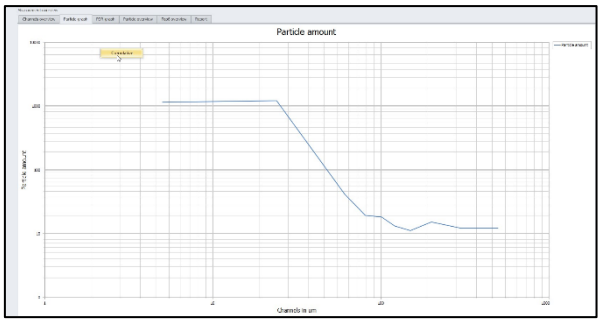
Diverse Display Methods in VAS for Particles and Data

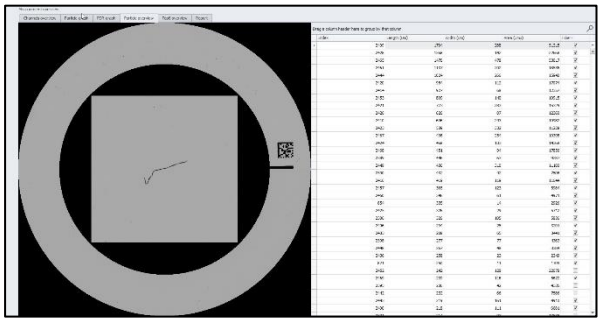
In addition to the quick overview of the data at the top of the screen, VAS provides detailed information on each measurement through various display methods. Users can access these displays by clicking on the 'Measurement overview' located on the left side of the screen. Upon clicking, several tabs will open in the center of the screen, providing access to these detailed displays.



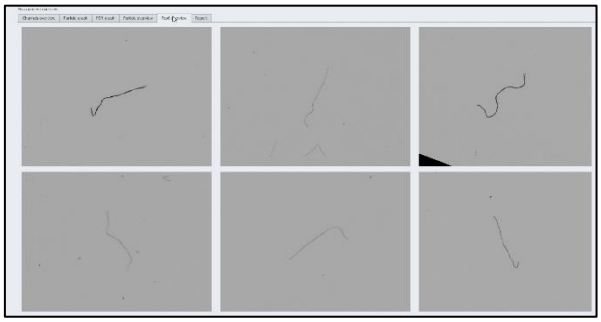
Overview of Channel Data



Particle Count Graph



Rendered Image of the Witness Plate with Information on Each Particle



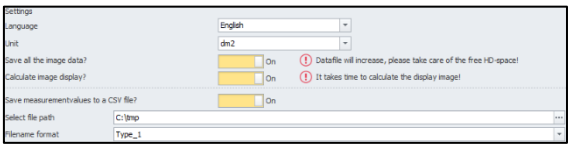
The Six Largest Particles

2.3 Automated Data Storage and Formats in VAS

The VAS generates unique files for each measurement, which are stored locally on a predefined path. Users have the option to refrain from saving the image data for each measurement, resulting in smaller file sizes. Additionally, there is an option to disable the calculation of image displays for subsequent measurements, leading to faster calculations.

When conducting measurements in real-time mode with short intervals, it is advisable to disable both options. This ensures that image data is not stored, and calculations are not performed even during the initial measurement. This, however, guarantees completion of the calculation before the next measurement is initiated.

Moreover, the VAS enables users to create a CSV file that can be imported into Microsoft Excel. Users can also choose the storage location for this file, including local servers. In the 'Filename format' box, users can opt to automatically generate unique names for each measurement, with an example provided next to this box.



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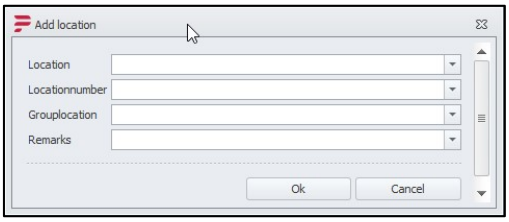
2.4 Database Usage

Understanding the database is crucial for utilizing the VAS effectively, as each measurement necessitates the input of specific parameters by the user.

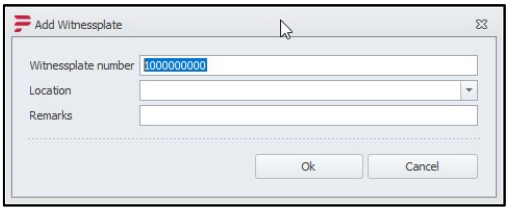
Creating a Location

On the left side of the screen, click the 'Locations' tab. This will open the tab, which initially appears empty, containing all locations. To create a new location, click the 'New' button. This action will prompt a window to appear, as seen on the right. Users can then input various parameters relevant to the location where the PDM is utilized. It is highly recommended to fill in all fields to maintain comprehensive records of the measurements.



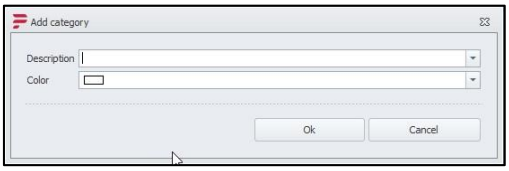
Adding Witness Plates

Below the 'Locations' tab, navigate to the 'Witness Plates' tab. This will display all the registered witness plates. To add a new witness plate, click the 'New' button. This action will trigger a window to appear, as shown to the right. In the first input field, enter the number as seen on the witness plate. Next, select the location from the dropdown menu where the witness plate will be utilized. This will associate the witness plate with the chosen location. Some witness plates may have a 6-digit code. Hold the ctrl-button and click in the first input field to change it to this format. To change the location of a witness plate, simply double click on the desired entry and change to location. Existing measurements will maintain the location tied to that measurement.



Creating Categories

In the 'Categories' tab, users can create any number of categories, each associated with a specific color. These categories can later be linked to particle sizes. To create a new category, simply click the 'New' button. This action will open a window, as depicted on the right. Within this window, users can provide a description for the category and select a color for it. For instance, one might create a category named 'Fibers' and assign it the color red.

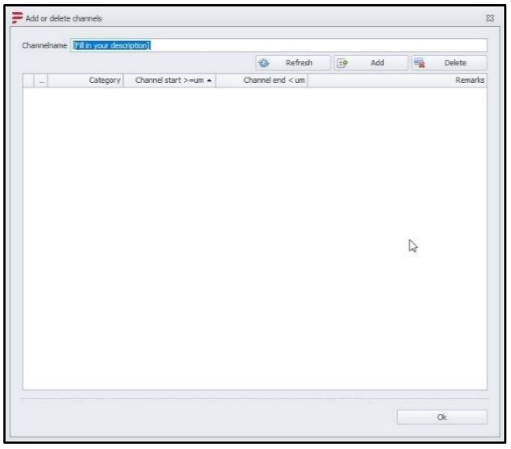


Creating a Channel Definition

In the 'Channels' tab, users can create channel definitions. A channel represents a particle length range, and a channel definition comprises a set of channels each associated with a category. Clicking the 'New' button will prompt the appearance of the window on the right. Within this window, users can add numerous channels by clicking the 'Add' button. For each channel, users can define the range (in micrometers) and assign a category to it. A few things to note:

- The lowest limit any channel can have, is 5μm.
- A channel range must at least span 5μm.
- A channel definition can be edited post-measurement.

In the 'Channelname' box, users can give the channel definition a name.



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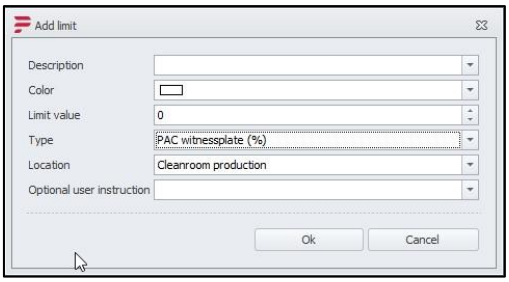
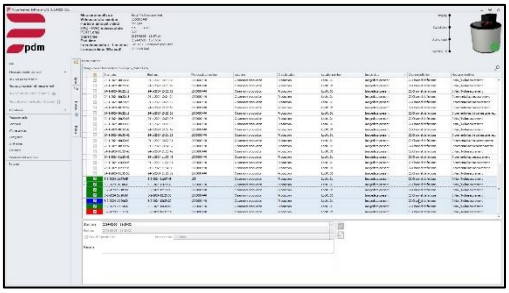
Creating Limit Values



The VAS is equipped to issue warning messages when specific events occur. To establish a limit, navigate to the 'Limit Values' tab and select 'New'. This action will bring up the window on the right. In the 'Type' box, users can specify the type of condition to which the limit should apply. Next, users can choose the limit value. For instance, if a user wishes to receive a warning when the particle area coverage of the witness plate exceeds 0.01%, selecting the type 'PAC witness plate (%)' with a limit value of 0.01% achieves this. Subsequently, users must assign a location that has been previously created. Finally, a description, color, and an optional instruction message can be provided. The limit will also be displayed on the graphs in the chosen color.

Loading and Exporting Measurements



In the 'Measurements' tab, users have the capability to load and export measurements. By selecting a measurement and clicking 'Open', users can view the summary of the measurement in the upper left corner. Further details of the measurement are accessible in the 'Measurement Overview' tab.

Users can export multiple measurements into a single CSV file by selecting them. The first selected measurement will cause the left column to turn blue, while subsequent selections will turn the corresponding boxes green. If a box turns red, it indicates that the measurement cannot be exported with the others due to a conflict in their channel definition. The most common reason for this conflict is a difference in the number of channels in their channel definitions.

2.5 Executing a Measurement in VAS

The following steps may be used to perform a typical measurement with the PDM:

1. Fill in the database as described in section 2.4.
2. Clean the witness plate using isopropanol and a polyester cloth. Wipe from the inside to outside and fold the wipe after every stroke.
3. Place the disk on the turntable keeping section 1.9 in mind. Press the 'New Null measurement' button found on the left side of the window.
4. A popup window will appear. Here the user can insert a username and select which channel definition to use.
5. The witness plate will rotate and the bar in the upper right will indicate at which stage of the measurement the VAS currently is. Once completed, the data acquired from the mask will be displayed on screen.
6. The witness plate can now be placed at the desired location.
7. Once the desired time has elapsed, the witness plate can once again be placed upon the PDM, and the 'New auto incremental measurement' can be clicked.
8. A new window will pop up, here the user can once again fill in a username and select a channel definition. The user can also choose to compare the new measurement to the initial mask, or to the previous measurement.
9. The VAS automatically calculates the time between each measurement. But this can also be customized at the bottom of the 'Measurements' tab.
10. The software will now perform another scan, after which the data regarding the newly deposited particles is displayed on screen.

The images below serve as an illustration to these instructions.

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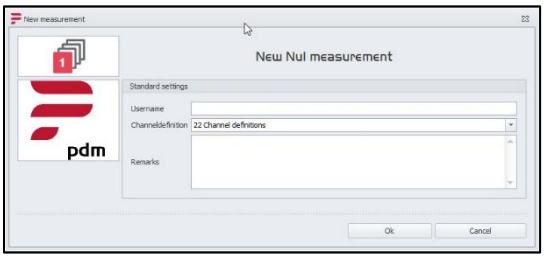
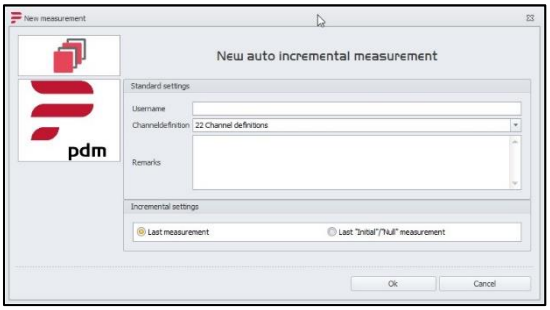
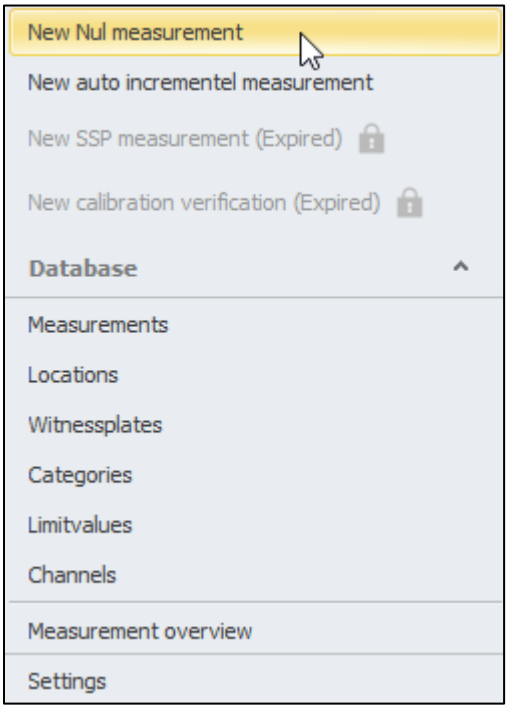


Step 3 & 4: Creating the Mask



Step 7 & 8: Taking the Incremental Measurement



The Action Buttons for Measurements and Database

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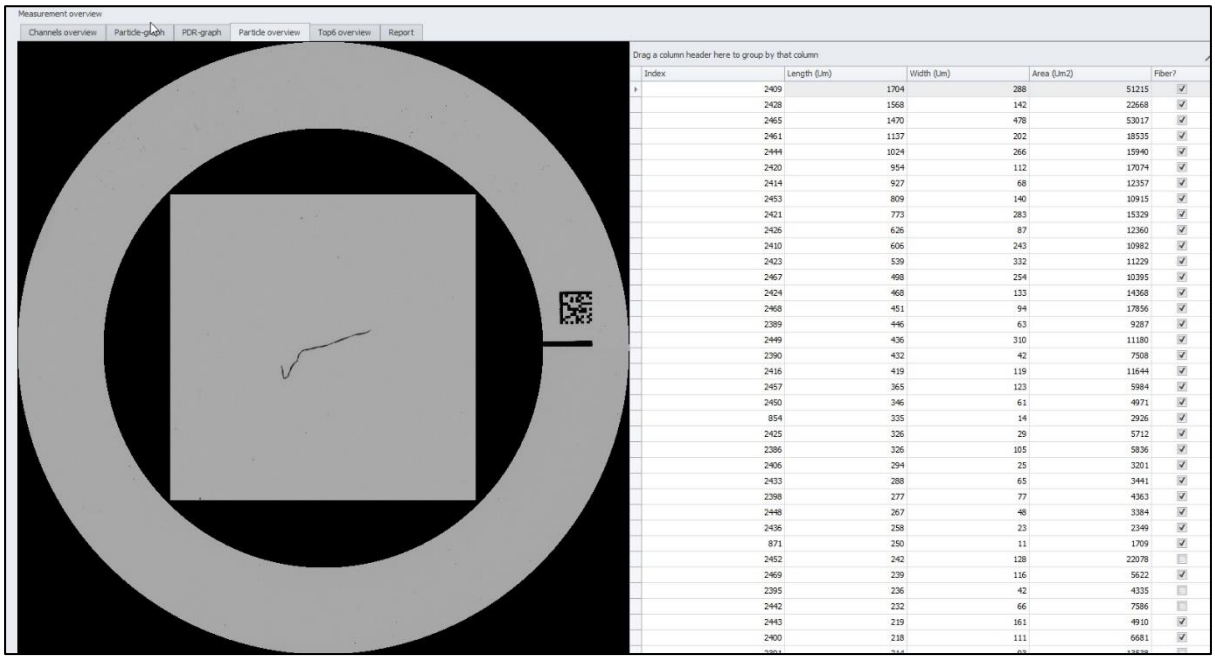
2.6 Analysis of Individual Particles

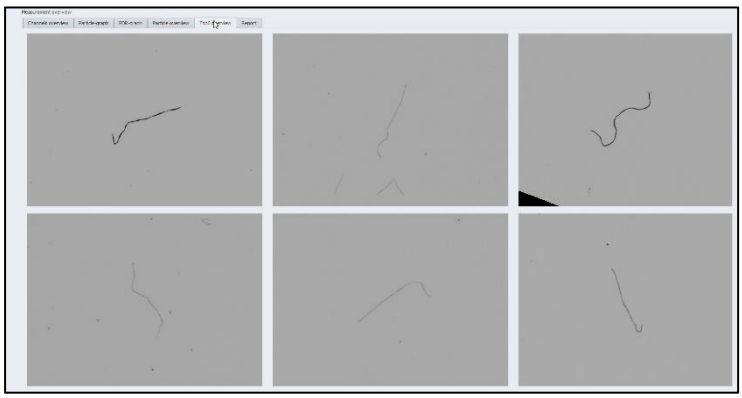
The 'Particle overview' in the 'Measurement overview' tab facilitates a closer examination of individual particles. Hovering the mouse over the image triggers an enlarged view of the section surrounding the cursor. Alternatively, the user can select a particle from the list on the right-hand side, and an image displaying the entire particle will appear in the center along with a red box showing its location. This is illustrated in the figure below. Additionally, right-clicking on the image allows the user to toggle the contours around the particles on or off.



Screenshot showing the selection of a particle in the list and the resulting image displayed

When contours are activated, users can observe how particles are distributed across the surface of the witness plate. Although particles beyond the edge of the detection range may still be visible, they will not show up with a contour and will not be counted by the VAS. Contour mode provides the location of particles, enabling targeted cleaning efforts.

The 'Top 6 overview' tab displays the six largest particles, selected based on their area parameter. The area parameter represents the number of square micrometers enclosed in the contour of the particle. On the right side of the previous picture, the particles are sorted by size. The top six from this list are shown in the middle of the screen. The orientation of the images aligns with the 'Particle overview' tab, adhering to the Cartesian coordinate system. Black areas in some images indicate where the edge of the scanning area was reached.



Large fibers may pose a challenge for the PDM to focus on entirely. The points where the fiber touches the witness plate will be in focus, while other parts may not be. The VAS acknowledges and compensates for this phenomenon. However, in certain cases, a single particle that extends beyond the focus of the scanning equipment may appear as multiple particles instead.

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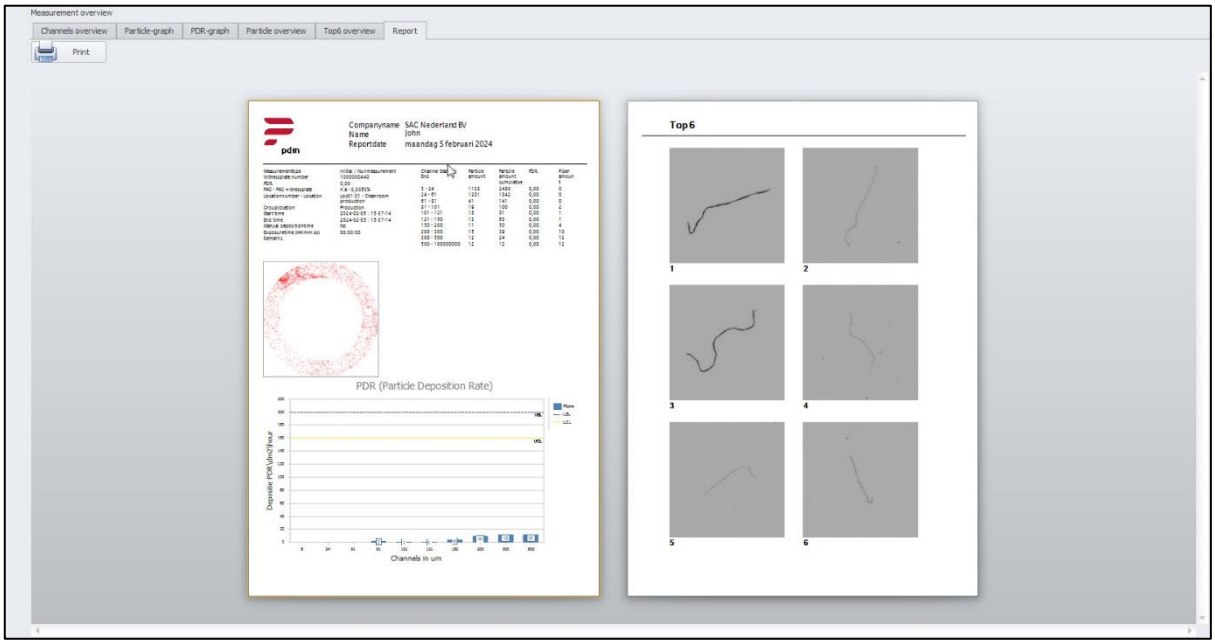
Channel Hopping

Channel hopping is a phenomenon observed when a particle's length is close to the border of a channel range. During the initial measurement, a particle may register in one channel, but upon a subsequent measurement, it may be registered in another. This occurrence is more prevalent in channels with a small range and those covering only part of the spectrum of frequently occurring particles in a cleanroom.

2.7 Printing a Report

The 'Report' tab provides an example of the report that can be printed by pressing the print button. The printed report of a measurement includes various result representations, such as the data in the left upper corner, channel data on the left side, as well as the line graphs. It is important to note that it is not possible to print a report of real-time measurements. An example is provided below.



2.8 Real-time Measurements (Future Update)

Real-time measurements can be initiated by pressing the 'Scan' button and clicking the 'Incremental' button in the lower left corner of the popup window. The live results will be displayed in the 'Realtime' tab, showcasing the increase of particles over time during exposure. Users can set the measurement intervals in the lower right corner of the tab. The minimal interval length is 30 seconds. If a shorter time interval is required, please contact your sales representative. This feature is to be implemented in a future update.

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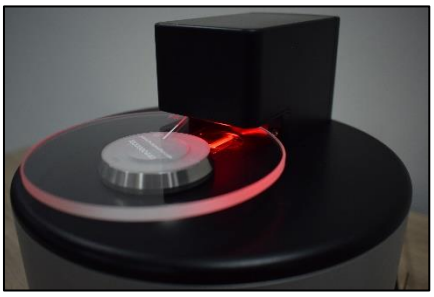
2.9 Normal Operation and Troubleshooting

Normal startup procedure on a PC with pre-installed VAS;

1. Connect the unit to the power supply. The lights will briefly turn on, and the turntable will rotate a few degrees.
2. Connect the ethernet cable between the PC and the PDM using the USB-C adapter.
3. Start the VAS. Within a minute, the software will detect the PDM unit, showing a green indicator in the top right corner.



In normal operation, pressing the 'Scan' button initiates a measurement. Upon completion, previous data is cleared, and all fields on the screen reset. After calculation, the new data is displayed. The green bar activity indicator progresses from left to right, indicating the operation's progress.

Causes and Handling of a Stagnant Progress Bar

In case a measurement goes wrong, the progress bar stagnates. This can have several causes. The bar will stagnate if the witness plate is moved during the scan, or if the witness plate is unreadable due to damage or obstruction of the data-matrix code.

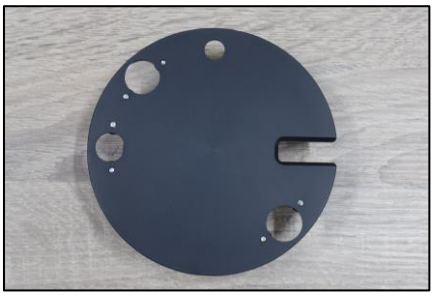
The bar will also stagnate if the witness plate is removed during real-time measurements, or if the 'Stop' button is pressed. If the witness plate was removed, the PDM will ignore that scan and enter a dormant state. If the witness plate is placed back, the PDM will resume operation without the need to restart. If the measurement was stopped using the 'Stop' button, the PDM will continue operation when the 'Scan' button is pressed, ignoring the old measurement, and starting a new one.

Troubleshooting

In case of an interconnection loss between the PC and the PDM, click on the red cross on the interconnection icon in the upper right corner. A popup window with suggestions will show. If a software hangup or freeze occurs, allow the VAS time to recover. If recovery does not take place, close, and restart the program.

2.11 Remote Calibration

Calibration and verification of the PDM's accuracy can be done remotely using the calibration plate seen to the right. To use this feature, contact your sales representative.



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3. Hardware Shipped with the PDM

Pre-installed PC

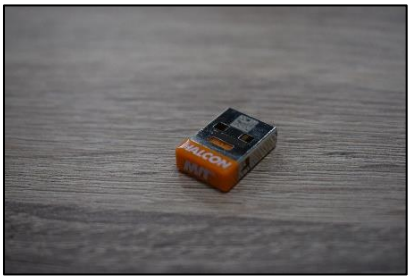
A laptop with VAS installed, requiring no additional installations.

- VAS pre-installed.
- Capable of running up to three PDMs via network.
- PDM license not included; the license is linked to the PDM unit.
- Comes with a Windows license.

Software License Key

A USB dongle containing the license key for VAS.

- One key required per PC, but linked to the PDM.
- PDM license is a lifetime license.



Optional Witness Plates

Borosilicate glass disk designed for the PDM.

- Unique serial number for each plate.
- New generation laser marking.
- Machine-readable DMC (QR-Code).
- Optional exposure box available.
- Website: www.particle-deposition.com

Optional Witness Plate Support

PETP naturel safe witness plate support

- Easy to clean, well rounded support.
- Support on crevice of the witness plate.
- Glue chamber on bottom for permanent adhesion.
- ESD dissipating material.
- Large table support.

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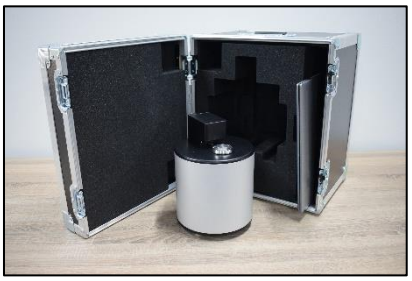
Optional Flight Case

Heavy duty flight case for shipping the Particle Deposition Monitor.

- Compartment for laptop.
- Foam filling to prevent damage during transport.
- Sturdy enough to prevent blunt force damage.



Optional Battery Pack

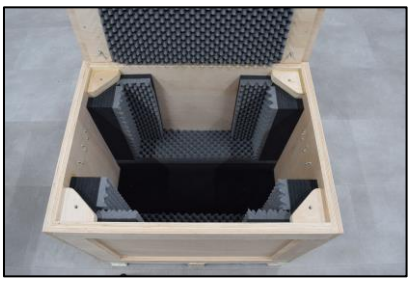
Heavy duty battery for remote PDM usage.

- Comes with all the necessary attachments and cables.
- Complete guide available.
- Can support the PDM and laptop.

Optional Cargo Box

Heavy duty cargo box for shipping the PDM.

- Sturdy frame for long distance shipping.
- Fits the entire flight case.
- Dampening on the inside to ensure safe transport.
- Easy to open and close.



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