



Institute of Environmental  
Engineering  
Polish Academy of Sciences

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## WEIGHING PROCEDURE

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### **Mass Determination of Filters Before and After Exposure With Use of the RB 2.4Y.F Robotic Weighing System by Radwag Wagi Elektroniczne**

Reference number: C2-001/2020/NP-I

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## 1. Procedure Aim

The procedure is aimed at presenting an accurate way for conditioning and mass measurement of various types of filters with use of the RB 2.4Y.F robotic weighing system by Radwag Wagi Elektroniczne, Poland.

## 2. The Scope and Application of the Procedure

This procedure describes how to determine the concentration of PM by means of gravimetric method using the automatic RB 2.4 Y.F robotic system. The guidelines of this procedure may also be used when testing the variability of filter mass as a result of physical, chemical and technological processes. Equipment and analytical measuring instruments under this procedure:

- RMCS Filter software, conditioning process control, filter mass measurement and calculation of relevant values from the research process,
- robotic system, automatic system operating inside the RB 2.4Y.F device used for transporting the filters between magazines and the balance weighing chamber,
- automatic ionization system installed inside the RB 2.4Y.F device,
- MYA 2.4Y microbalance, reading unit  $d \leq 1 \mu\text{g}$ , used for mass measurement of filters before and after exposure, manufactured by Radwag Wagi Elektroniczne, Poland,
- filters, diameter: 47 mm, used for the concentration determination of the PM particulate matter in low-flow monitoring stations.

## 3. Definitions

The basic terms related to the process of conditioning, mass measurement and determination of particulate matter concentration are presented below.

Unsampled filter	clean filter (filter before exposure; without particulate matter) , before exposition in the field,
Sampled filter	filter with particulate matter (filter after exposure), after exposition in the field,
Sample for testing	a single sample of particulate matter obtained in the field,
Weighing room blank	a single unsampled filter stored in the same conditions and analysed in the same way as the sample for testing, taking into account all analytical steps,
Field blank	a sample subjected to the same procedures as the test samples, without taking the analyte, intended to determine the background resulting from the transport and storage of samples,

## **4. Responsibility**

The Team Leader is responsible for the implementation and supervision of this procedure. The procedure applies to all employees within the scope of the tasks assigned to them.

## **5. Technical Infrastructure and Ambient Conditions**

For proper operation, the RB 2.4Y.F robotic system requires the supply of water of appropriate purity or the installation of a water treatment module, a place to drain the water that is stable in terms of ground vibrations, external RMCS Filter application and personnel with proven competence. The tested filters in specially-designed trays are placed inside the robotic system. The robotic system is equipped with a holder that takes the filter tray and transports it to the microbalance weighing chamber. Before weighing, the filter marking is checked, usually the QR code, and deionization is carried out (optional).

Inside the RB 2.4Y.F measuring system there is a separate magazine for reference filters and mass standards. They are used to assess the quality of the device. The measuring system is equipped with a HEPA filter, which purifies the air, preventing possible contamination of the filters during the testing process. The measuring system can be connected to the Ethernet network, which allows for remote supervision and control of its operation.

The temperature and humidity inside the RB 2.4Y.F robotic system are controlled via ambient conditions module, which enables operation within the temperature range of  $20 \pm 1^\circ\text{C}$  and relative humidity of  $50 \pm 5\%$  RH, in accordance with EN 12341:2014. Monitoring of ambient conditions inside the robot chamber is carried out using internal THB sensors manufactured by Radwag Wagi Elektroniczne, Poland. The basic mechanical design elements of the measuring system are presented in Annex 1.

## 6. Procedure Description

### 6.1. Filter Numbering

The filters used for tests carried out using the RB 2.4Y.F robotic system shall be made of standard filter materials, i.e. glass fibre, quartz fibre, nylon, polycarbonate or Teflon. Each filter shall feature a unique number. The determination of the test samples can be performed by applying QR codes to the filter structure or by using the filter position number in the magazine (level/position number)

### 6.2. Handling Filters Before Exposure

- a. Place the filters into the trays. Place the trays into the internal magazine of the RB 2.4Y.F robotic system (Annex 1, figure 2).
- b. Confirm the filter conditioning start in the RMCS Filter software by issuing a filter conditioning order. Indicate the positions in the magazine that will be subjected to conditioning and weighing.
- c. The conditioning process will be carried out in accordance with the requirements of EN 12341:2014 standard in terms of time and accuracy of the measuring system.

#### Caution:

1. The conditioning process will be carried out only when the ambient conditions outside the robotic system are correct, i.e. the temperature is  $20\text{ °C} \pm 1\text{ °C}$ , and the humidity is  $50\% \pm 5\%$ . When ambient conditions are out of range, the measuring process will be stopped. The system administrator will receive information about the event.
  2. Before each filter mass measurement session, the microbalance is adjusted and the mass of the reference filters is checked (assessment of the effect of conditioning conditions on filter mass) and the mass standard is weighed (tracing deviation of the microbalance indication).
- d. Each filter designed to test the concentration of particulate matter is automatically weighed without operator intervention.
  - e. For each filter the condition of its mass stability is verified in accordance with relation (1) or (2).

$$m_u = m_{u1} - m_{u2} \leq 40\ \mu\text{g} \quad (1)$$

where:  $m_u$  – mean mass of unsampled filter (before exposure)  
 $m_{u1}$  – unsampled filter mass for the first weighing  
 $m_{u2}$  – unsampled filter mass for the second weighing

If condition (1) is not met, the robotic system automatically performs a third measurement of the filter mass after prior conditioning (see requirements of EN 12341:2014) - the stability of the filter mass is reverified according to relation (2):

$$m_u = m_{u2} - m_{u3} \leq 40 \mu\text{g} \quad (2)$$

where:  $m_u$  – mean mass of unsampled filter (before exposure)

$m_{u2}$  – unsampled filter mass for the second weighing

$m_{u3}$  – unsampled filter mass for the third weighing

- f. The mass of the unsampled filter is presented as the average of two separate measurements of the unsampled filter according to relation (3).

$$\overline{m}_u = \frac{m_{u1} + m_{u2}}{2} \text{ or } \overline{m}_u = \frac{m_{u2} + m_{u3}}{2} [\text{mg}] \quad (3)$$

- g. Failure to meet condition (2) is equivalent to removing the filter from the measuring session. The unsampled filters shall be kept in the weighing room for no longer than 28 days before sampling.

### 6.3. Preparation of Unsampled Filters for Transport

Weighed unsampled filters shall be placed in the holders and inserted into transport and measurement trays in order to protect them from airborne contaminants that may occur during transport. Hand over the filters packed in this way to the operator of the monitoring station or send them to the final sampling point (monitoring station).

### 6.4. Field Blanks

During each measuring series (at least once a month), prepare the so-called field blanks, which shall be treated as each filter before exposure, taking into account the steps involving transporting the filters to the monitoring station and placing them in the sampler - see the requirements of EN 12341:2014 point 6.6. The procedure for handling the field blanks is the same as for sampled filters.

## 6.5. Handling Filters After Exposure

- a. Remove the filters after exposure from the transport and measurement trays and check for potential damage. If the filter is found to be damaged, this event must be recorded and the filter must be removed from the weighing session.
- b. Place the filters into the trays. Place the trays into the internal magazine of the RB 2.4Y.F robotic system (Annex 1, figure 2).
- c. Confirm the start of the filter after exposure conditioning process in the RMCS Filter software by issuing a filter after exposure conditioning order. Indicate the positions in the magazine that will be subjected to conditioning and weighing.
- d. The conditioning process will be carried out in accordance with the requirements of EN 12341:2014 standard in terms of time and accuracy of the measuring system.

### Caution:

1. The conditioning process will be carried out only when the ambient conditions outside the robotic system are correct, i.e. the temperature is  $20\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ , and the humidity is  $50\% \pm 5\%$ . When ambient conditions are out of range, the measuring process will be stopped. The system administrator will receive information about the event.
  2. Before each filter mass measurement session, the microbalance is adjusted and the mass of the reference filters is checked (assessment of the effect of conditioning conditions on filter mass) and the mass standard is weighed (tracing deviation of the microbalance indication).
- e. Each filter after exposure is weighed automatically, without operator assistance.
- f. For each filter after exposure the condition of its mass stability is verified in accordance with relation (4) or (5).

$$m_l = m_{l1} - m_{l2} \leq 60\text{ }\mu\text{g} \quad (4)$$

where:  $m_l$  – mean mass of sampled filter (after exposure)

$m_{l1}$  – sampled filter mass for the first weighing

$m_{l2}$  – sampled filter mass for the second weighing



If condition (4) is not met, the robotic system automatically performs a third measurement of the filter mass after prior conditioning (see requirements of EN 12341:2014). The stability of the mass of the filter after exposure is reverified according to relation (5):

$$m_1 = m_{l2} - m_{l3} \leq 60 \mu\text{g} \quad (5)$$

where:  $m_1$  – mean mass of sampled filter (after exposure)  
 $m_{l2}$  – unsampled filter mass for the second weighing  
 $m_{l3}$  – unsampled filter mass for the third weighing

- g. The mass of the sampled filter is presented as the average of two separate measurements of the filter according to relation (6).

$$\overline{m}_l = \frac{m_{l1} + m_{l2}}{2} \text{ or } \overline{m}_l = \frac{m_{l2} + m_{l3}}{2} [\text{mg}] \quad (6)$$

- h. Failure to meet the condition of stability of the sampled filter mass according to relation (5) is equivalent to removing the filter from the measurement session.

**CAUTION:**

It is possible to set different filter conditioning intervals, to adjust the mass measurement intervals according to the required test process and to set different limits for the test mass variation of the filters.

## 6.6. Determination Method of Particulate Matter Concentration

The particulate matter concentration ( $C$ ) is calculated automatically by dividing the difference between the sampled filter (after exposure) ( $m_l$ ) and the unsampled filter (before exposure) ( $m_u$ ) and the air flow volume ( $V$ ) in accordance with relation (7).

$$C = (\overline{m}_l m - \overline{m}_u) / V [\mu\text{g}/\text{m}^3] \quad (7)$$

where:

$\overline{m}_l$ : – mean mass of sampled filter (after exposure)  
 $\overline{m}_u$  – mean mass of unsampled filter (before exposure)  
 $V$  – air volume taken during sampling

### **6.7. Preparation of Filters for Analysis and Archiving**

After weighing, the filters shall be packed, cut, with a zirconium knife or a cutter, to 2 or 4 equal pieces. Place such prepared filters on marked Petri dishes and store them in low air temperature in order to limit the loss of volatile and semi-volatile compounds. The numbering of filters both before and after exposure shall be in accordance with the system adopted in the laboratory for the determination of test samples.

## **7. Related Documents**

- a. EN 12341:2014 – Ambient air - Standard gravimetric measurement method for the determination of the PM<sub>10</sub> or PM<sub>2,5</sub> mass concentration of suspended particulate matter
- b. [General Procedure PO 1 - NP-I: Handling test samples - samples numbering [issued on 09.01.2017]]
- c. [General Procedure PO 3 - NP-I: Handling test samples - database and results calculating [issued on 09.01.2017]]
- d. [General Procedure PO 4 - NP-I: Handling test samples - transport [issued on 09.01.2017]]
- e. 4Y series balances. User manual. IMMU-01-33-12-19-PL, Radwag, Poland, December 2019
- f. RMCS Filter RB 2.4 Y.F. User manual. ITKU-25-01-06-20-PL, Radwag, Poland, June 2020

## 8. Annex 1 - Mechanical Design of the RB 2.4Y.F Robotic Weighing System

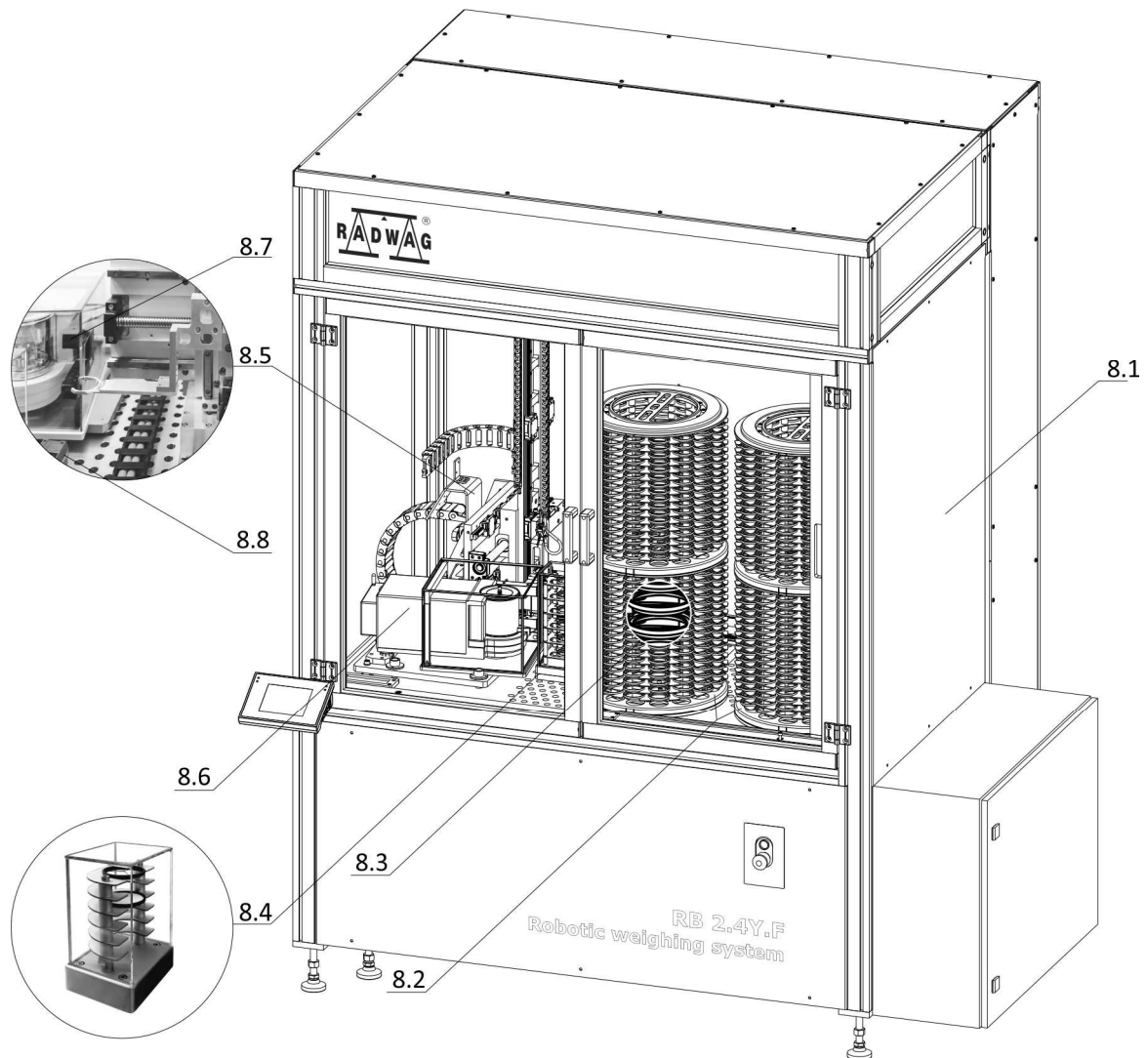


Figure 1. The RB 2.4Y.F robotic system mechanical design

### 8.1. Housing

Protects the measuring system and filters from potential contamination and ensures stable ambient conditions during conditioning and mass measurement of filters before and after exposure. The overpressure in the device chamber blocks the penetration of pollutants.

### 8.2. Filter Magazine

The robot is equipped with two magazines for up to 1020 filters (each magazine features 510 positions: 34 discs with 15 positions).

### **8.3. Filter Trays**

The tray is made of antistatic material - polyoxymethylene (POM). The tray design (Annex 1) ensures unambiguous positioning of the filter in the magazine, which is a basic requirement for the correct operation of the robotic system.

The view of the filter tray and the correct positioning of the filter tray in the magazine are presented in Figures 2 and 3.

### **8.4. Reference Magazine**

A six-position reference magazine for storing mass standards and reference filters. With use of reference filters it is possible to determine the potential impact of ambient conditions on the variation in mass of unexposed and sampled filters. The mass standard is used to track the accuracy drift of the measuring system in accordance with the requirements of EN 12341:2014, Annex E.

### **8.5. Robotic System**

Filters are transported between device elements using a robotic arm. Automatic transporter assembly movement is accordant with a set procedure. In the robot arm system there is an infrared sensor which task is to control the presence of the filter in the magazine and in the robot arm holder (during transport from the magazine to the weighing chamber).

### **8.6. Microbalance**

The MYA 2.4Y microbalance integrated with the RB 2.4Y.F is a measuring device of professional-class. It is placed on a granite anti-vibration table separated from other elements of the RB 2.4Y.F robotic system. The accuracy of the microbalance is periodically determined by internal adjustment.

### **8.7. Ionizer**

Eliminates uncompensated electrostatic charges on the weighed filter. The ionizer activity can be defined for each measurement session in the RMC Filter software.

### **8.8. QR Code Reader**

A component of the device that enables readout of QR codes, which are a unique system of numbering and identification of filters in the software.

## Software

The software is an integral element that controls the process of filter conditioning, weighing and ambient conditions stability. On the basis of obtained information, the RMCS Filter calculates the quantity and concentration of particulate matter in relation to a specific monitoring station. The import/export options also enable to collect and analyse information about sampling conditions and transfer it to other external applications.

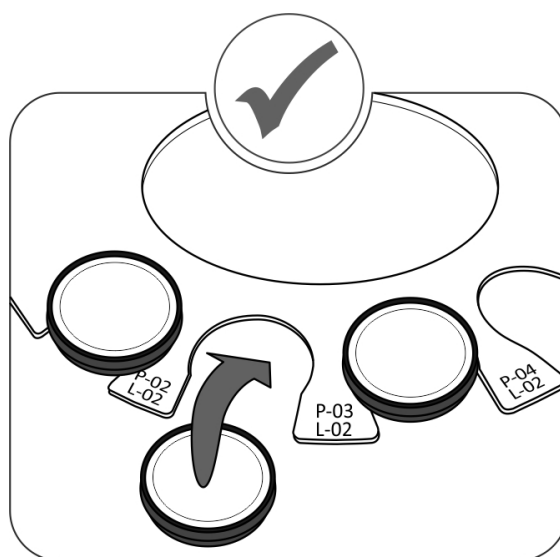


Figure 2. Filter magazine of the robotic system

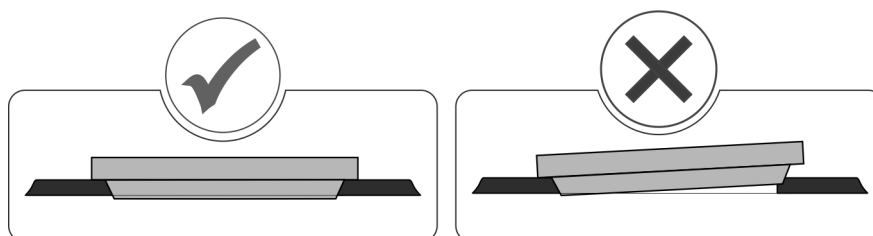


Figure 3. Positioning of the filter tray in the magazine

## 9. RMCS Filter Software Structure

### SETUP

Thresholds	Apply to changes in the mass of reference filters, test filters, mass standard, ambient conditions and filter conditioning intervals.
Alerts	Information about the weighing system operation displayed in the RMCS software and sent remotely.
Action log	Record of all non-standard events in the system.
Operators	Operators carrying out sampling.
Test stations	Sampling locations (monitoring stations).
Connections	IP addresses of devices.
QR code printout	With a QR code printer it is possible to automatically mark filters with a QR code (data in the QR code is programmable).

### ORDERS

Filter mass before exposure	Magazine position of filters used for testing.
Filter mass after exposure	Magazine position of filters used for testing. Determination of the place and times of particulate matter collection.

### REPORTS

Mass change of filter before exposure	Filter masses determined during weighing session (mean mass of a filter before exposure)
Mass change of filter after exposure	Filter masses determined during weighing session (mean mass of a filter after exposure)
PM concentration	Particulate matter concentration for weighing session

### AMBIENT CONDITIONS

Current temperature value	Temporary value / hourly average
Current humidity value	Temporary value / hourly average
Temp./humidity graph	Graphic visualisation of ambient conditions variations

### CONTROL PROCEDURES

Annex E1. EN 12341:2104	Accuracy and stability of temperature and relative humidity
Annex E2. EN 12341:2104	Accuracy and stability of balance
Annex E3. EN 12341:2104	Accuracy and precision of the weighing procedure
Annex D4. EN 12341:2104	Static charging test
AutoTest Radwag	Determination of precision of filters and mass standards mass measurement

## **10. Distribution List**

Team Manager - paper version and electronic version

Workstation for determination of particulate matter mass using gravimetric method and automatic weighing system.

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