SM200-series
Dust Monitor
Dust Sampler
Stability Monitor

User´s Guide

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May 19, 2004

Declaration of Conformity

Opsis AB declares that the product SM200 conform to the following EEC Directives:

- 73/23/EEC regarding low voltage electrical material
- 89/336/EEC regarding Electromagnetic Compatibility
- 93/68/EEC regarding the CE marking

and that the below harmonised standard specifications have been applied:

Safety:

EN 61010-1:2001, Safety requirements for electrical equipment for measurement, control and laboratory use

Electromagnetic Compatibility:

Emission: EN 55011:1998

Immunity: EN 50082-1:1997

Svante Wallin, President

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Introduction 1

This chapter gives an overview of the operating principles of the SM200 series dust monitor, dust sampler and stability monitor. Detailed descriptions are found in the following chapters.

All instruments in the SM200 series are based on the same monitoring principles and the same main components. Ambient air is sampled through a head by means of a pump. Any particulate matter is caught on a filter. In the mass and stability monitoring versions, the filter is analysed using a beta radiation source and a Geiger tube as a detector. The sampled filters are stored and can be retrieved for additional analysis.

Measurement results are stored in the instrument, from where it can be downloaded to an external computer or simply viewed on the instrument display.

1.1 Main features

An instrument of the SM200 series is an advanced system for sampling and measurements of suspended particulate matter. It allows collection of suspended particles on standard 47 mm membrane filters, making it possible to further examine the collected material by means of other qualitative and quantitative methods. Except for the pure sampling and stability models, the system itself is able to determine the amount of particulate matter collected on the filter by using the beta ray attenuation method.

Extensive quality assurance procedures, automated and/or on demand, makes sure that the instrument delivers validated and reliable data.

In short, the main features are:

- Automatic sequential system for sampling and mass measurement of suspended particulate matter.
- Standard 47 mm filters stored in removable external filter holders, at room temperature. New filters can be added and old removed without interrupting instrument operation.
- Sampling is made at ambient temperature.
- Samples immediately become available both for chemical analysis and manual gravimetric mass measurements.
- Complete set of quality assurance parameters related to all steps in the sampling and mass measurement procedures.

1.2 Models

The SM200 series analysers are available in the following models:

- **Sampler:**
  Suspended particulate matter is collected on membrane filters. The filters are stored in special filter containers attached to the instrument. A pump makes sure to keep a well defined flow of air through the system. There is no measurement performed in the sampler model, hence, there is no beta source in the instrument.
- **Dust monitor:**
  The instrument has the same features as the sampler, but has a built-in beta source and a Geiger tube for measurements of the mass concentration in the air. The filters are stored for further analysis, if required.
- **Stability monitor:**
  This model also operated as the sampler. However, in addition, it monitors the natural radiation from the filter using a Geiger tube. The result are parameters useful for estimating the stability of the air. A number of scientific papers have been written on this subject. Contact Opsis for more information. The stability monitor does not have any beta source.
- **Dust and stability monitor ("Combined"):**
  Dust and stability monitor in combination. This model is only available with minimum 8 hour sampling.

This manual is written primarily for the pure dust monitoring model, since this is the most common type. However, the manual does point out differences between this and the other models, in the case of noticeable deviations.

1.3 Sampling heads

A number of different sampling heads can be used, no matter the model of the SM200. Sampling heads are normally standardised, and you select sampling heads depending on what type of particles you want to collect. Sampling heads available from Opsis includes:

- TSP
- PM10
- PM2.5

The mechanical design of the heads varies depending on what particulate fraction to sample, and there are even different designs available for the same particulate standard.

Please refer to the documentation of the individual sampling heads for more information.

1.4 Filters

The SM200 is designed for standardised 47 mm circular filters. The filters can be of any type: Teflon, cellulose nitrate, cellulose acetate, plastics, etc., with a typical porosity of 2 µm (standard). The filters are kept in place by filter holders. Up to 40 filter holders can be housed in a filter container, automatically storing sampled filters and providing clean filters to the instrument.

1.5 Technical specifications

Physical dimensions	
Main sampling unit	440 × 630 × 300 mm / 42 kg
Pump module	310 × 280 × 250 mm / 20 kg
Sampling head	See separate specifications

Power supply	
Mains voltage	230 VAC (+6 %, - 10 %), 50/60 Hz
Current	3.5 A max.
Power consumption	800 W

Operating conditions	
Temperature	recommended: +5 to +35 °C (+41 to +95 °F) maximum rating: +5 to + 40 °C (+41 to +104 °F)
Humidity	Max. 80 % relative humidity

Flow specifications	
Flow rate range	8 to 25 litres per minute Option: 8 to 40 litres per minute
Operative flow	16.67 litres per minute, as determined by type of head Option: 38.3 litres per minute
Flow rate precision	1 % of read value
Flow rate accuracy	2 % of read value
Flow rate constancy	0.5 % of read value
Maximum pressure drop	60.0 kPa at 16.67 litres per minute

Radioactive source (Dust and Combined models)	
Type	^{14}C polymethyl methacrilate
Decay	Beta
Dimensions	39 × 39 × 1 mm
Total activity	9.9 MBq, 267 µCi Option: 99 µCi
Specific activity	55.5 MBq/g, 1.5 mCi/g

Radioactive source (Dust and Combined models)	
^{14}C half life	5730 years
Energy of emission	0.156 MeV max. / 0.049 MeV max.

Note: *An operative flow of 16.67 litres per minute (1 m^3 per hour) is sufficient if the activity of the radioactive source is 267 µCi. If the activity of the radioactive source is 99 µCi, the operative flow should be 38.3 litres per minute (2.3 m^3 per hour) to achieve the same performance.*

Mass measurement specifications (Dust and Combined models):	
Mass measurement range	0 to 60 mg
Mass measurement precision	14 µg
Mass measurement accuracy (gravimetric technique)	±1 % (reference membranes)
Concentration measurement precision	< 1 µg/m^3 (24 h sampling)
Lower limit of detection	2.5 µg/m^3 (24 h sampling)
Concentration quantity sensitivity limit	10 µg/m^3 (24 h sampling)
Cycle time (usage of one filter)	8 h to 100 days (Dust, Combined) 4 h to 100 days (Stability)
β measurement time	120 min (Dust, Combined) 30 min (Stability)

Stability specifications (Stability and Combined models):	
β^*	β activity associated with the short life products of radon. Function of atmospheric stability.
β1	Residual β activity, background and long life decay products of radon. Used for quality control.
R	Regression coefficient, expresses the confidence in estimation of β^*.

Other features	
Display	LCD, 4 × 20 characters
Keys	Membrane key-pad, 16 keys
Data storage	> 100 sets of data
Clock / calendar	Each set of data marked
Serial port	3 × RS232
Communication	Download of data, remote control, terminal
Analogue output	0 to 10 V or 0 to 20 mA (user selectable, e.g. 0 to 1000 µg/m^3, 0 to 4095 decays)

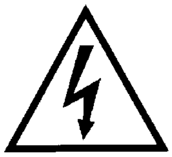
Other features	
Status output	Relay (closed = status OK)

User accessible fuses (at power intakes)	
Sampling unit	2 × 6.3 A / 250 V slow
Pump module	1 × 4 A / 250 V slow

Internal fuses, not user accessible	
High voltage module	1 × 3.15 A / 250 V slow
	1 × 1.6 A / 250 V slow
	1 × 500 mA / 250 V slow
	1 × 50 mA / 250 V slow

Temperature stabiliser, TS200	
Aluminium tube	Diameter 75 mm, length 1350 mm
Plastic tube	Diameter 50 mm, length 1500 mm
Ventilation hose	Diameter 50 mm, length 5 metres
Drain hose	Diameter 12 mm, length 2 metres

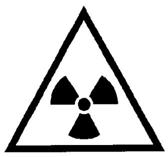
1.6 General safety warnings



Warning*: High voltage is present inside the instrument when plugged in to mains. Switch off power and unplug the mains cord before removing the cover from the instrument or the pump.*

Warning*: Only run the instrument on mains supply as specified. Failure to do so may result in damage to the instrument.*

Warning*: Moving parts inside and outside the instrument. Do not touch the filter holders when the instrument is loading or unloading filters.*



Warning*: A radioactive beta source is present inside the instrument if it bears this symbol. Do not under any circumstance attempt to disassemble the housing around the beta radiation source.*

The instrument is intended for air sampling, suspended particles concentration measurements, and /or air stability measurements. Do not use it for any other purpose.

For reliable and safe operation, make sure the instrument is kept and operated according to the specifications in section 1.5. The instrument must not operate in an potentially explosive (Ex) environment. Maintenance schedule and/or instructions given by the instrument supplier must be followed.

Hardware description 2

The SM200 system consists of the following main items:

- The main sampling unit, see section 2.1
- The sampling head and inlet tube, see section 2.2
- Inlet tube temperature stabiliser, see section 2.3
- Filter holders and filter containers, see section 2.4
- The pump module, see section 2.5

The main sampling unit consists of the following main units:

Hardware	Sampler	Dust/Combined	Stability
Mechanical system	Yes, see section 2.1.1		
Pneumatic system	Yes, see section 2.1.2		
Beta source	No	Yes, see section 2.1.3	No
Geiger tube	No	Yes, see section 2.1.3	
Electronics	Yes, see section 2.1.4		
Fan heater	No	Yes	
Analogue output	No	Yes, see section 2.7	
Serial communication	Yes, see section 2.8		

This chapter describes each of these features, plus some additional sub-systems. The chapter also gives detailed explanation of the operating principles of each of the SM200 models available.

Please refer to section 4 for installation instructions.

2.1 The sampling and measurement module

The main sampling unit is the heart of the SM200 system, and is shown in figure 2.1. In this figure, the unit is equipped with the two filter containers, see section 2.4, but the sampling head has not been attached (section 2.2).

Figure 2.1. The sampling unit.

The front panel of the sampling unit holds the user interface with display and keys for controlling the instrument. The user interface and the menu system is described in detail in section 5.

On the rear panel, there are connectors for:

- Mains power supply. Instrument fuses can be found next to the power intake.
- Power supply to the pump module (section 2.5).
- Tubes to and from the pump module.
- External temperature sensor.
- Analogue/digital output.
- RS232 serial communication interface.

The interior of the sampling unit houses the mechanical system for filter movements, large parts of the pneumatic system, the measurement system (mass concentration and/or stability), and necessary electronics and microprocessors for instrument control. These systems are described in the following sub-sections.

2.1.1 Mechanical system

The mechanical system inside the sampling unit is based on a rotating disc, usually referred to as a carousel. The carousel transports filters from the clean filter container (section 2.4) to the sampling and measurement positions as required by the measurement mode, and finally to the unloading position at the sampled filter container. Figure 2.2. illustrated the design of the carousel.

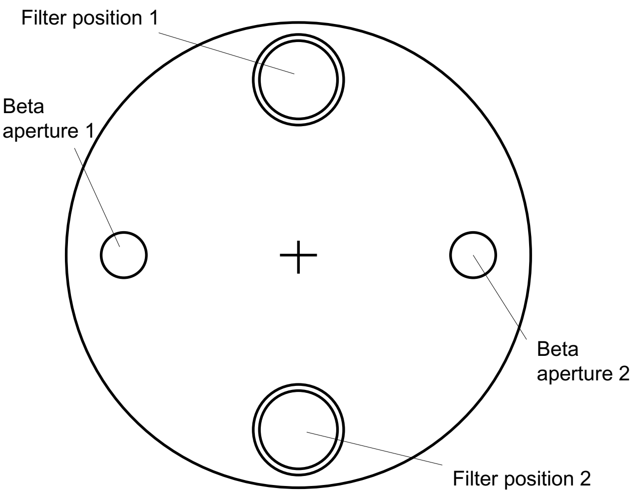


Figure 2.2. The filter carousel.

There are four different positions for the carousel, allowing a filter to be:

- loaded on the carousel
- placed in sampling position
- placed in measurement position
- unloaded from the carousel

The carousel holds two filters at the same time. When one filter is being sampled, the other is in the measurement position. Likewise, when a new filter is being loaded, one of the old ones is being unloaded.

The carousel also has two built-in apertures for calibration of the beta source and the Geiger tube, see section 2.1.3.

The carousel is controlled by a high precision stepper motor. A locking mechanism makes sure that the carousel stays in position throughout sampling and measurements. The actual position of the carousel is monitored by optical sensors.

2.1.2 Pneumatic system

The pneumatic system is shown in figure 2.3. The key items are:

- Sampling head
- Filter chamber
- Pump
- Flow measurement chamber

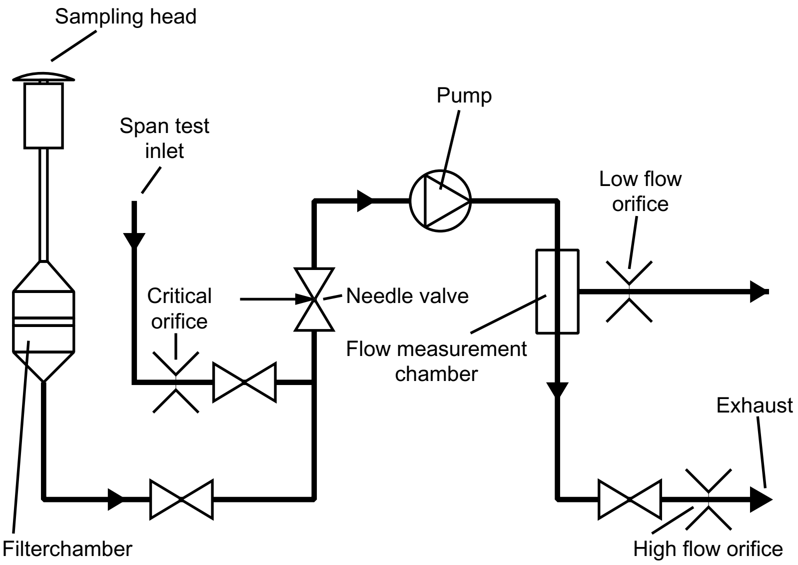


Figure 2.3. The pneumatic system.

Under normal operation, air enters the sampling head and flow through the filter inside the filter chamber. The air then passes the needle valve used for regulating the air flow, before it goes through the pump, see section 2.5. The air is pumped through the flow measurement chamber and exits the system at the exhaust, after having passed the high flow orifice.

The needle valve regulating the air flow is controlled by measuring the pressure drop across the high flow orifice.

The other valve and critical orifice are used for quality assurance tests of the system. Please refer to section 3 for more information on this.

The filter chamber is divided in two halves, allowing the carousel (section 2.1.1) to place a filter at the chamber. When in place, the chamber closes by means of a stepper motor, ensuring that the chamber becomes air tight.

2.1.3 Measurement system

The measurement system is in use in all models of the SM200 except for the pure Sampler. Figure 2.4 illustrates the measurement system. A Geiger tube monitors beta radiation, giving one “count” for each detected beta decay. The beta radiation is generated by the beta source, or by the sample itself. A moveable shutter can isolate the Geiger tube from the source, allowing measurements of the background radiation. By rotating the carousel, it is possible to insert new filters between the source and the detector. The carousel also holds calibration apertures for the quality assurance of the source and the detector. See section 2.1.1.

Please refer to section 2.6 for information on how the carousel, pneumatic system and measurement system work together in the different models of the SM200. Also, see section 3 for a detailed description of the quality assurance of the measurement system.

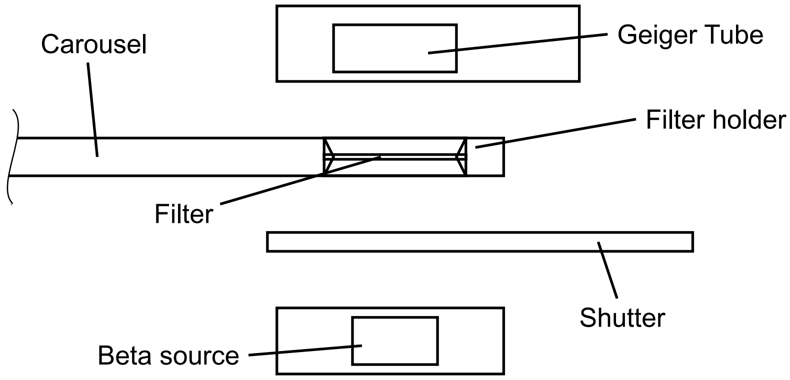


Figure 2.4. The measurement system.

The beta source is not in place in the sampler version of the SM200.

2.1.4 Electronics and microprocessor

The entire operation of the instrument is controlled by a central microprocessor. The microprocessor controls the user interface, the mechanics, the pneumatic system and the data acquisition as well as the communication through the RS232 ports. All sensors in the instrument are continuously monitored for possible failures, see section 3.

2.2 Sampling heads and inlet tubes

The sampling of dust is normally made through a sampling head, located in ambient air right above the SM200 sampling unit. Different heads can be used, depending on what particle fractions to sample.

Figure 2.5. A PM10 sampling head.

Figure 2.5 shows a typical sampling head. The design can vary from one manufacturer to another. The heads are normally available at least with the following particle fractions:

- TSP (Total Suspended Particles)
- PM10 (10 µm particles or less)
- PM2.5 (2.5 µm particles or less)

Sampling heads are designed to be wind- and rain-proof, and to manage condensation problems properly.

In some cases additional devices, “impactors”, can be placed in series with the sampling head, allowing further reduction of the particulate fractions.

The heads normally need regular servicing and cleaning. Please refer to the documentation of the individual head for more information.

The sampling head is connected to the sampling unit through an intake tube. The tube should be straight to guarantee unaltered particulate fractions, and the inside of the tube should be polished electrically.

2.3 Temperature stabiliser

The intake tube normally requires some protection against the sampling air condensing in side the tube. This is a noticeable problem in locations with high humidity and ambient air temperatures above the temperature in the vicinity of the sampling unit. Also, losses of volatile chemical compounds must be minimised, requiring minimum change of temperature. A way to handle this is to use a temperature stabiliser, TS200, illustrated in figure 2.6.

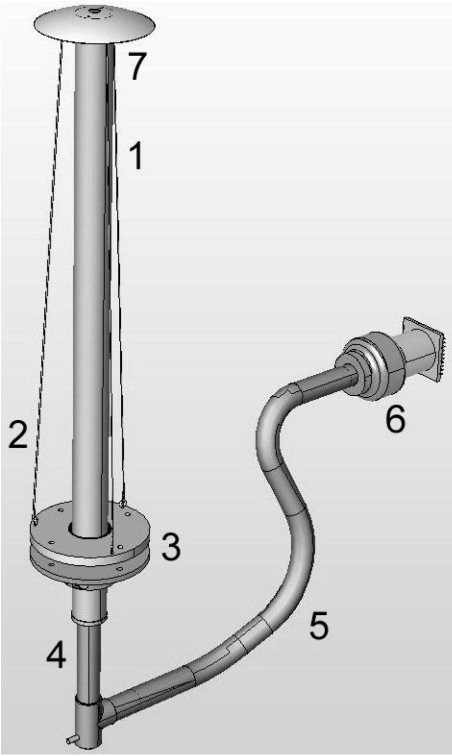


Figure 2.6. Temperature stabiliser TS200.

TS200 Temperature stabiliser	
1	Aluminium tube
2	Support wire
3	Roof flange
4	Plastic tube
5	Ventilation hose
6	Wallmounted fan
7	External temperature sensor holder

The method used to prevent condensation and to minimise losses of volatile particulate matter is a coaxial tubing outside the inlet tube, where ambient air is circulating. An external pump is required to provide the air flow. The circulating ambient air in the outer tube makes sure that the sampled air in the inner tube keeps its original temperature all the way to the filter. Please refer to section 4 for installation instructions.

2.4 Filter holders and filter containers

Figure 2.7. The filter holder.

Figure 2.8. The filter container.

The filters used by the instrument can be of any type of standard 47 mm filters, providing that the pressure drop across the filter when sampling is not too high.

The filters are normally of Teflon, but other material can also be used, like cellulose nitrate, cellulose acetate, plastics and similar. The porosity is typically 2 μm (standard).

When in use in the instrument, each filter is kept in place by a filter holder, shown in figure 2.7. Once the filter has been used for sampling, the holder can be removed and used for a new filter.

When the SM200 runs with the 1 hour dust sampling option, a special metal aperture must be placed in the filter holder, next to the actual filter. The apertures are reused with new filters, just like the holders.

The filter holders with their filters are stored in a filter container. A container can house up to 40 filter holders. There is one container for clean, non-sampled filters, and one for used, sampled filters. Either of the containers can be removed without interrupting the operation of the instrument. The containers are protected by a plexiglass case, and the top can be used to close the container during transport.

Refer to section 4 for further information on how to use the filter holders, containers and apertures.

2.5 The pump module

The pump module holds a two-head vacuum diaphragm pump, responsible for the circulation of air through the instrument. The pump module is connected to the sampling unit by two tubes, one for incoming and one for outgoing air. The pump is powered from the sampling unit, allowing it to control the pump operation.

Figure 2.9. The pump module.

The sampling unit is responsible for controlling the air flow through the system. It also runs quality assurance checks, including pump performance. During operation, the sampling unit switches on and off the pump, as required by the different stages in the sampling and measurement cycle.

The pump has its own fuses, located at the power intake.

***Note**: The pump module requires regular maintenance. Please refer to section 6 for more information.*

2.6 Operating principles

The different models of the SM200 instrument all have the same main features, like mechanical design, pneumatic system, Geiger tube and electronics. However, there are some noticeable differences in operation depending on model. The different operating modes are described below.

2.6.1 Sampler and standard dust monitor

Let us start by discussing the standard dust monitor, since this is the most common model in the SM200 series. The easiest way to understand how the instrument works is to follow a filter on its way through the SM200. See figure 2.10.

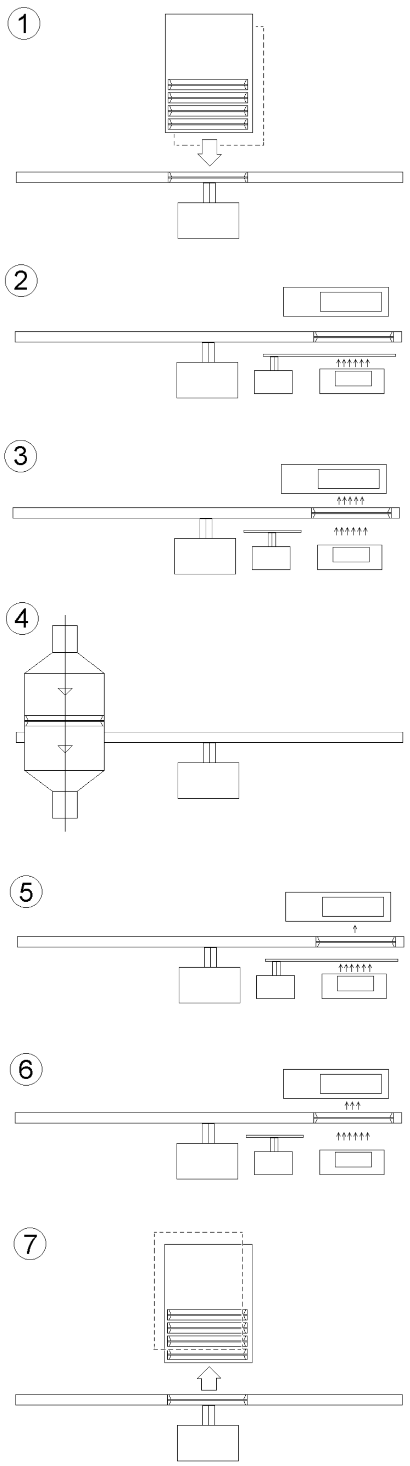


Figure 2.10. *Dust monitor.*

1. A new filter is taken from the clean filter container, and put on the carousel.

2. The filter is given time to condition itself, that is it adapts to the temperature of the interior of the instrument. By doing this, any residual humidity of the filter will evaporate and will therefore not influence the measurements. Then, the filter background radiation is measured by the Geiger tube. Here, the beta source is blocked by the shutter. This is called "dark" measurement.

3. The shutter is brought aside, and the radiation from the beta source is allowed to reach the Geiger tube through the filter. This is the "blank" measurement, where the initial transmission through the filter before sampling is checked.

4. The carousel rotates the filter to the sampling position, and the sampling chamber closes around the filter. The filter stays in this position for as long as the sampling has been requested.

5. The now dust laden filter is rotated back to the Geiger tube, where it again is allowed to condition itself, that is adapt to the instrument temperature. The filter is therefore dry when the "natural" radiation from the dust is checked, keeping the beta source blocked by the shutter.

6. The shutter is removed, and the beta rays are again allowed to pass through the filter. The beta radiation not absorbed by the filter and the particles on it will be detected by the Geiger tube. This is the "collect" measurement.

7. When the Geiger tube measurements have finished, the now used filter is rotated to the sampled container position, and the filter is unloaded to the container.

8. The dark, blank, natural and collect measurements now makes it possible to calculate the thickness of the dust on the filter. Knowing the total sampled volume, the dust concentration can be found.

The instrument always works with two filters at the same time. When one filter is in sampling position, the previous one is in measurement position, where the filter conditioning and the dark, blank, natural and collect measurements are made.

As a sampler and a standard dust monitor, the SM200 is guided by a characteristic cycle time. This is the time for a filter residing in the sampling position. However, before this, the filter must be conditioned and the dark and blank measurements must be made. Also, after sampling, filter conditioning and natural and collect measurements must be done. Therefore, the total time a filter stays inside the instrument is longer than the cycle time. Figure 2.11 illustrates the different stages for the filters on the carousel.

The filter conditioning and the different types of measurements takes several hours. For instance, natural and collect measurements each takes two hours. This is required to get high precision in the measurements. However, since the previous or next filter is being sampled at the same time as the current filter is in the measurement position, there is no loss of sampling time because of any of these procedures. Again, see figure 2.11.

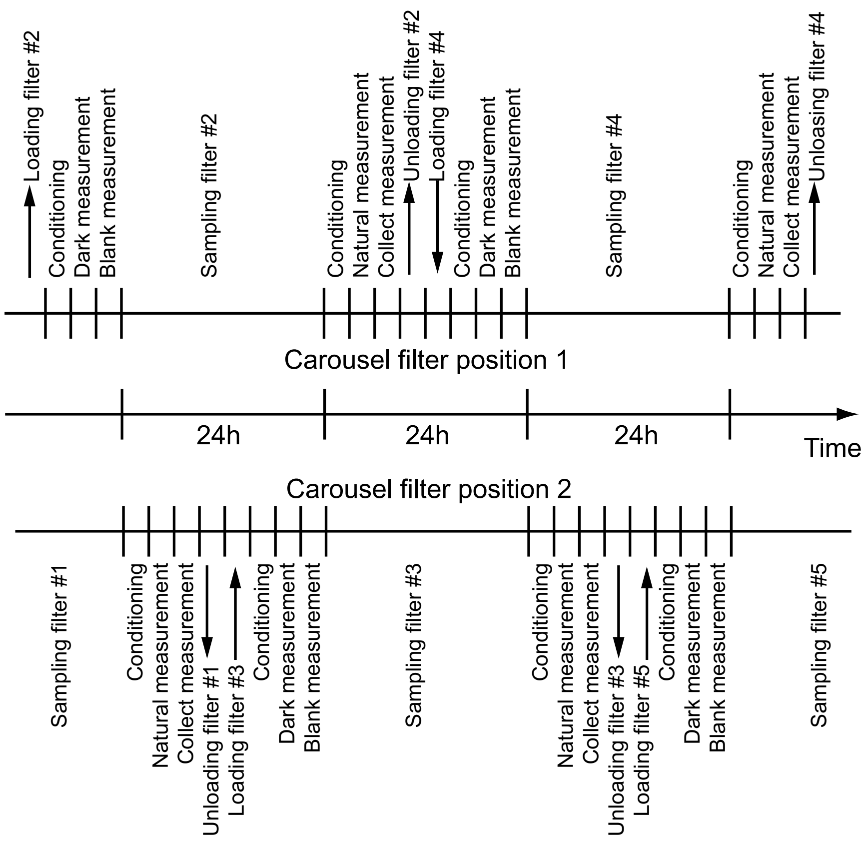


Figure 2.11. The conditioning, measurement and sampling phases for the two filter positions on the carousel. Cycle time 24 h. The first sampling is already running when the second filter is loaded to the left in the figure.

The cycle time can be from 8 hours and upwards. Often, a one day (24 h) cycle time is used. See section 2.6.4 for a discussion about how to select the cycle time.

The difference between the sampler model and the standard dust monitor is simply that the sampler does not have any beta source in it. Both models have exactly the same software, meaning, among other things, that the sampled filter in the sampling model actually spends some time being “measured”. Of course, this gives no useful result since there is no beta source in the instrument. After this “unnecessary” stop-by, the sampled filters are however forwarded to the sampled filter container, just as expected.

2.6.2 Stability monitor

In the pure stability monitor, the Geiger tube only measures the natural radiation of the sampled dust. No beta source is required, and the operating cycle is more simple than the cycle in the dust monitor. Figure 2.12 shows the steps in the stability monitor operating cycle.

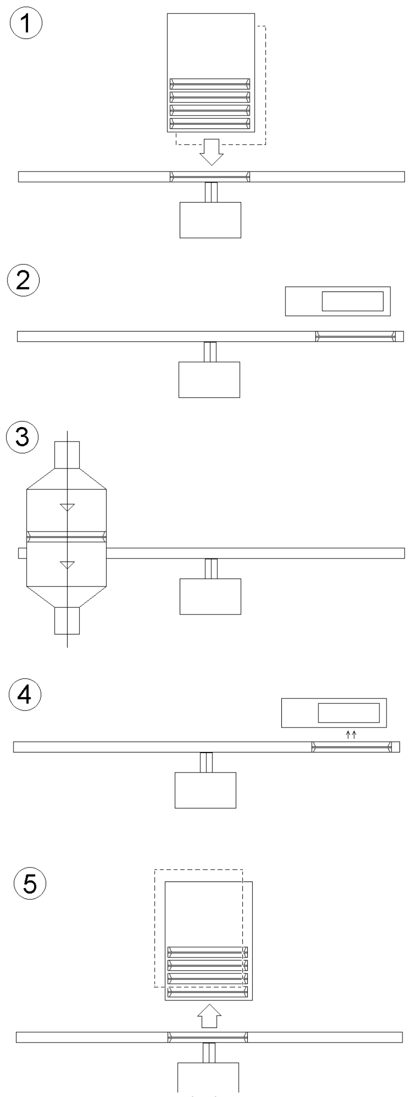


Figure 2.12. Stability monitor.

1. A new filter is taken from the clean filter container, and put on the carousel.
2. After conditioning, the filter background radiation is measured by the Geiger tube. This is the “dark” measurement.
3. The carousel rotates the filter to the sampling position, where it stays the time determined by the instrument settings.
4. When the sampling is finished, the filter is rotated back to the Geiger tube, which now can detect the “natural” radiation from the dust on the filter, after the filter is conditioned.
5. The now used filter is rotated to the sampled container position, and the filter is unloaded to the container.
6. The dark and the natural measurements are used to calculate the radiation activity from the short life and long life radon daughters. This gives a measurement of the air stability.

The system always works with two filters at the same time. When one is in sampling position (step 3), the other is being checked for natural radiation (step 4). Like the one hour dust sampler, the pair of filters is normally used for several sampling / measurement sequences, before they are unloaded and a new pair of filters starts to be used.

As for the other models, the stability monitor performance is guided by a cycle time. This is the total time during which a pair of filters is used. The cycle time is divided in a number of checks, specifying the total number of collect measurements being made on either of the two filters during the cycle, before they are shifted out and a new pair o filters are brought in from the clean filter container.

The filter conditioning and natural measurement on the sampled filter always finishes before the sampling of the next filter is completed. The conditioning and measurement after sampling also works as conditioning and dark measurement for the next sampling on the same filter.

Normally, the sampling time for a single filter is two hours. This is also the shortest possible sampling time. To get this, the number of checks should be set to half the cycle time in hours. For instance with 24 hour cycle time, the number of checks should be 12. Cycle times are discussed in section 2.6.4.

2.6.3 Combined

The combined model of the SM200 is nothing but the standard dust monitoring model, but with extended calculation capacity giving the short life and long life Radon daughters decay counts as well. The operation follows the dust monitoring sequence shown in figure 2.10.

2.6.4 Cycle times

The cycle time has to be selected with the following in mind:

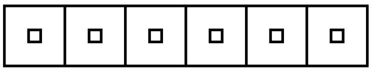
- The sampling time may be set by legislation. There should then be no doubt about how to select the cycle time.
- The cycle time should be long, in order to get the instrument running for long time without having to remove used filters and adding clean ones.
- The cycle time should be short if a high time resolution is required.
- The cycle time may be limited due to high dust content in the air. At some stage, the dust build-up on the filter will increase to such extent that the pressure drop across the filter becomes too high and the pump cannot keep the required flow rate. The remedy to this is to change filter type or shorten the cycle time. If there is no significant sign of pressure build-up during sampling, the cycle time may be made longer without problems.

Hence, the cycle time is a trade-off between legislation, instrument autonomy, time resolution and sampling conditions.

2.7 Analogue output

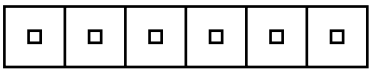
The SM200 is equipped with an analogue output connector on the rear panel. The output gives 0 to 10 V_{DC}, or 0 to 20 mA. In the setup for the analogue output it is possible to define the corresponding dust concentration for dust monitor models (i.e. 0-200 $\mu g/m^3$) or counts for the stability monitor model (i.e. 0-4095 counts). The connector also provides a relay contact closure corresponding to the status signal on the front panel. A closed contact means that the status is OK.

The analogue output connector is a 6 pin terminal block, see figure 2.13 and figure 2.14.



1	+ output
2	n.c.
3	- output
4	n.c.
5+6	status, closed = OK

Figure 2.13. The analogue output, 0-10 V_{DC}.



1	n.c.
2	+ output
3	- output
4	n.c.
5+6	status, closed = OK

Figure 2.14. The analogue output, 0-20 mA.

2.8 Serial communication

The serial connectors on the rear panel of the SM200 are standard 9 pin male RS 232 ports, configured as DCE (data communications equipment). The ports are normally used for data transfer, including a large number of status parameters, and for remote control of the SM200.

The serial ports can be used in the following configurations:

- Direct connection to a computer/datalogger for local communication.
- Connected to a cable/radio/GSM modem for remote access by computers with software for data acquisition and/or remote control.
- One of the ports is reserved for optional communicaton with other sensors.

See section 5 for configuration of the serial port. Figure 2.15 shows the pin configuration.

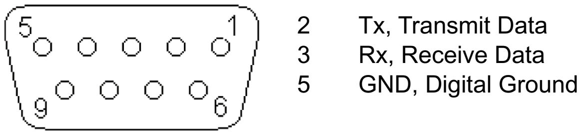


Figure 2.15. The serial port.

Use a null modem cable to connect the SM200 directly to a standard RS232 port on a PC or a datalogger, see the left part of figure 2.16. The SM200 does not support hardware handshaking.

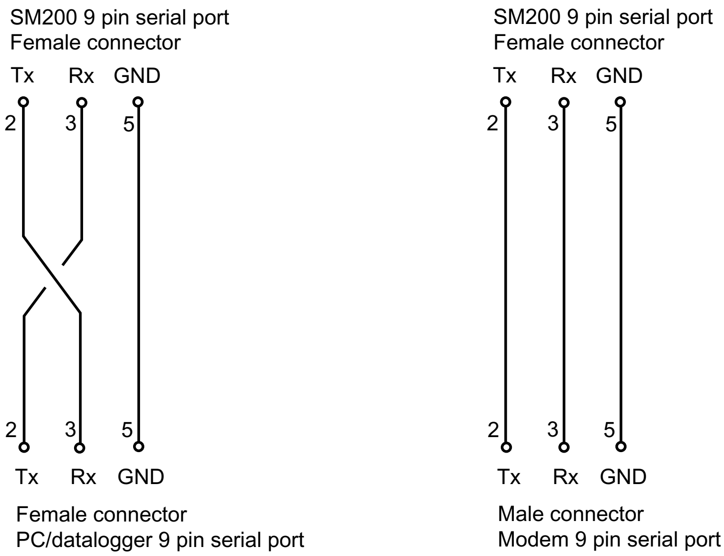


Figure 2.16. Cable for connecting the SM200 to a PC/datalogger (to the left). Cable for connecting the SM200 to a modem (to the right).

Since the SM200 itself is configured as a DCE, a straight cable must be used when connecting to a modem, see the right part of figure 2.16.

The SM200 communication protocol is available from Opsis on request.

Quality Assurance and Quality Control 3

One of the main features of the SM200 system is the extensive quality assurance and quality control checks made automatically and/or on demand from the operator. The checks verify the functionality of the instrument, ensuring that the monitoring results are correct.

Using the quality assurance parameters correctly, the results of the checks also serves as early warnings for required maintenance. In case of instrument failure, the results can be used to troubleshoot the system.

This chapter gives detailed information on the quality assurance and quality control (QA/QC) of the SM200 system. The chapter describes the functions in the dust monitoring models. There are only minor differences in QA/QC in the other models of the SM200.

The presentation in this chapter is basically the same as can be found in the "PM10 Field Studies" report by CNR-IIA (Rome, Italy), Umweltbundesamt (Berlin, Germany) and JRC ERLAP (ISPRA, Italy).

3.1 QA/QC overview

Figure 3.1 shows a block diagram overview of the different steps of the QA/QC procedures in the SM200.

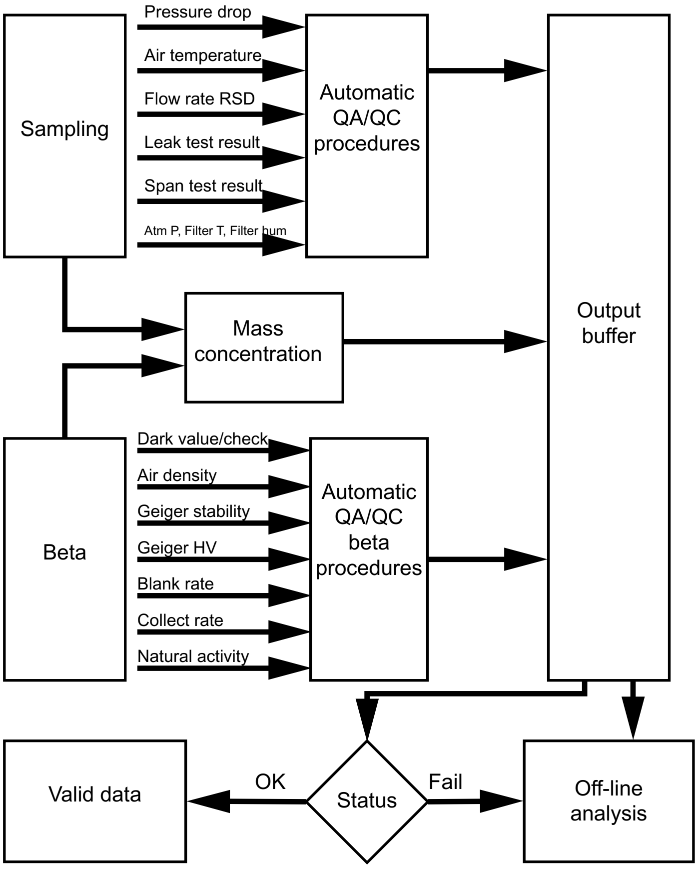


Figure 3.1. Logical block diagram of the QA/QC procedures in the SM200.

The QA/QC procedures are required to yield data at a high degree of accuracy and precision. This is obtained through the implementation of complete QA/QC procedures on both the sampling step and the beta measurement step.

3.2 The sampling system

A block diagram of the sampling system is shown in figure 3.2. The sampling system is characterised by

- Air temperature check at the accumulation point
- On-line dynamic leakage check (membrane pressure drop)
- On-line flow rate stability check
- Regular flow rate accuracy test
- Regular static leakage test

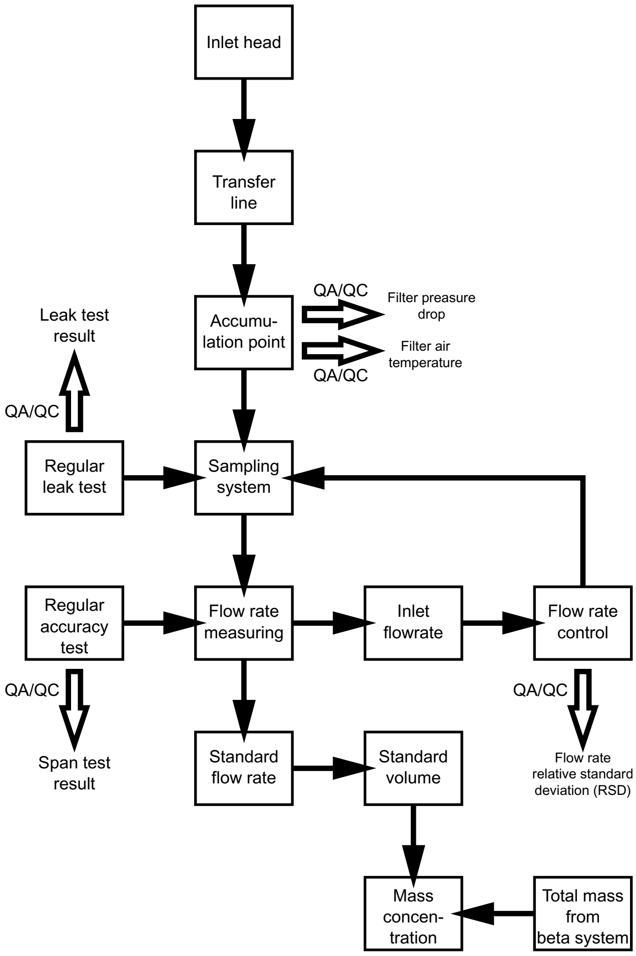


Figure 3.2. The sampling system block diagram. Compare figure 3.1.

3.2.1 Sampling system details

The SM200 sampling system is built around a sealed membrane pump. The real time flow regulation is performed by a stepper motor controlling the regulating needle valve. Three two-way (on/off) valves are used to alter the pneumatic circuit between normal sampling, span (flow) testing and leak testing.

The flow rate is monitored by measuring the pressure drop across an orifice located downstream of the pump. This location gives high performance of the pressure drop reading stability. The pressure drop, the absolute pressure and the temperature in the measurement chamber yields the mass flow.

The flow rate measurement can be checked by enabling the built-in reference circuit, based on a critical orifice.

The sampling system with its measurement points is shown in figure 3.3.

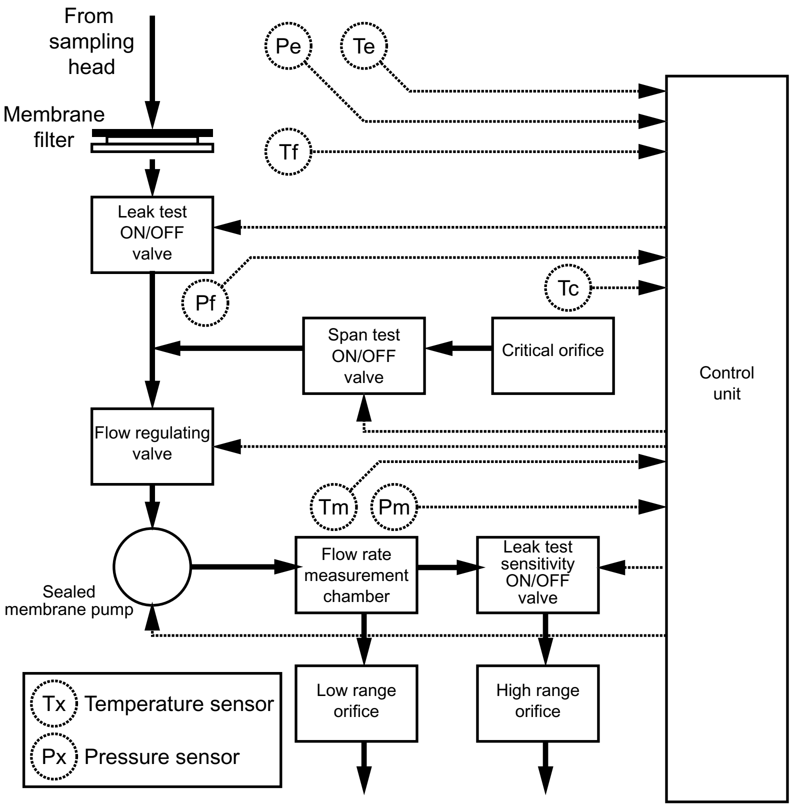


Figure 3.3. The sampling system.

3.2.2 Air temperature

Differences between the air temperature at the sampling head and at the filter may cause losses of volatile chemical compounds. The sampling line should therefore be maintained at ambient temperature, resulting in a minimum of temperature difference between the filter and the ambient air, see figure 2.6 in section 2.

In order to estimate the loss of volatile compounds, both the external temperature (Te) and the filter temperature (Tf) are stored in the instrument memory for retrieval and off-line analysis.

3.2.3 Filter pressure drop

The pressure drop across the filter gives information about the sampling performance, including

- Filter damage
- Bad filter positioning in the sampling line
- Equivalence assurance of the mass flow rates at the inlet, at the filter and at the measurement point.

The instrument registers the filter pressure drop (Pe - Pf) both before and after sampling. The difference (if any) gives information about the suitability of the filter type with respect to dust load and moisture.

The initial and final pressure drops are stored in the instrument, for later analysis. In addition, a limit can be set for the minimum drop, giving a real time status alarm in case the actual drop goes below this limit.

The pressure drop should be fairly constant, using the same type of filter and sampling roughly the same dust concentrations, typically showing variations within a few kPa. Variations not explainable by these factors indicate a problem with the sampling line.

3.2.4 Flow rate relative standard deviation (RSD)

The flow rate is a function of the pressure drop across the high volume orifice (Pm - Pe) and the temperature in the measurement chamber (Tm). Variations in external temperature and pressure (Te, Pe) and in filter load makes it necessary to constantly compare the actual flow rate with the pre-set value, and adjust the regulating valve accordingly.

The deviation of the actual flow rate from the pre-set one during the sampling is expressed as a relative standard deviation (RSD) The RSD is stored in the instrument together with other information for later evaluation and analysis.

Under normal circumstances, the RSD should be at the most a few percent. A higher value indicates a problem with the pneumatic system, which should be attended to.

3.2.5 Span test

The calibration of the flow rate is checked by temporarily shutting off the normal air intake, and instead pumping in air from a calibration inlet. This calibration inlet flow is well-known due to a critical orifice located before the span test valve. The orifice becomes critical when the system pressure Pf becomes low enough, which happens at

$$Pf < 0.45\ Pe$$

At this pressure, the flow rate becomes constant, about 15 litres per minute. The exact flow rate depends on the temperature Tc. The measured flow rate during the test is compared with the original factory calibrated flow rate. The result of the test is a percentage deviation from the calibrated flow, which normally should be well below a few percent. A flow rate status alarm is trigged if the difference is outside ±3 %.

The span test, together with the leak test, can be made manually or automatically on a regular basis, between measurement cycles.

3.2.6 Leak test

The leak test is linked to the span test, and is performed by shutting off all inlet valves. The pump will then evacuate the pneumatic system to the pump capacity limit.

The test result is a residual internal pressure Pf, and a low range leak flow (Pm - Pe). Both results should stay fairly constant from one test to another. The residual pressure is typically 10 to 15 kPa, with a status alarm limit of 25 kPa.

An increase in any of the two test result parameters indicates a deteriorated pump performance (may need service) or a leakage in the internal pneumatic system of the instrument.

3.3 The beta system

The beta system is the common name for the beta radiation source, the Geiger tube, and support devices linked to these. A function block diagram with respect to QA/QC is shown in figure 3.4.

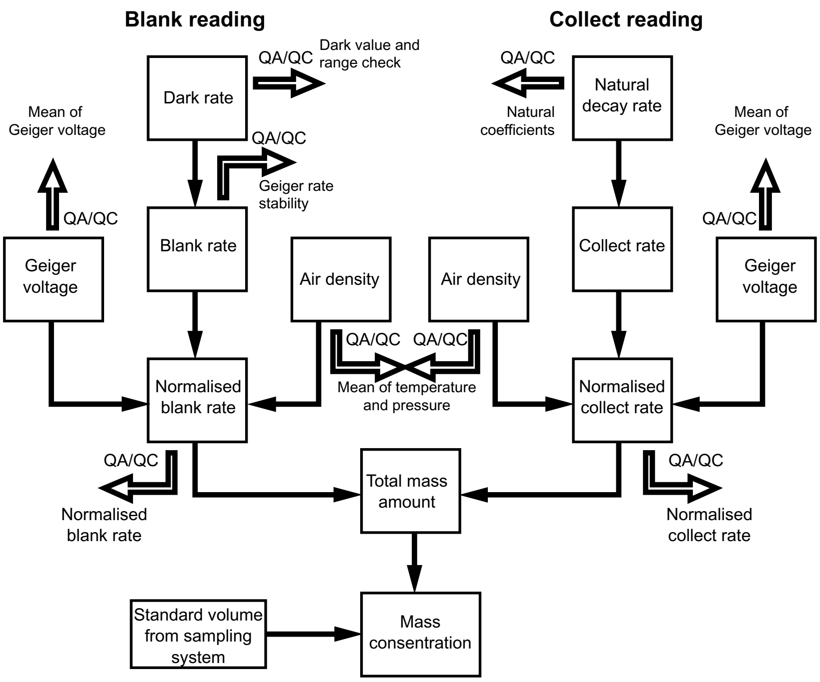


Figure 3.4. The beta system block diagram. Compare figure 3.1.

The beta system has the following characteristic features:

- Automatic beta response accuracy test
- On-line Geiger tube high voltage stability check
- On-line Geiger tube signal stability check
- On-line dark count level check

- Correction for natural radioactivity
- On-line air density correction

3.3.1 Beta system details

The SM200 mass measurement system is based on the physical laws governing the attenuation of beta rays when passing through a layer of matter. The thicker layer, the higher attenuation. Knowing the absorption coefficient of the matter and the surface, it is possible to calculate the total mass of the matter.

The precision of the mass measurement is linked to the statistics of the beta decay, giving a clear dependence on measurement time. The precision also depends on:

- Variations in air density between the beta source and the detector.
- Natural radioactivity of the collected particles.
- Efficiency and stability of the Geiger tube, used to detect the beta rays.

Figure 3.5 shows the details of the beta system. It consists of:

- Internally sealed low level 14C beta source.
- Shutter able to cover the beta source.
- Filter positioning mechanism (carousel).
- Geiger-Müller beta radiation detector (“Geiger tube”), with stabilised high voltage power supply. The detector generates counts corresponding to detected beta radiation.
- Local temperature and absolute pressure sensors.

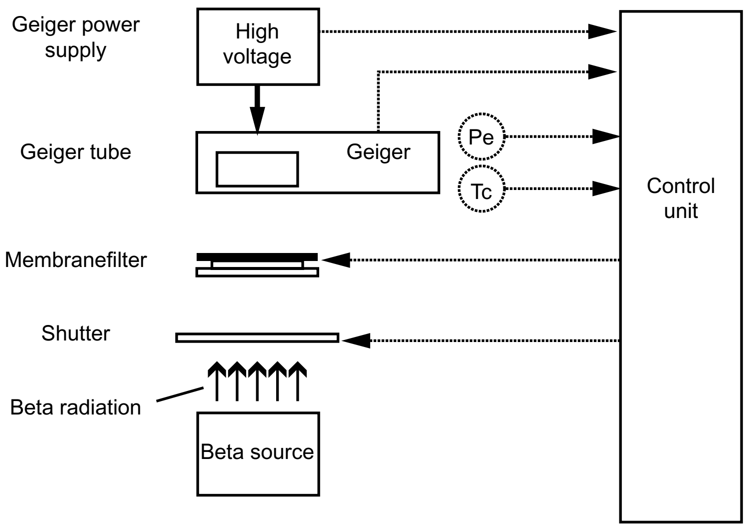


Figure 3.5. The beta system.

The performance of the beta system for determination of mass amount on a filter depends on several factors:

- The measurement geometry has been optimised to minimise the total mass amount of the air seen by the system.
- A precision mechanism with optical sensors control the position of the carousel, minimising variations in the count rate due to incorrect position of the filter inside the beta system geometry.
- The density of the small volume of air between the source and the detector is taken into account by registering local temperature and pressure.
- The voltage of the power supply is constantly monitored, since this highly influences the Geiger tube response.

In all, this gives the possibility to calculate a normalised beta count reading, giving better performance in mass determination accuracy.

3.3.2 Beta span test

The beta mass response is verified by temporarily inserting two reference apertures with different diameters between the beta source and the detector. At the time of manufacturing, the detector response is recorded with the two different apertures in place. This gives the reference, which the corresponding values from the beta span tests are compared with. The result is a percentage difference, which should be as low as possible.

Normally, the beta span test gives differences of at the most a percent or so. The limit for status failure of the beta test is at ±3 %. An increase in beta test deviation from pre-recorded values indicates problems with beta source, carousel positioning or the Geiger tube.

3.3.3 Geiger tube high voltage

The efficiency and stability of the Geiger tube is highly linked to the Geiger voltage. The voltage is normally around 600 V_{DC}. Under normal operation, the Geiger voltage is monitored in real time and carefully regulated. At the end of a measurement, the average of the voltage is registered to verify its stability and to normalise the beta flux readings to a normalised high voltage value. As a result, the residual relative variation in beta flux measurement may be as low as 10^{-4}.

The registered Geiger tube high voltage should normally stay very stable, with variations of less than 1 V. An increase in Geiger instability indicates problems with the high voltage power supply and/or the regulating circuit.

3.3.4 Geiger tube stability

The Geiger counts during blank measurements are registered and used for statistical evaluation of the Geiger tube stability. Under normal circumstances, the distribution of the counts should follow the Poisson distribution. Deviations from this will be registered and trig the system status alarm.

The absolute value of the blank count depends on the mass thickness of the clean filters being used. Changing filter batch may lead to a step change in the blank rate number.

3.3.5 Dark count level

When registering the background radiation of the Geiger tube, the shutter is moved between the source and the tube, and no filter is present in the line of sight. The reading in this state is due to the Geiger tube itself, and gives an offset for all other beta measurements.

The count reading after each dark measurement is stored and checked against its allowed limits: the value should be between 10 and 100 counts per minute. A failure will result in the status alarm flag being set.

There should be no significant variation in the dark rate seen over a long period of time. Normally, the variations should be within 10 counts. A slow trend change indicate a beginning problem with the Geiger tube, and it should then be replaced with a new one.

The absolute value of the dark rate depends on the individual Geiger tube, and can vary noticeable from one tube to another. Still the dark reading should in all cases be between 10 and 100 cpm.

3.3.6 Correction for natural beta activity

Short life radon daughters on the sample causes a positive artefact when measuring the absorption of the sample. (On the other hand, this is of course the measurement result of the sampler model). Before making the actual absorption measurements, the natural radiation from the dust is registered with the shutter blocking the beta source. A quantitative correction of the beta flux is then carried out, to allow the true absorption to be calculated.

The residual relative variation in flux after correction is as low as the order of 10^{-4}.

3.3.7 Correction for air density

The presence of air between the source and detector contributes to the absorption of the beta rays. This absorption can vary depending on the air density. The variations are generally small, but noticeable. To correct for this, the temperature and pressure at the beta system is detected, and the flux is corrected to a normalised air density at 40 °C and 101.3 kPa. As a result, the residual relative variation of the flux is again at the order of 10^{-4}.

3.4 Verifying instrument response

Despite the numerous efforts to secure a reliable instrument reading, there can always be weak points in the chain of evidences. Therefore, please observe the possibility to run manual gravimetric determinations of the weight of the sampled dust.

The air flow through the instrument can be verified by externally mounted high precision flow reference methods, at the choice of the user.

Installation 4

The first step to ensure a well operating system is to make a good installation. A bad installation makes it less likely that the instrument will produce valid data, and maintenance may be required more often.

This chapter gives guidelines for the installation. It includes descriptions of site preparations, instrument assembly, filter handling, and initial start-up instructions.

4.1 Items list

The SM200 system consists of the following items, included in the delivery:

- Complete sampling unit
- Pump module
- Power cable for the sampling unit
- External temperature sensor, including 5 m cable
- 2 air tubes for connecting the pump with the sampling unit
- Power cable between the sampling and the pump module
- 2 filter containers
- 40 filter holders
- Inlet tube, length 2.5 m or specially ordered
- Test protocol
- This manual

In addition, the following items are ordered seperately:

- Sampling head (TSP, PM10, PM2.5 or other)
- Documentation for the sampling head
- Sampling filters (number, porosity and material as ordered)

Additional filters, filter holders, etc., can be ordered as spare parts from your Opsis representative. There are also maintenance kits for the pump module available, see section 6.

The beta radiation source included in the dust monitoring models of the SM200 may be delivered in a separate shipment due to radiation regulations. See section 4.5 for more information.

***Note**: Sampling filters are ordered separately, since porosity, material and number may vary considerable depending on application.*

4.2 Site preparations

The SM200 sampling unit and pump module must be placed indoors, while the sampling head of course is located outdoors. The inlet tube is to be mounted vertically, requiring the sampling unit to be located immediately beneath the sampling head.

In detail, the required site preparations are:

- The room (cabin, shelter) where the sampling unit and pump module is located must be kept between 5 and 40 °C, with relative humidity of 80 % or less. It is strongly recommended to keep the room at normal indoors conditions, (about 20 °C) using air conditioning or heating as required.
- The operating environment of the modules must be clean and tidy. Do not operate the modules themselves in a high dust concentration environment. In extreme cases, the shelter may have to be slightly pressurised to keep the dust away.
- The sampling unit and pump module must be operated in horizontal position. Do not attempt to operate the units in any other orientation.
- Plan for placing the sampling unit on a levelled bench. To avoid overheating of the instrument and any equipment near by it, make sure there is at least 20 cm free space on all sides of the sampling unit and pump module.
- The power supply for the modules must be able to deliver 230 V_{AC} (+6 %, -10 %) 3.5 A at 50/60 Hz. The nominal power consumption is 800 W for both modules. The inlet tube conditioning may require additional power depending on what solution has been chosen, see section 2.2.
- Be aware that the pump module is noisy. It is normally not possible to keep it in the same room as where people stay for longer periods of time.
- There must be a hole in the roof for the inlet tube straight above the location of the sampling unit. The tube diameter is normally 18 mm. Make sure the inlet becomes water tight when the tube is in place - use rubber bellows or similar to allow the tube to move. Make sure to keep any roof insulation intact, to avoid condensation problems.
- If the installation includes a temperature stabiliser, TS200, the hole in the roof should be 80-90 mm. Mount the roof flange and the ceiling flange using M10 bolts of appropriate length (not included). Seal the bolts with silicon. See the installation drawing enclosed with the TS200 unit.

- The temperature sensor should be mounted next to the sampling head. Allow for the sensor cable to lead out of the room. On the TS200 there is a fitting for the temperature sensor.

***Note**: The temperature sensor must be installed in the shadow, in a well ventilated place where the temperature is the same as the inlet air. This sensor is used to regulate the air inlet flow to match the sampling head specifications.*

- It may be desired to lead the exhaust air from the sampling unit to the outdoors. If so, allow for appropriate passage. Place the emission point far away from the sampling head.

4.3 Unpacking

Open the transport cases carefully, and remove packing material. Identify the items listed in section 4.1. Verify that no packing material is present inside any of the modules or other items.

***Note**: Keep the original transport cases and packing material for future use.*

Carefully note how the equipment was packed, so it can be re-packed if the system needs to be transported in the future.

Use the handles (one handle on the rear side and two handles on the front side) to move the sampling unit into position. See figure 4.1.

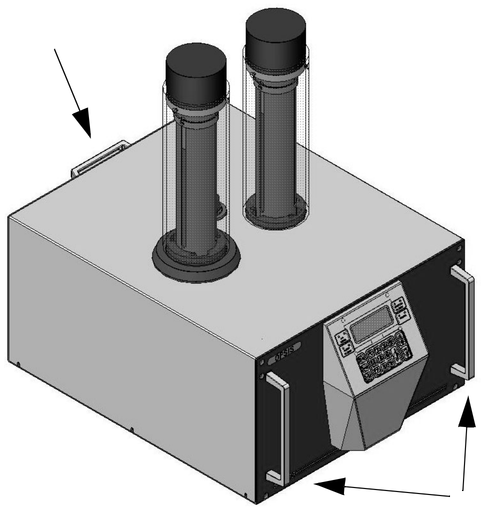
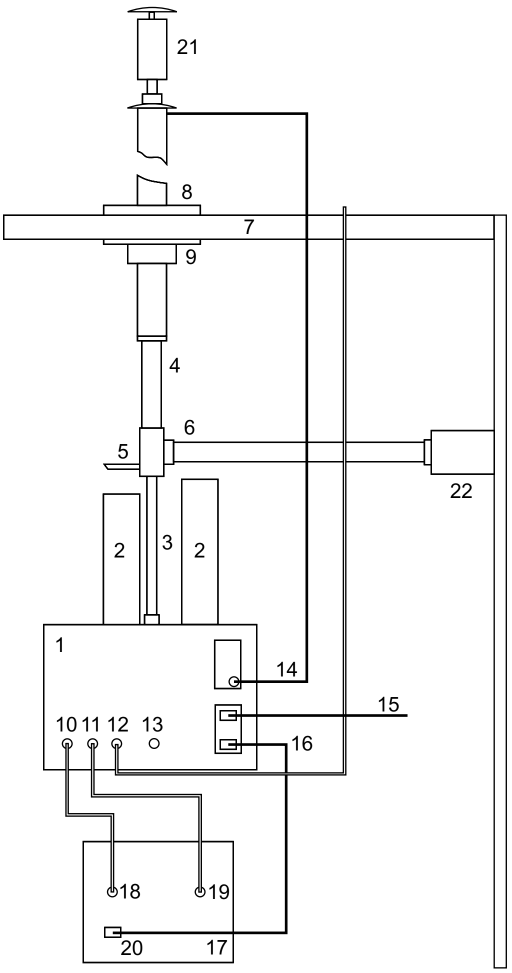


Figure 4.1. The handles.

__Warning__: Make sure that no foreign objects enter the sampling unit through the holes on the top, see figure 4.1. Keep the holes covered until it is time to mount inlet tube and filter containers.

4.4 The sampling unit and pump module

Figure 4.2 shows how to connect air tubes, power supply and sensors to the sampling unit and pump module. The illustration also shows how to mount the inlet tube and the filter containers, but this is further covered in section 4.6 and section 4.7.



1 SM200
2 Filter containers
3 Inlet tube
4 Temperature stabiliser TS200
5 Drain hose from TS200
6 Ventilation hose from TS200
7 Roof
8 Roof flange
9 Ceiling flange
10 Air outlet, SM200
11 Air inlet, SM200
12 Exhaust
13 Span test
14 External temperature probe
15 Main power
16 AC out, SM200
17 Pump module
18 Air inlet, pump module
19 Air outlet, pump module
20 AC in, pump module
21 Sampling head
22 Wallmounted fan

Figure 4.2. The SM200 system assembly.

Proceed as follows to connect the modules:

- Connect the sampling unit Air outlet to the pump module Air inlet.

- Connect the pump module Air outlet to the sampling unit Air inlet.

The two tubes have different dimensions.

- If desired, connect a tube to sampling unit Exhaust and let it end outdoors.
- Connect the sampling unit AC out to the pump module AC in.
- Lead the external temperature sensor to outdoors, with the sensor close to the sampling head location. If necessary, put the sensor in a shadow position, or use a sun radiation shield. The TS200 has a fitting for the sensor near the inlet.
- Check the main voltage.
- Connect the sampling unit to mains.

***Note**: Make sure that all tube connectors are firmly tightened. Use a tool to do this. It is generally not sufficient to use hand force only.*

***Note**: Do not yet switch on power. Wait until the rest of the installation is finished.*

4.5 Installing the beta source

The beta source may be transported and delivered separated from the rest of the equipment. This may be due to legal or other reasons. If so, the beta source needs to be mounted in the sampling unit before the instrument can be used.

***Warning**: Follow these instructions carefully. If followed, beta radiation cannot leak out from the transportation block or the sampling unit. Do not under any circumstance expose yourself to the beta radiation.*

The following instruction applies if the beta source has to be mounted in the sampling unit.

When outside the instrument, the beta source is kept in a special transportation block, illustrated in figure 4.3. As long as the beta source is inside this block, no beta radiation can leak out.

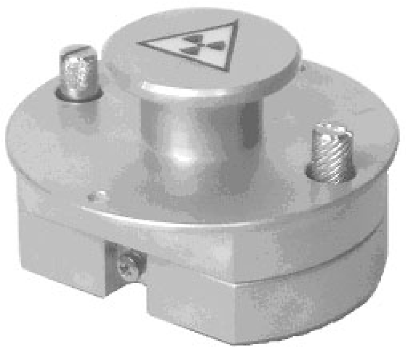


Figure 4.3. The beta source transportation block.

To insert the beta source in the sampling unit, proceed as follows:

1. Make sure the power is switched off and the mains cord is disconnected. Remove the cover from the sampling unit.
2. Locate the so far empty position of the transportation block, close to the front of the unit, see figure 4.4.

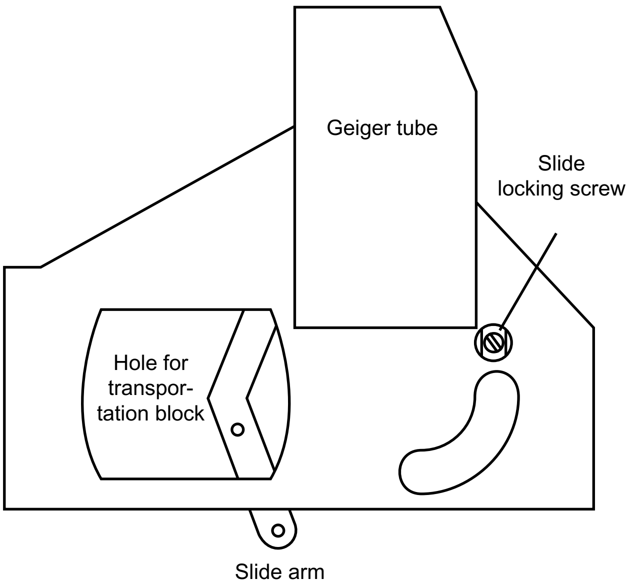


Figure 4.4. The slide in its locked position, without the transportation block in place.

3. The beta source is to be moved from the transportation block to the normal measurement position below the Geiger tube by a slide. The slide is secured by a locking screw to the right, seen from the front. Remove the locking screw completely and move the slide arm counter-clockwise, as shown in figure 4.5.
4. The hole in the slide for the beta source now becomes visible. Insert the transportation block in the hole. Make sure the block goes all the way down to the chassis. See figure 4.5.

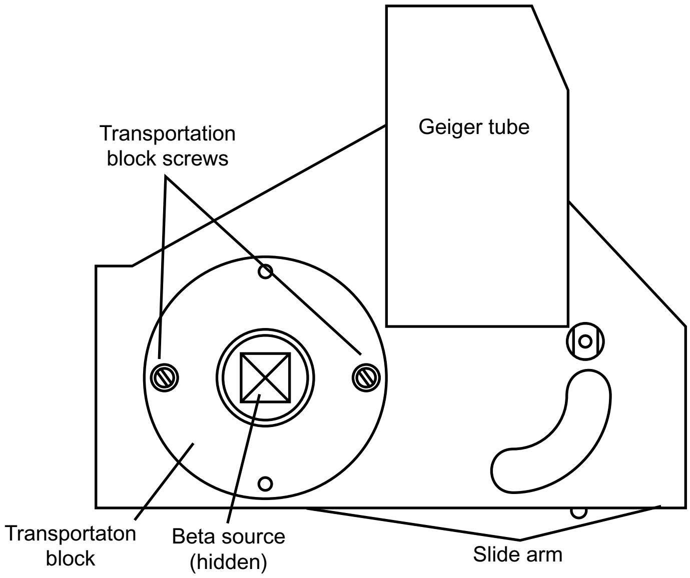


Figure 4.5. The slide in position for inserting the transportation block.

5. Remove the two transportation block screws visible from the top. This releases the beta source cradle from the top part of the transportation block.

Warning: *Do NOT lift the top part of the transportation block after having removed the screws. This would expose the beta source.*

6. Push the slide arm back to its normal measurement position. This moves the beta source from the transportation block position to its normal position under the Geiger tube.
7. Secure the slide by the locking screw.
8. The transportation block top has to be locked to the chassis by the two block screws. Insert and secure them in the two alternate positions, 90° to the previous ones. Always keep the top in this position, also when the beta source is safely secured under the Geiger tube. The final assembly is shown in figure 4.6.

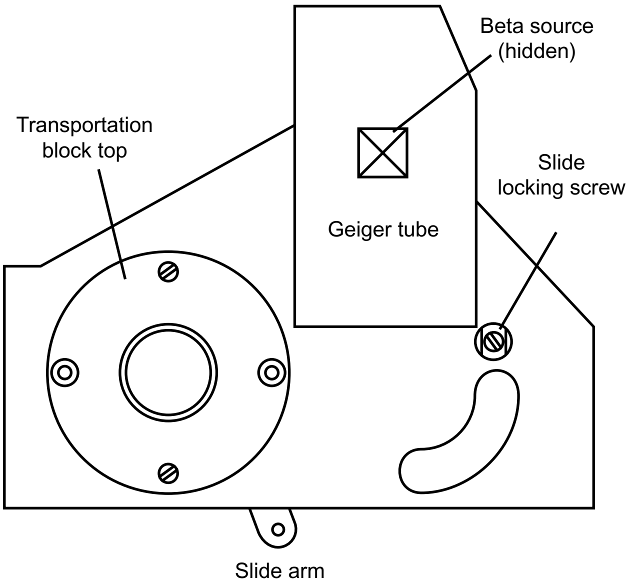


Figure 4.6. The slide back in its locked position, with the transportation block secured and the beta source below the Geiger tube.

***Warning**: Make sure to firmly secure the slide locking screw and the transportation block screws.*

***Warning**: Do not remove or loosen any other screws than those three indicated in this instruction.*

***Warning**: Failure to follow these instructions may result in exposure to beta radiation.*

Follow these instructions in reverse order to move the beta radiation source from the measurement position to the transportation block.

4.6 Sampling head and inlet tube

Make sure to position the air intake of the SM200 straight below the hole in the roof, see preparations, section 4.2.

***Warning**: Make sure that no foreign objects reaches the interior of the SM200 during the installation procedure. Permanent damage to the instrument may otherwise occur.*

4.6.1 Installation including TS200

1. Mount the TS200 aluminium tube through the flange. Tighten the bolts of the ceiling flange when the position of the tube is correct. The recommended height from

the top of the sampling head to the roof is 1000 mm. Mount the top flange on the aluminium tube.

2. Mount the TS200 plastic tube. If necessary this tube can be shortened in the top end.
3. Mount the loops on the roof flange and then mount the support wires.
4. Mount the fan on the wall following the installation instructions enclosed with the fan.
5. Mount the inlet tube through the TS200 tubes. When the inlet tube is in contact with the SM200 inlet, lift the inlet tube 1-2 millimeters and tighten the screws of the load releiving ring.
6. Connect the ventilation hose to the fan and to the nipple on the TS200 tube.
7. Connect the drain hose to the nipple on the TS200 tube.
8. Mount the sampling head, carefully following the installation instruction enclosed with the head.
9. Mount the external temperature sensor in the fitting near the top of the air inlet. The cable to the sensor is led through the TS200 tubes.

4.6.2 Installation without TS200

1. Mount the inlet tube through the hole in the roof. When the inlet tube is in contact with the SM200 inlet, lift the inlet tube 1-2 millimeters and secure its position. The inlet tube should be insulated to avoid condensation problems. Consult your Opsis representative if in doubt about how to proceed.
2. The sampling head can now be mounted on the inlet tube end. The head should come with proper installation instructions. Make sure to follow these instructions carefully.

4.7 Filter holders and filter containers

Each filter used in the SM200 must have a filter holder. Figure 4.7 shows how the filter is inserted between the two halves of the holder. Make sure the filter is centred and that the two halves are properly put together.

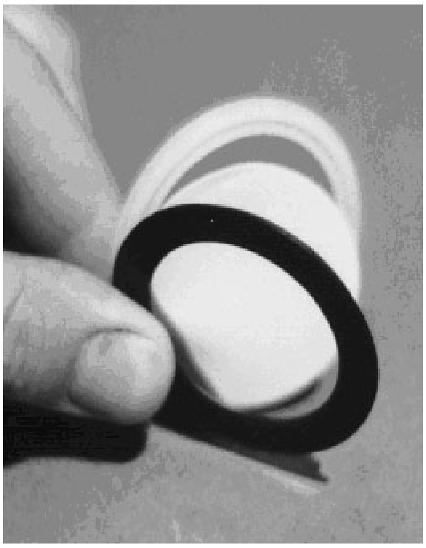


Figure 4.7. Mounting the filter.

The flow will go from the black side (ring) to the white side (ring). Please observe this in case the filter has a side that has to be towards the flow direction. The shapes of the rings may vary. It is the colour that counts.

Important note about the 1 h dust monitoring model of the SM200:

A special restriction plate must be inserted in each filter holder together with the filter, when measuring hourly averages. Figure 4.8 shows how to mount the plate. Please observe that the restriction plate is to be mounted on the white side (ring) of the filter holder.

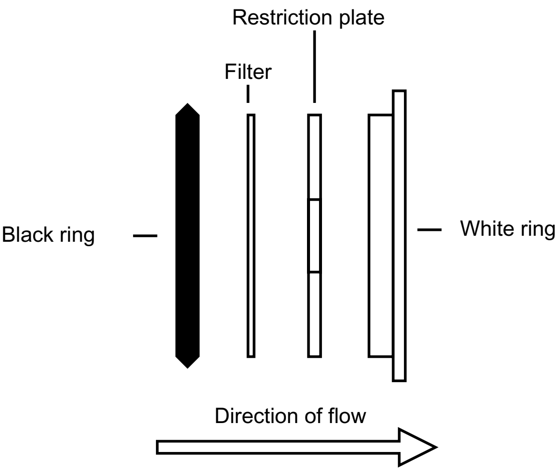


Figure 4.8. The filter holder with restriction plate. The plates must be used in the one hour dust monitoring model, and only in this model. Note that the shapes of the rings may vary. No matter what they look like, make sure to assemble the holder with colours oriented as indicated in this figure.

***Note**: Only use the restriction plates in the one hour dust monitor model.*

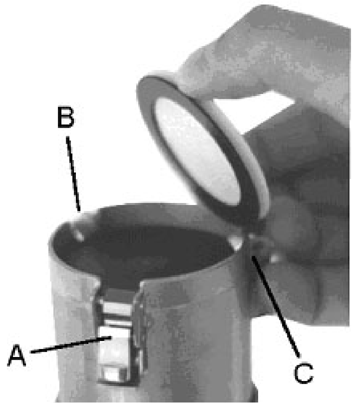


Figure 4.9. Inserting filters in the filter container. With this container orientation, the white ring of the holder should face upwards.

There are two tubes-like filter containers. Initially, one container should be filled with filters (including filter holders), and one should be empty. The former container is the clean filter container, which gradually will be relieved of its filters. The filters will be collected by the latter container, being the sampled filter container. This container will gradually be filled with sampled filters. When the sampled filter container is getting full, the sampled filters has to be removed, and the clean filter container has to be reloaded with new filters.

Figure 4.9 shows how to insert the filters in the clean filter container. Position the container upside down, with the solid end downwards. There are three locks holding the filters in place inside the container, A to C in figure 4.9. Gently push the filter holders past the locks, with the white side facing upwards. The container can host up to 40 filters holders.

When the clean filter container has been loaded with filters, it can be mounted on the sampling unit together with the yet empty sampled filter container. Figure 4.10 shows which container goes where.

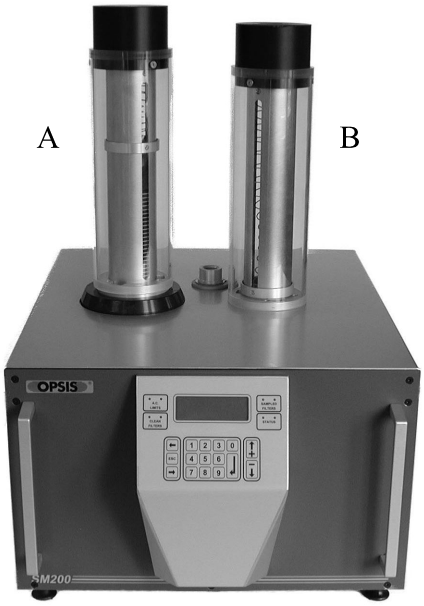


Figure 4.10. The sampling unit with filter containers. A = clean filter container, B = sampled filter container.

Gently insert each container in the sampling unit so that the three locks match the corresponding slots in the hole. Then rotate the container counter-clockwise until a distinct click can be heard and it cannot be rotated further. The container is now in its operating position, and the instrument is ready to be used.

When inserting the clean filter container, the first few filters will drop down inside the sampling unit. This is normal.

To remove a container, grab the cylinder and rotate it clockwise until the three locks are seen through the corresponding slots. Then pull the container straight out of the unit until it comes completely free.

Filters can be removed from any of the containers by simultaneously pressing in the three tab locks (lower part of the lock assembly as seen in figure 4.9) and pushing up the outer ring of the container (also seen in figure 4.9, below the tab, here in its uppermost position). You may need more than two hands to do this!

Unless the instrument has not run out of filters, there are still filters inside the sampling unit. They can be both on the carousel, if the instrument is sampling and/or measuring, and below the clean container location, waiting for pick-up by the carousel. There is a special menu to remove all filters residing in the instrument, if this should become necessary. See section 5 for more information.

Warning: *Do not manually try to remove filters from the instrument, neither by tools, nor by hand. You may damage the instrument if you try. Use the unload function, see section 5.*

Warning: *Make sure that no foreign objects can fall down into the sampling unit when the containers are removed. Cover the holes as appropriate.*

4.8 Starting the instrument

Providing that the installation instructions found in the previous parts of this chapter has been followed, the instrument is now ready to be started. Make a final check that everything is in order, and switch on the instrument at the rear of the sampling unit.

When switched on, the instrument makes an internal check of the different sub-systems. It then enters a warm-up phase, since the interior of the instrument is to be at about 40 °C during sampling and measurements. After the warm-up, the instrument is ready for use.

Please refer to section 5 for information on how to configure and use the instrument.

Note: *If the instrument has been transported in an environment colder than the place of use, let the instrument warm up to surrounding temperature before starting. This avoids possible problems with condensation.*

Operation 5

This chapter describes the software user interface of the SM200. The display and control keys are found on the front panel. It also gives detailed information about all menus in the software and how to use them.

To allow a quick start of the instrument, a step-by-step start-up instruction can be found at the end of this chapter.

5.1 User interface

Figure 5.1 shows the front panel of the SM200 with the display, key-pad and status indicators. The display has four lines of text.

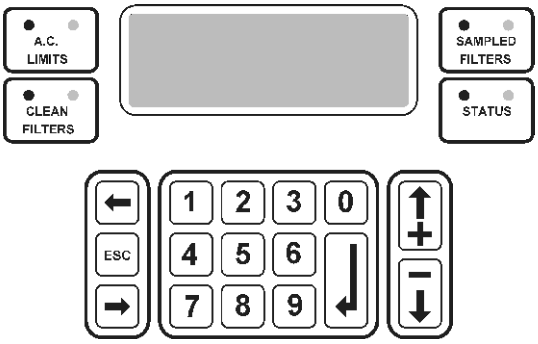


Figure 5.1. The SM200 front panel.

The keys are used to navigate in the menus. Use the [Up Arrow] and [Down Arrow] keys to move up and down in the menus. Press [Enter] to activate a function. Press [Esc] to return to the previous menu. The [Left Arrow], [Right Arrow] and numeric keys are used when data is entered in menus. Press [Enter] to accept a new value or [Esc] to leave without changing.

5.2 Status signals

The tables below shows the meaning of the status indicators on the front panel (figure 5.1).

Indicator	Green	Red
A.C. LIMITS	Mains voltage is within specifications.	Mains voltage is outside specifications. The instrument will not work. If both red and green shines simultaneously: The power is acceptable but close to the limits.
STATUS	The system is running.	There is a problem with the system. Refer to system status menus and troubleshooting section in this manual.

Green	Red	Explanation
On	Off	Container with filters in position
Off	On	Container missing
Off	Blink	Container in position but could not load filter
Blink	Blink	Container with 5 or less filters
On	On	Filter already loaded

5.3 Start-up

When the power is switched on, a start-up message (see figure 5.2) showing the serial number of the instrument and the software version is displayed.

```
      SM200-1005
       Ver. 1.03
   (C) OPSIS AB
      ≡OPSIS≡
```

Figure 5.2. The SM200 start-up message.

Within a few seconds the SM200 main menu starts, see figure 5.3. When switching on power for the first time, the instrument displays a warm-up message in the Info line. This message remains displayed until the interior of the instrument has reached its operating temperature, which is about 40 °C (313 K).

When the instrument has reached its operating temperature, all functions in the instrument can be accessed.

It is possible to interrupt the warm-up phase by pressing the [Esc] key. However, for proper measurement performance, the instrument should be allowed to warm up to its normal operating temperature. Only bypass the warm-up phase if you do not intend to start measuring directly. Heating will continue also after pressing [Esc].

```
2003-09-23  11:43:07
[1]-Measure [2]-Def.
[3]-Service [4]-Data
Info:
```

Figure 5.3. The SM200 main menu.

If a restart of the instrument has been done during measurement and the temperature is close to 40 °C, the message “Resuming meas soon” is displayed in the Info line. If the [Esc] key is pressed, the measurement will not be resumed and the message “Meas. halted” is displayed. Otherwise the instrument will start the measurement when the operating temperature is reached. See section 5.5.7 for instructions how to start the measurements again.

5.4 The menu structure

The menu system consists of several individual menus. The structure of these menus is shown in figure 5.4.

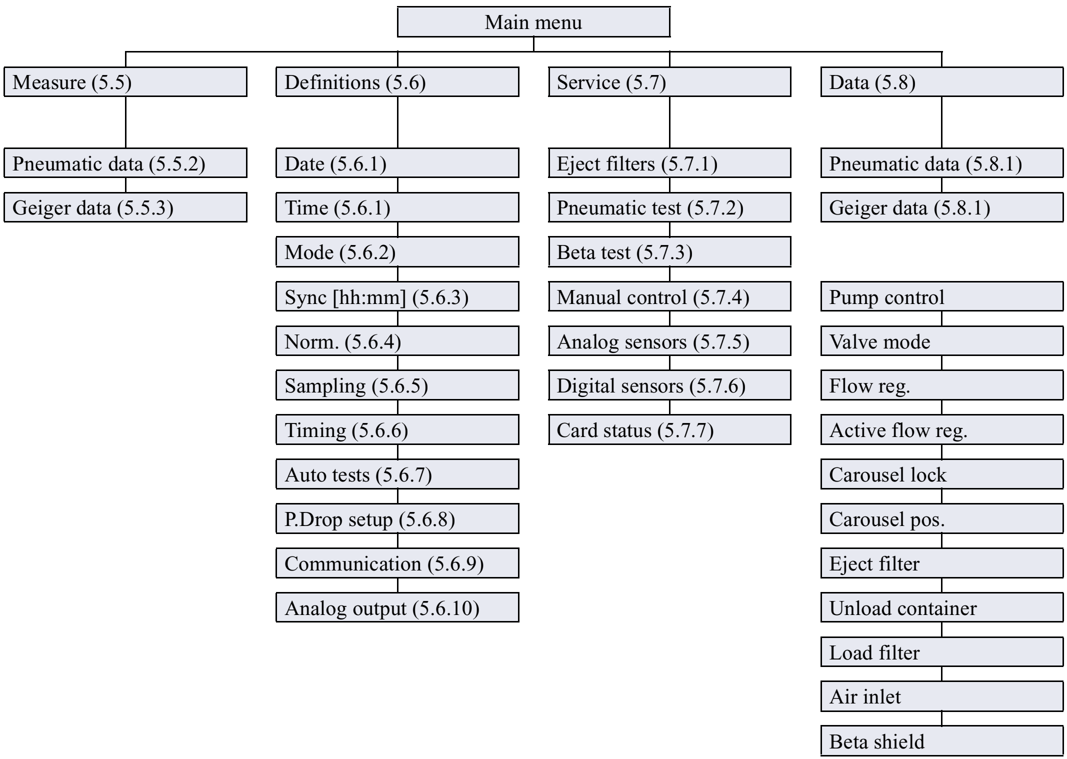


Figure 5.4. The menu structure including references to the sections where the menues are described.

5.5 The Measure menu

From this menu it is possible to start, halt and abort measurements. The menus Pneumatic data and Geiger data gives access to data from sensors in the instrument and parameters used when calculating the mass concentrations.

```
Meas mode:  Measure
Pneu:      01:30:13
Geiger:    Blank 30
2003-10-12 16:29:57
Pneumatic data  [+]
Geiger data     [+]
```

Figure 5.5. The Measure menu.

5.5.1 Measurement mode

The top line in the Measure menu states the measurement mode. There are three different measurement modes: Measure, Idle and Halted.

When the analyser is in the mode Measure it performs measurements according to the setup in the Definition menu. The measurement procedure is described in detail in section 2.

5.5.2 Pneumatic information

The Pneu line holds information about the ongoing measurement. The remaining sampling time is stated (1 hour, 30 minutes and 13 seconds in figure 5.5).

If the analyser has finished a sampling period the Pneu line shows the total sampling time, see below.

```
Pneu: 07:58 [hh:mm]
```

5.5.3 Geiger information

The Geiger line gives information about what type of Geiger measurement that is going on. The three different measurement types are, Dark, Blank and Collect. The elapse time of the current measurement (in minutes) is also stated.

5.5.4 Starting a new measurement

Move the cursor to the Meas mode line and press [Enter]. Use the arrow keys to choose the alternative New start. Press [Enter] and a new measurement will start and the measurement mode changes to Measure.
When a measurement is going on the Info line in the main menu states: "Meas. active".

5.5.5 Aborting measurements

When the analyser is in the mode Measure or Halted it is possible to abort the ongoing measurement.

Move the cursor to the Meas mode line and press [Enter]. Use the arrow keys to choose the alternative Abort. Press [Enter] and the measurement will be aborted and the measurement mode changes to Idle.

5.5.6 Halting measurements

When the analyser is performing measurements it can be temporarily halted for service purposes.

Move the cursor to the Meas mode line and press [Enter]. Use the arrow keys to choose the alternative Halt. Press [Enter] and the measurement will be halted. The measurement mode changes to Halted. To restart the measurement, see section 5.5.7 below.

5.5.7 Restart measurements

A measurement that has been halted can be restarted by moving the cursor to the Meas mode line and then press [Enter]. Use the arrow keys to choose the alternative Continue. Press [Enter] and the measurement will continue and the measurement mode changes to Measure.

5.5.8 The Pneumatic & Geiger data menus

In the Pneumatic data menu, information about the pneumatic parameters from the current measurement is found. The Geiger data menu holds information about the Geiger parameters. The values of the parameters are updated every minute. See figure 5.6.

The parameters are explained in section A.1, Buffer information. The same menus with data from completed measurements can be found in the Data menu, see section 5.8.

Start 2003-10-01 15	Start 2003-10-01 15
Sample time: 6:25	Dark : 27 [CPM]
Vol S: 5.790 [Nm3]	Blank: 104974 [CPM]
Vol I: 6.418 [m3]	Blank time : 30
PDrop I: 9.840[kPa]	Coll.: 0 [CPM]
PDrop F:10.117[kPa]	Coll. time : 0
Flow RSD: 1.1 [%]	Natural [1] : 0
Flow T : 37.84 [°C]	Natural [2] : 0
Ext. T : 25.05 [°C]	Natural [3] : 0
Atm P : 99.764[kPa]	Natural [4] : 0
Filter hum:28.75[%]	Natural [5] : 0
Filter T: 20.34[°C]	Natural periods : 0
Valve pos F : 17116	Blank T : 40.02[°C]
Pneu status : 0000	BlankP: 99.619[kPa]
	Blank hum :24.01[%]
	Blank HV:603.942[V]
	Coll. T: 0.00[°C]
	Coll.P: 0.000[kPa]
	Coll. hum : 0.00[%]
	Coll. HV: 0.000[V]
	G. stab.: 0.0[rel]
	Geiger Status: 0000

Figure 5.6. The Pneumatic and Geiger data menus.

5.6 The Definitions menu

From the Definitions menu it is possible to:

- Set the operation parameters of the instrument.
- Change date and time.
- Set intervals between auto tests.
- Configure the serial communication.
- Configure the analog output.

```
Date        2003-09-23
Time          11:43:07
Mode              Dust
Sync  [hh:mm]    00:00
Norm.         NTP 0 °C
Sampling           [+]
Timing             [+]
Auto tests         [+]
P.Drop setup       [+]
Communication      [+]
Analog output      [+]
```

Figure 5.7. The Definitions menu.

5.6.1 Change date or time

Move the cursor to the Date or Time line. Press [Enter]. Use the numeric keys to enter a new date or time. Press [Enter] to accept the new date or time.

5.6.2 Mode

The setting should correspond to the model of the instruments. The different models are:

- Dust
- Stability
- Combined
- Sampler

5.6.3 Sync [hh:mm]

The setting defines which hour sampling will syncronise on. If the sampling time is 24 hours, a 00:00 sync. time the instrument will make measurements between midnight this day and midnight the next day.

The time to prepare a filter for sampling is typically 2.5 hours.

Example: If the instrument is started at 18.00, a filter will be prepared for 2.5 hours and then the instrument starts sampling at 20.30. The next filter will then be prepared and be ready for sampling at midnight.

5.6.4 NTP correction

The measured concentrations can be corrected to a standard temperature. The options are:

- NTP 0 °C
- NTP 20 °C
- NTP 25 °C
- No corr. Disable the NTP correction by selecting this alternative.

5.6.5 Sampling

The menu for setting sampling parameters is shown in figure 5.8.

```
FlowRate[m3/h] 1.00
Min drop  [kPa]  0.0
Min flow[m3/h] 0.00
```

Figure 5.8. The Sampling menu.

There are three parameters to set, all relating to the sampling of the air:

- Flow rate is the nominal flow rate of the air through the instrument. The flow rate depends on which sampling head is used. Please refer to the head specifications for the correct flow rate. Use the numeric keys and press [Enter] to set a new value for the flow rate. The rate (at the sampling head) is given in cubic metres per hour.
- Min drop is used to trig an alarm if the pressure drop across a filter becomes too small. Normally, there is a noticeable pressure drop across the filter due to its flow resistance. Something is wrong if this drop disappears; typically, the filter is broken.

  Enter a value for the minimum pressure drop, and press [Enter]. The pressure drop is given in kPa. Set the value to 0, to disable the alarm.

  The normal filter drop depends on the type of filters being used. Therefore, it is recommended to let the instrument initially operate with the filter drop alarm disabled. Then study the obtained normal filter drop values in the buffer, and set the minimum filter drop somewhat lower, typically 5 kPa lower than the normal filter drop.

***Note**: If you change the filter type or the flow rate, a new minimum drop value should be found and set.*

- Min flow is used to set a lowest acceptable flow rate through the instrument. If the flow rate drops below this value, an alarm is set and the instrument stops measuring. The nominal flow rate is set at Flow rate, as described above, but for different reasons, the actual flow rate may vary. This can be due to increasing pressure drop across the filter and limited capacity of the pump. Use the numeric keys, and press [Enter] to set a new value for the minimum flow rate. The rate is given in cubic metres per hour. The sampling head performance may depend on the flow.

  Normally, the minimum flow rate can be set 0.1 to 0.2 m^3/h below the nominal flow rate. To disable the function, set the minimum flow rate to 0 m^3/h.

5.6.6 Timing

The sampling time and number of samples per filter is defined in this menu. It is also possible to change the conditioning time of the filters.

```
Sampling time[h]  24
Conditioning[10m]  6
Samples/filter     1
Filters (max)     40
Service [d:h] 40:00
```

Figure 5.9. The Timing menu.

The Service line gives information about how long time a full container will last, i.e. the service interval.

5.6.7 Auto tests

As a part of the quality assurance, the instrument can perform tests of the pneumatic and beta systems. The interval between the tests are set in the Auto test menu, see figure 5.10.

```
Pneumatic cycle    1
Pneu.int[d:h]   1.00
Beta span cycle   30
Beta int[d:h] 30:00
```

Figure 5.10. The Auto tests menu.

The pneumatic test includes a span test and a leak test of the sample lines. Set the period to zero cycles to disable the test function during measurements. The test takes 2 - 3 minutes. It is recommended to perform a test every cycle. The pneumatic test results can be reviewed in the Pneumatic test menu, see section 5.7.2. From this menu it is also possible to make a manual pneumatic test.

The beta test takes approximatly 40 minutes. It is recommended to perform a test once a month. The beta test result can be reviewed in the Beta test menu, see section 5.7.3. From this menu it is also possible to make a manual beta test.

5.6.8 Pressure drop setup

In this menu it it possible to change the calibration factor mass/pressure drop.

```
Mass/PD:  1.0 ug/m3
```

Figure 5.11. The Pressure drop setup menu.

5.6.9 Communication

In this menu it is possible to set the baud rate of the communication ports. The baud rate can be set to 2400, 4800, 9600 19200, 38400 or 57600 bps. If a com port not is used the baud rate is set to Inactive.

***Note**: Com port A is reserved.*

```
Baud ComA: Inactive
Baud ComB:    19200
Baud ComC:    19200
```

Figure 5.12. The Communication menu.

5.6.10 The Analog output menu

The analog output connector on the rear panel of the instrument gives 0 to 10 V_{DC}, or 0 to 20 mA. In the Analog output menu it is possible to define the corresponding dust concentration for dust monitor models. The Analog type is set to Voltage or Current. The analog output can be activated and tested using the two functions Test min and Test max.

```
Analog type:Voltage
Range[ug/m3]:1000.0
Zero level [%]:   0
Test min
Test max
```

Figure 5.13. The Analog output menu.

5.7 The Service menu

From the Service menu it is possible to run test functions, manual controls and display the values from the analog and digital sensors in the instrument.

```
Eject filters
Pneumatic test   [+]
Beta test        [+]
Manual control   [+]
Analog sensors   [+]
Digital sensors  [+]
Card status      [+]
```

Figure 5.14. The Service menu.

5.7.1 Eject filters

Under normal operation, there are always some filters on the carousel inside the instrument. If you remove the filter containers without doing anything else, the carousel filters will still remain inside the instrument.

You may wish to remove all filters from the instrument, for instance after having completed a measurement campaign. To do so, follow these steps:

- Move the cursor to the line Eject filters in the Service menu and press [Enter] to unload the filters inside the instrument. These filters will be placed in the sampled filters container.
- Remove the clean filters container.
- Remove the sampled filters container.
- Visually inspect through the filters container holes that there are no remaining filters inside the instrument. If there are, put back the sampled filters container again, and repeat the unload process.

The unloading procedure may take a minute or so. A wait message is shown on the display during unloading. It is not possible to interrupt the unloading procedure once it is started.

The unloading procedure also makes a quality assurance test on the mechanics of the instrument. It may therefore be interesting to request an unloading sequence also when there are no filters in the instrument. An error message is shown if there is a mechanical problem inside the instrument. Please refer to the appendix for interpretation of the error codes.

5.7.2 Pneumatic test

Select [3]-Service and then Pneumatic test to enter the Pneumatic test menu. Two different tests are included in the pneumatic test:

- The span test checks the measurement of the flow through the instrument.
- The leak test makes sure that the lines are air tight.

The display shows the result from the last performed pneumatic test, see figure 5.15. This information is important for quality assurance and for troubleshooting.

```
Span/leak test
S: 2.544 0.29   0.1
L:   9.3 kPa    0 Pa
D:2003-09-26  08:29
```

Figure 5.15. The Pneumatic test menu showing the result from the last performed pneumatic test.

5.7.2.1 Span test

The flow through the system is monitored by the pressure drop across an orifice and controlled by a needle valve. The pressure drop relates to the flow rate by a certain factor. This factor is stored permanently in the instrument when it is built. The result of the span test is a new factor. This new factor is compared with the stored one, and the difference is shown as a percentage value. This is the test result. The test result should be as close to zero percent as possible. A few percent difference is acceptable, but re-calibration may be necessary if the result is noticeable greater.

The result from the span test (S) gives three test parameters:

- The first parameter is a calibration value for the flow monitoring. At the start of the test, the stored calibration value is shown. After a while, this value is replaced by the corresponding value for the span test. The two values are normally just around 2.0.
- The mid parameter shows the pressure in the air lines inside the instrument during the test. The value is the internal pressure fraction of the external pressure. Initially, this value is 1.0, but as the pump runs, it falls down to and below 0.45, which is the operating point for the orifice in use during the span test. At this stage, the test calibration value (see above) is calculated.
- The third parameter is the deviation of the test calibration value from the stored calibration value. It should be low, at the most a few percent.

The test does not change the stored calibration value; it just compares it with the test calibration value.

5.7.2.2 Leak test

The leak test (L) is based on pumping out as much air as possible from the internal air lines, and then stopping the pump.The leak test results in two test parameters:

- The first test parameter is the residual pressure in the system. It starts at atmospheric pressure, but drops quickly as the pump evacuates the air. When the valve closes, the value should be well below 30 kPa, typically 15 kPa or lower in a new system. The value is an indicator of the pump efficiency.
- The second leak test parameter shows a low range pressure for a deliberate leak flow. It is zero when the air is evacuated, but starts climbing when the test begins. The climb should be very small, not exceeding 0.08 kPa, since it is an indication of the leakage in the system.

See the section about quality assurance (section 3) for more information about these test results and how to interpret them.

5.7.2.3 Run a new pneumatic test

To perform a manual pneumatic test press [Enter]. Figure 5.16 shows the display when a pneumatic test is running.

```
Span/leak test    ...
S: 2.545 1.00     0.0
L: 99.4 kPa     13 Pa
Testing           ...
```

Figure 5.16. The Pneumatic test display during a span/leak test.

5.7.3 Beta test

When entering this menu the reult from the last performed test of the beta counter (Geiger tube) is displayed, see figure 5.17 . This information is important for quality assurance and for troubleshooting.

```
 Beta test
 Dk:     27 CE:  0.0%
 A:1291924 B:1005210
 D:2003-10-01  07:04
```

Figure 5.17. The Beta test menu showing the result from the last performed beta test.

The test results are four parameters: a beta error and three counter values.

- The first counter value (Dk) is the dark count. This is the signal from the Geiger tube when it is shielded from the beta source. The counter value should be low, between 10 and 100 counts. The absolute value varies from one Geiger tube to another, the important thing is that no significant changes occur in the dark value from one test to another.
- The second and third counter values (A and B) are the Geiger tube signals with two different apertures between the source and the tube. The two aperture diameters are well known, and the relationship between the two counter values should therefore be fixed. The absolute counter values may vary, but the relationship should be constant.
- The beta test result (parameter CE in figure 5.17) is the percentage difference between the calibrated counter values relationship, set when the instrument was manufactured, and the measured counter values relationship. The error should be as close as possible to zero percent. Normally, it should not exceed a few percent. The test result will depend on the amount of and variation in the natural background radioactivity.

5.7.3.1 Run a new beta test

To perform a manual beta test press [Enter]. Figure 5.18 shows the display when a beta test is running.

```
Beta test          ...
Dark: 120
A:1291924  B:1005210
Testing            ...
```

Figure 5.18. The Beta test display during a beta test.

5.7.4 Manual control

From this menu it is possible to manually control the instrument.

```
 Pump control :  Off
 Valve mode : Sample
 Flow reg. :  Closed
 Active flow reg:Off
 Carousel lock:   On
 Carousel pos :L1_U2
 Eject filter
 Unload container
 Load filter
 Air inlet :Inactive
 Beta shield :    On
```

Figure 5.19. The Manual control menu.

5.7.4.1 Pump control

Press [Enter] to start the pump. Press [Enter] again to stop it.

5.7.4.2 Valve mode

The valve can be set in three different positions: Sample, Span or Leak.

5.7.4.3 Flow reg.

The flow regulator can be set in three different positions: Regulate, Max flow or Closed.

5.7.4.4 Active flow reg.

The flow regulator control can be: On or Off.

5.7.4.5 Carousel lock

The carousel lock can be: On or Off.

5.7.4.6 Carousel pos

The carousel can be set in four different positions:

- L1_U2, load filter 1 and unload filter 2.
- S1_G2, sample filter 1 and beta test filter 2.
- L2_U1, load filter 2 and unload filter 1.
- S2_G1, sample filter 2 and beta test filter 1.

5.7.4.7 Eject filter

Eject the filter in the actual position. Nothing happens if there are no containers or the carousel position is wrong.

5.7.4.8 Unload container

All the remaning filters in the clean filters container will be transported to the sampled filters container.

5.7.4.9 Load filter

One filter from the clean filters container will be loaded in the instrument. Nothing happens if there are no containers or if there is a filter on the load position already.

5.7.4.10 Air inlet

The air inlet control can be set to: Sealed or Inactive.

5.7.4.11 Beta shield

The beta shield between the beta source and the Geiger tube can be in two positions: On or Off

5.7.5 Analog sensors

Readings from the analog sensors found inside the instrument are presented in this menu, see figure 5.20. These readings are important tools for quality assurance, and can also be used for troubleshooting.

Press [Enter] to view the units of the parameters on a line.

```
eT   24.2 eP   100.9
fiT  20.0 fiRH 32.9
fiD 11.04 flD  3405
flT  37.5 flS  15.3
flI 16.61 flV 0.997
gT   40.0 gC     60
gHV         603.936
TC   6.97 Pos 17119
```

Figure 5.20. The Analog sensors menu.

It is recommended to check sensor readings regularly, and to look for changes in their values. A complete list of the various sensors, including short descriptions follows in the table.

Sensor	Explanation	Format	Unit
eT	External temperature	xx.x	°C
eP	External pressure	xxx.x	kPa
fiT	Filter temperature	xx.x	°C
fiRH	Filter relative humidity	xx.x	%
fiD	Filter pressure drop	xx.xx	kPa
flD	Flow regulator pressure drop	xxxx	Pa
flT	Flow temperature (in regulator)	xx.x	°C
flS	Standard flow	xx.x	normal l/min
flI	Inlet flow rate	xx.xx	l/min
flV	Inlet flow rate	x.xxx	m^3/h
gT	Geiger temperature	xx.x	°C
gC	Geiger counts	xxxxxxx	cpm
gHV	Geiger high voltage	xxx.xxx	V
TC	Temperature control	xx.xx	(0 .. 20)
Pos	Position of flow regulator	xxxxx	cnt

5.7.6 Digital sensors

Readings from the digital sensors found inside the instrument are presented in this menu, see figure 5.21. These readings are important tools for quality assurance, and can also be used for troubleshooting.

***Note**: To be used for service purpose.*

```
Carousel          [+]
Carousel lock     [+]
Sampled filters   [+]
Loader            [+]
Clean filters     [+]
Beta shield       [+]
Flow regulator    [+]
```

Figure 5.21. The Digital sensors menu.

5.7.7 Card status

The status of the hardware of the analyser can be found in this menu.

***Note**: To be used for service purpose.*

```
CPU Master    : 1.02
Flow regulate: 1.01
Power supply : 1.05
Pusher        : 1.01
Shield        : 1.01
Carousel lock: 1.01
Ejector       : 1.01
Load damper   : 1.01
Loader        : 1.01
Carousel      : 1.01
LED card 1    : 1.01
LED card 2    : 1.01
PT2 card      : 1.04
HT1 sensor    : 1.01
PT1 card      :   OK
External T    :   OK
OM001         : 1.01
```

Figure 5.22. The Card status menu.

5.8 The Data menu

In this meny, data from completed measurements can be viewed. The first line of text in the Data menu is always displayed in the window. The first number on the line is the position in the memory bank. To scroll between records in the memory bank, use the [Right arrow] and the [Left arrow] keys. The number after the date is the hour of the day when the measurement started.

```
00015 2003-10-21 15
Mass :    0.162 [mg]
MassErr: 0.013 [mg]
MassC:  22.2[ug/m3]
Pneumatic data  [+]
Geiger data     [+]
Filter P.drop   [+]
Filter samples:   1
Filter pos:       0
```

Figure 5.23. The Data menu.

The parameters presented in the Data menu are:

- Mass
  Total collected dust weight on the membrane.
- MassErr
  Error in total mass.
- MassC
  Dust concentration.

Further pneumatic and Geiger data are presented in the Pneumatic and Geiger data menus, see section 5.8.1.

5.8.1 The Pneumatic & Geiger data menus

The parameters in the menus are described in section A.1, Buffer information. The same menus with data from an ongoing measurement can be found in the Measure menu, see section 5.5.8.

The first line of the menus, with memory bank position, date and start hour for the measurement, is always displayed even during scrolling up and down in the menus.

00015 2003-10-21 15	00015 2003-10-21 15
Vol S: 7.290 [Nm3]	Dark: 24 [CPM]
Vol I: 7.968 [m3]	Blank: 103686 [CPM]
Sample time: 7:58	Natural: 22 [CPM]
PDropI:10.669 [kPa]	Coll: 103726 [CPM]
PDropF:10.701 [kPa]	Short: 65 [CPM]
FlowRSD: 0.9 [%]	Long: 3 [CPM]
Flow T : 37.82 [°C]	Nat. Res: 1.0 [%]
Ext. T : 24.91 [°C]	Natural [1]: 176
Atm P :101.127[kPa]	Natural [2]: 346
Filter hum:30.76[%]	Natural [3]: 496
Filter T: 22.17[°C]	Natural [4]: 647
Valve pos F: 17147	Natural [5]: 794
Pneu Status: 0000	Blank T : 40.00[°C]
	BlankP:101.531[kPa]
	Blank hum : 5.58[%]
	Blank HV:603.941[V]
	Coll. T: 40.00[°C]
	Coll.P:101.332[kPa]
	Coll. hum : 3.64[%]
	Coll. HV:603.941[V]
	G. stab.: 0.0[rel]
	Geiger Status: 0000

Figure 5.24. The Pneumatic and Geiger data menus.

5.8.2 The Filter P.drop menu

In this menu it is possible to show momentary parameter values from the end of every hour. The parameters are pressure drop, mass concentration, sampling volume, atmospheric pressure, external temperature, filter temperature and filter humidity.

```
00015 2004-05-21 11
Mass/PD:  0.0 ug/Pa
Show :       P.Drop
H:00-PDrop: 1788 Pa
H:01-PDrop: 1780 Pa
H:02

H:24
```

Figure 5.25. The Filter P.drop menu.

5.9 Quick start guide

This section provides a start-up guide with recommendations on what to set and what to test before starting measurements.

Proceed as follows to start measuring (within parenthesis are the sections where the function is described in detail):

1. Make sure the installation is made correctly. Put filters in the clean filters container. Connect the pump and install the beta source. (section 4)
2. Switch on the instrument. Let it heat up by itself, without bypassing the warm-up message. This may take a while, but it is necessary for the instrument to be able to operate properly. (section 5.3)
3. Press [2]-Definitions:
   - Enter Date and Time. (section 5.6.1)
   - Enter Mode = Dust. (section 5.6.2)
   - Enter Sync = starting time for new filter = 00:00. (section 5.6.3)
   - Enter Norm = NTP 0 °C. (section 5.6.4)

   Enter the Sampling menu: (section 5.6.5)
   - Enter Flow rate = 1.00 m^3/h.
   - Enter Min drop = 0 kPa.
   - Enter Min flow = 0 m^3/h.

   Enter the Timing menu: (section 5.6.6)
   - Enter Sampling time = 24 h.
   - Enter Conditioning [10m] = 6.
   - Enter Samples/filter = 1.
   - Enter Filter max = 40 (all filters loaded).

   Enter the Auto tests menu: (section 5.6.7)
   - Enter Pneumatic cycle = 01:00 (pneumatic test once per day)
   - Enter Beta span cycle = 30:00 (beta test once per month)

   Enter the Communication menu: (section 5.6.9)
   - Enter COMB = 19200 (other options for rate available, COMA can not be set).

   Enter the Analog output menu: (section 5.6.10)
   - Enter Range = 1000 µg/m^3 (if used, can be set to voltage or current).

   Go back to the main menu by pressing [Esc], [Esc].
4. Press [4]-Data: (section 5.8)

Data from previous cycles can be displayed by using the left and right arrow keys. No data is present when the analyser is started for the first time. When the analyser is measuring, old data can be displayed without stopping measurements.

Go back to the main menu by pressing [Esc], [Esc].

5. Press [3]-Service: (section 5.7)
   Pneumatic test takes 2 minutes to perform. (section 5.7.2)
   Beta test takes 45 minutes to perform and requires a beta source. (section 5.7.3)

   Go back to the main menu by pressing [Esc], [Esc].

6. Check that the status signals on the front panel are green. (section 5.2)

7. Press [1]-Measure: (section 5.5)

   - Enter Measure mode = New start.

   The system will prepare a new start by performing dark and blank measurements and synchronise measurement cycle with Sync time.

8. The analyser is now in the mode Measure and it will display current activities. Stored data can be displayed by pressing [4]-Data and live data can be viewed in the [1]-Measure menu.

Maintenance 6

As any other type of instrument, it is important to do preventive checks and maintenance on the SM200 on a regular basis. This is the best and possibly only way to get good function of the instrument and high quality of the measurement results.

A maintenance schedule is specified in this chapter, together with detailed descriptions of each step involved in the maintenance procedures.

A list of consumables for one year of normal operation can be found at the end of this chapter.

6.1 Maintenance overview

Table 6.1. gives a summary of the normal maintenance routines. Each of these routines are described in the following sections.

Operation	**Interval**	**See section**
Instrument status supervision	Daily	section 6.2
Sampling filter replacement	Depends on cycle time	section 6.3
Beta and pneumatic tests	Monthly	section 6.4
Instrument inspection and cleaning	Before start of each measurement sequence and then monthly	section 6.5
Instrument test	Before start of each measurement sequence and then monthly	section 6.6
Pump humidity trap filter replacement	Every six months	section 6.7
Pump membrane replacement	Every twelve months	section 6.8
Pump gasket replacement	Every six months	
Sampling head maintenance	Depending on head type	-

The above maintenance intervals are recommendations for instruments operating under normal conditions. Depending on instrument environment, the intervals may have to be shortened. It is possible that other maintenance operations will have to be added to guarantee a well working system. Always follow any additional instructions given at the delivery of the system or later.

If the instrument has been inactive for a longer period of time, all maintenance operations should be carried out before starting to use it.

Please consult your Opsis representative if you are in doubt of any of the maintenance procedures.

***Warning**: High voltage components inside the instrument. Always switch off power and disconnect from mains before doing hands-on maintenance.*

6.2 Instrument status supervision

One of the main features of the SM200 is the built-in quality assurance procedures including numerous sensors for instrument performance supervision. Sensor values and test results should be checked as regularly as possible. This is easily done without site visits, and can even be done automatically, providing that the instrument is accessible from an external computer, for instance through a modem. Software running in the external computer, for instance Opsis EnviMan ComVisioner, should be able to download information from the instrument buffer for remote evaluation.

It is recommended to check the following information from the buffer:

Parameter	**Check / comment**
Sampling uptime	Should be close to measurement cycle time. If not, there is a mains voltage problem or measurements have been halted or aborted manually.
Initial and final pressure drop across filter	Should be stable without noticeable variations between filters and without showing slowly moving trend towards increasing pressure drop. The reading will change if starting to use a different type of filter.
Flow rate RSD	Should be low and stable, without showing any slow trends towards increasing instability.
Pneumatic status	Should be zero. If not, there is a problem with the pneumatic system, see section A, Appendix.
Dark rate	Should be between 10 and 100 counts without significant changes or slow trends.
Geiger temp.	Should be above 308 K (blank and collect).
External pressure	Should be at atmospheric pressure (blank and collect).
Geiger voltage	Should be very stable (blank and collect).
Beta status	Should be zero. If not, there is a problem with the beta source or detection system, see section A, Appendix.

See section A, Appendix for a complete list of information found in the instrument buffer and for further interpretation of the results.

With on-line remote control of the instrument (EnviMan ComVisioner or other software), it is also possible to call the instrument manually and check status information and test results in detail, without interrupting sampling or measurements. See section 5 and section A, Appendix for information on what status signals are available and how to interpret them.

See section 7 for troubleshooting if the test results or sensor signals indicate a problem with the instrument.

6.3 Filter replacement

Make sure to calculate the running time of the instrument with whatever number of clean filters it is started with, and plan filter replacement well within this time. See section 5 for information about the running time.

Make sure to empty the sampled filters container at the same time as the clean filters container is filled with new filters.

The last filter to be inserted in the clean container is the first to be used. When unloading sampled filters, the last sampled filter is the first to come out of the container. Make sure to keep track of the filter order, possibly by marking the filter holders or the filters themselves in some way, if the filters are to be used for further analysis at a laboratory or similar.

Please refer to section 4.7 for information on how to insert new filters in the clean container. The sampled filters are removed from the sampled container by reversing the procedure.

When there are only five filters left in the clean filter container, the red and green clean filter status lights on the front panel will start flashing. New filters should then be inserted without delay. When there are no filters left in the clean container, or when the sampled container is full, the corresponding status light will be red and the instrument will stop sampling.

6.4 Beta and pneumatic test

If automatic beta and pneumatic tests not are activated, do the tests manually once a month. Halt the measurements and perform as follows:

- The beta test procedure (quality assurance), see section 6.6.
- A pneumatic test, see section 6.6.

Follow the instructions in section 5 to halt the ongoing sampling and measurements. The maintenance procedures described in section 6.5 to section 6.8 should be done as appropriate when measurements are aborted. See the corresponding sections for further instructions.

6.5 Inspection and cleaning

Visually inspect the following items:

- Power cord and other cables. Make sure the cables are not squeezed or damaged in any way, and that all connectors are in place.
- Pneumatic tubes. All exposed tubes should be in good condition. Make sure they are not folded causing restrictions in the air flow.

The instrument should be kept clean and tidy. If necessary

- Clean the sampling unit and pump cover with a cloth, possibly with some water and light detergent in. Do not use alcohol or other strong solvents.
- See the documentation for the sampling head for instructions on how to clean the air intake.
- Keep the instrument site clean.

6.6 Instrument test

An instrument test includes

- Checking the pneumatic system
- Checking the beta system calibration
- Checking the system sensor readings
- Verifying the filter loading and unloading mechanism

6.6.1 Pneumatic system

The pneumatic test can be made both manually and automatically between measurement cycles. See section 5.7.2 for information about how the pneumatic test is performed and how to interpret the results.

6.6.2 Beta system

The beta system test can be made both manually and automatically. See section 5.7.3 for information about how the beta test is performed and how to interpret the results.

The beta test can of course not be made in an SM200 operating as a pure sampler, not being equipped with any beta source.

6.6.3 Sensor readings

Information from the numerous system sensors can be found in the analog sensors menu, as described in section 5.7.5. The sensor reading can also be checked during sampling and measurements without having to restart the measurement procedures.

Some of the information from the sensors is also available in the buffer, as described in section 6.2.

6.6.4 Filter loading / unloading

When starting sampling and measurements, pay attention to the movements of the filters. Listen carefully for any unusual mechanical dissonance. Contact your Opsis representative if you are in doubt of the filter mechanism.

In case of serious problems with the filter mechanism, an error message will be shown on the display and the instrument will not make any sampling or measurements. See section A, Appendix for a list of the error codes and their meaning.

6.7 Replacing pump humidity trap filter

The filter in the humidity trap of the pump should be replaced regularly, to ensure trouble-free operation of the instrument. The procedure should be preceeded by halting the measurements before switching off the mains power.

The humidity trap assembly is shown in figure 6.1.

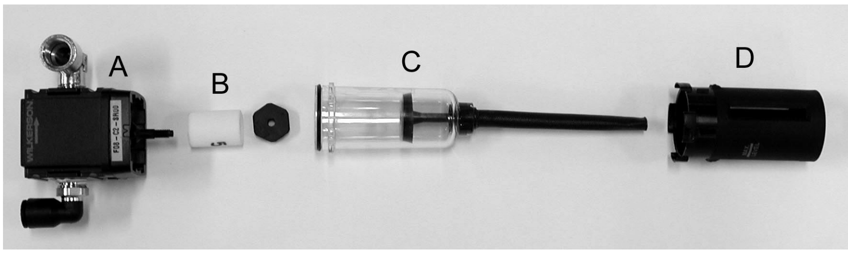


Figure 6.1. The humidity trap. A) container holder, B) filter, C) water container with drain hose, D) plastic cover.

Proceed as follows to replace the humidity trap filter:

- Abort measurements and switch off power. Disconnect the power cord from the mains.
- Remove the cover from the pump module. Locate the humidity trap.
- Loosen the screws to the humidity trap and remove it from the pump module.
- Remove the plastic cover and the water container. Clean the container, if necessary.
- Remove the old filter and put the new one in place.
- Put back the water container and the plastic cover. Make sure to screw the container firmly in its holder.
- Put back the humidity trap in the pump module.

- Lead the drain hose through the hole in the bottom plate of the pump module.
- Restore the pump cover and connect the mains again.

The pump is now ready to be used again. Make sure to run a pneumatic test to ensure that all connectors are air tight, see section 6.6.

6.8 Replacing pump membranes

The pump membranes should be replaced regularly. The indicator for required membrane replacement is an increase in the residual pressure during the leak test part of the pneumatic test, but also without this indication, the membranes should be replaced since they have a limited lifetime. The replacement requires the power to be switched off. It is therefore recommended to replace membranes at the same time as a system restart is done.

Proceed as follows to replace pump membranes in both pump halves:

1. Remove the five screws holding the top lid, see the left part of figure 6.2.
2. Remove the old gasket as shown in the right part of figure 6.2. Note the orientation of the holes, and make sure the new gasket ends up in the same position.

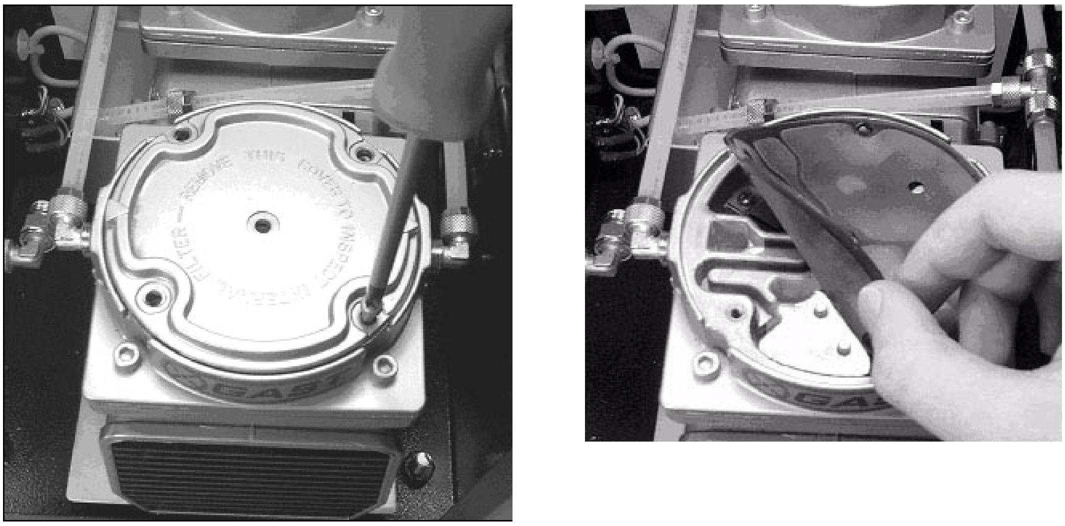


Figure 6.2. Replacing pump membranes, step 1 and 2.

3. The upper blade valve is kept in place by a valve restrictor, seen to the left in the upper pump chamber in figure 6.3. Remove restrictor and the blade valve.
4. The cylinder head can now be removed as illustrated in figure 6.3. Use an Allen key size 3/16” for the screws. In order to access the lower side of the head, the air inlet and outlet may have to be disconnected.

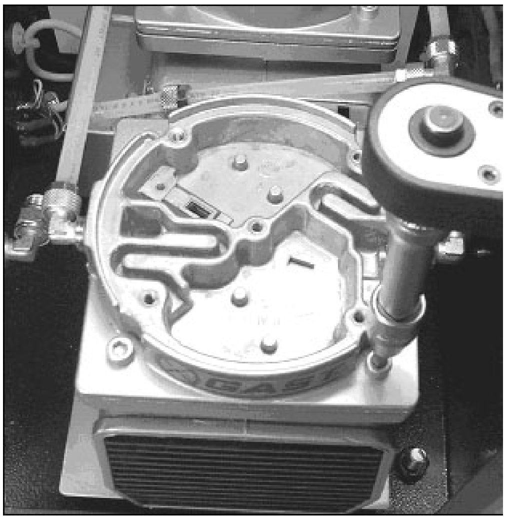


Figure 6.3. Replacing pump membranes, step 3 and 4.

5. The left part of figure 6.4 shows the cylinder head turned upside down, revealing the lower blade valve. Remove this. Note the four shims below the cylinder head, indicated in the right part of figure 6.4. The shims may be of different thickness, so it is important to keep each of the shims in its original place.

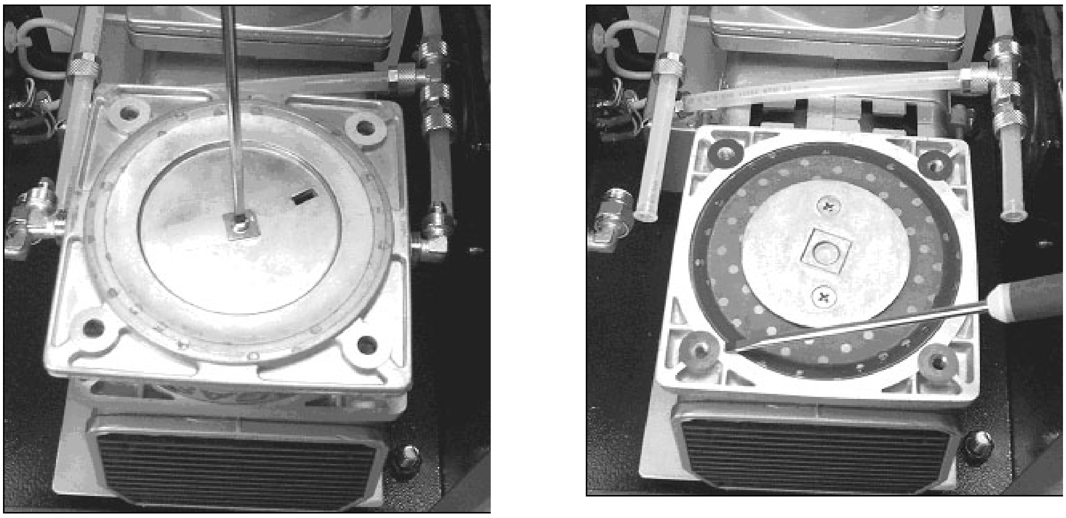


Figure 6.4. Replacing pump membranes, step 5.

6. Remove the lower membrane holder as illustrated in figure 6.5.

7. The pump can now be assembled again in the reverse order, using the new items included in the membrane kit. Make sure to tighten all screws firmly. Use loctite 243. The kit included parts for both pump halves.

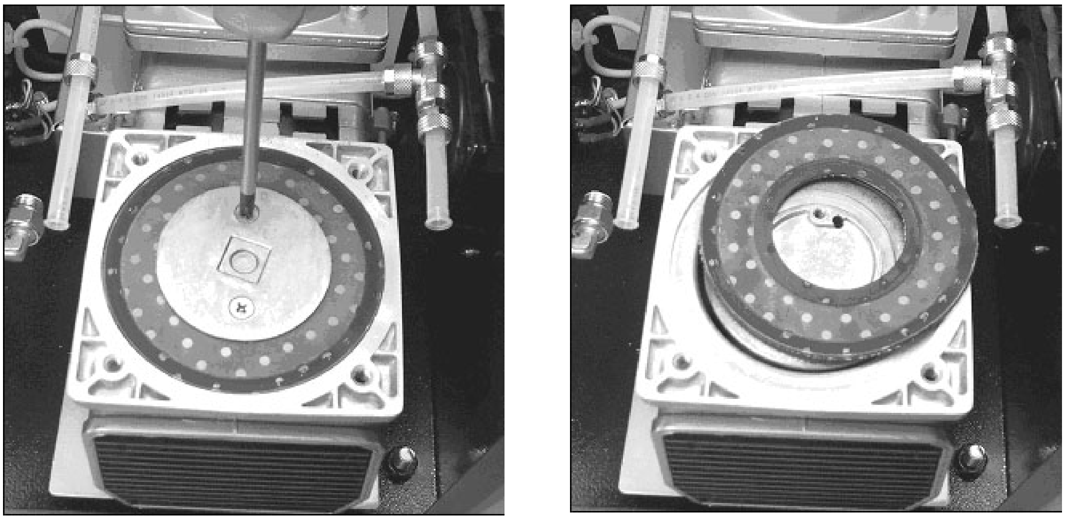


Figure 6.5. Replacing pump membranes, step 6 and 7.

The pump is now ready to be used again. Make sure to run a pneumatic test to ensure that all connectors are air tight, see section 6.6.

6.9 List of consumables

The table below shows the consumables required for normal operation of the pump module during one year.

Consumables for 1 year operation, prod. no. M300500	Product no.
Membranes for pump, 1 set alt. 2 pcs.	M000511
Rubber membranes and valves for pump, 2 sets	A0973070
Humidity filter, 2 pcs.	M300510

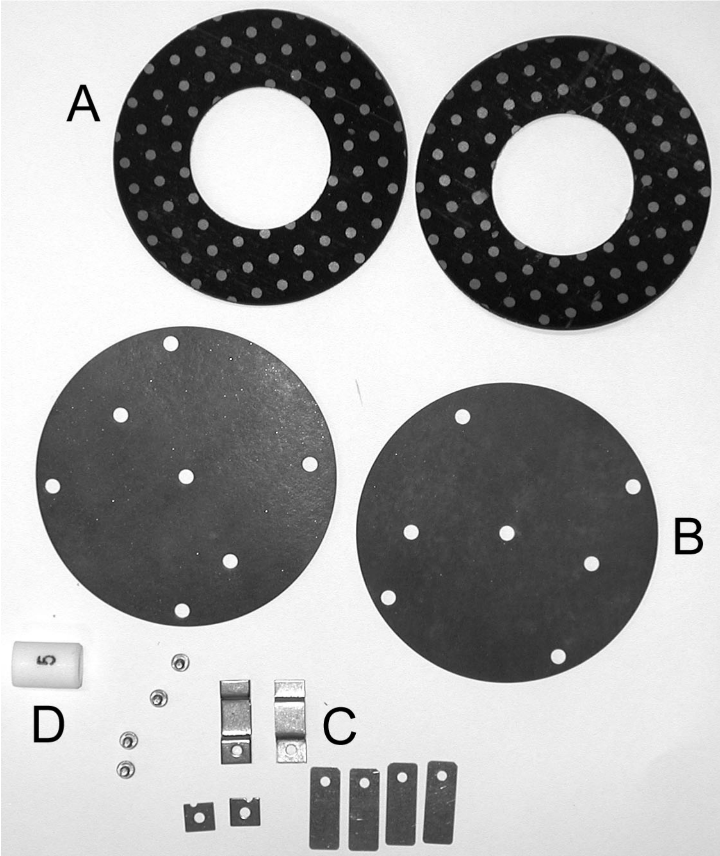


Figure 6.6. The consumables for six months. A: Membranes for pump, B: Rubber membranes, C: Valves, D: Humidity filter.

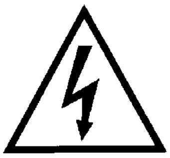
The rate of pump membrane and humidity trap filter replacement may vary depending on operating conditions.

Troubleshooting 7

The SM200 system has been designed to minimise operational problems, and it has been thoroughly tested to confirm that it operates well under actual monitoring conditions. Also, a lot of effort has been spent on quality assurance routines, as described in section 3. Still, the instrument could fail for various reasons, due to internal or external factors. This section contains a guide on how to locate and correct problems with the instrument.

7.1 Restrictions and warnings

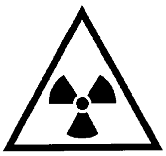
The SM200 series instruments are complex technical systems. Do not attempt to service or repair the instrument to any further extent than described in this manual. Leave this to trained and qualified service personnel.



***Warning**: High voltage is present inside the instrument when plugged in to mains. Switch off power and unplug the mains cord before removing the cover from the instrument or the pump.*

***Warning**: Only run the instrument on mains supply as specified. Failure to do so may result in damage to the instrument.*

***Warning**: Moving parts inside and outside the instrument. Do not touch the filter holders when the instrument is loading or unloading filters.*



***Warning**: A radioactive beta source is present inside the instrument if it bears this symbol. Do not under any circumstance attempt to disassemble the housing around the beta radiation source.*

7.2 Troubleshooting guide

Problem	Cause	Solution
The instrument does not start when switching on power.	Main supply failure.	Check that the instrument is connected to mains. Check the fuses. Replace if blown. Request service if the problem persists.
The instrument clock is not correct when power is switched on.	The built-in lithium battery may be unloaded or fails.	Request service if the problem persists after one day of operation while reloading the battery.
Instrument display shows corrupted messages.	Failure in instrument initialisation.	Restart the instrument by turning off and on the power. Ask for service if the problem persists.
The status indicator is red.	There is a problem with the movements of the filter mechanics.	Switch off power. Remove the filter containers and the instrument cover. Check that no filter or foreign object blocks the carousel. Restart the instrument. Request service if the problem persists.
Pneumatic test failure.	Error in the pneumatic system: head, air intake, tubes, pump and/or internal system.	Check if the pump is able to evacuate the system (section 5). If not, Check that air tube connectors are well tightened, and that no tubes are folded causing restrictions in the air flow. Check that there is no moisture in the air tubes. If there is, make sure to dry out the system well, and investigate the cause of the presence of the water. If the problem persists, request service.
Beta test failure.	Error in the beta system: beta source, Geiger tube or mechanical movement of filters and shields.	Check if the chamber has reached its operating temperature, >308 K (section 5). If not, wait for the instrument to heat up. Ask for service if this does not help.
Serial communication failure.	Broken cable or mismatch of communication speed.	Check that the settings of transfer speed match and that the port settings are correct. Check that the cable connection is working properly, using a line listener.
Problem with loading/unloading filters	Meachanical errors.	Test the loading/unloading meachanism manually from the Service menu, see section 5.7. Use the function checks Eject filters or Unload container.

Problem	Cause	Solution
The filter container status on the front panel is red.	The container is full (sampled filters) or empty (clean filters). The container is not in place, or it is not properly secured. The optical sensor does not recognise the container.	Make sure there are filters in the clean container and that the sampled container is not full. Make sure the container is properly inserted in its hole and that it is rotated counter-clockwise. A distinct click should be heard. Make sure that nothing is blocking the optical sensor (can be seen from above when the container is removed), and that the container locks are blank (sensor requires reflection against the surface).

7.3 Getting support

Contact your Opsis representative if you need support on your SM200. To facilitate the support, please be prepared to give the following information when asked:

- Instrument serial number. This is found on a label on the rear panel.
- Software version is displayed during start-up.
- Program settings (cycle time, alarm limits, etc.). See section 5.
- Latest system information. See section 5 and section A, Appendix. Make sure to write down the full system status code correctly.
- Latest results of the pneumatic and beta tests, see section 5.7.2 and section 5.7.3.
- Latest record data found in the buffer. Go through all pages and make notes of the readings. See section 5. Alternatively, download data through the serial port using appropriate software.
- Type of sampling head in use.
- Type of filter being used for sampling (material, porosity).
- Ambient air conditions (temperature, humidity, normal dust content).
- Operating conditions (location, system layout, shelter temperature and pressure).

Appendix A

This appendix contains detailed information about

- Buffer contents
- Pneumatic and beta system status codes

The information has been placed in this appendix since it is not likely that it is needed during regular operation of the instrument. However, in some cases, this information can be useful for instance for advanced troubleshooting.

A.1 Buffer information

The instrument buffer stores all measurement data together with important quality assurance parameters. The buffer can be accessed and read either from the menu system (see section 5), or by serial communication using suitable software in an external computer.

The pneumatic and beta activity are shown, followed by separate menus for more detailed information about the beta and pneumatic activity. The information in the Measure menu (actual measurement) and the Data menu (previous measurements) is as follows:

Name	Description	Format	Unit	QC	M/D
Pneu	Time left of the pneumatic cycle.	hh:mm:ss			
Geiger	The Geiger activity (Dark, Blank or Collect).				
Start	Date and time of the start of the cycle or check.	yyyy:mm:dd hh:mm			
Sample time	Duration of the sampling.	hh:mm			
Volume Std.	Total sampling volume.	x.xxxe+xx	Nm^3		
Volume Inlet	Total volume through inlet	x.xxxe+xx	m^3		
Initial P drop	Pressure drop across the filter at the start of sampling.	xxx.xxx	kPa	x	
Final P drop	Pressure drop across the filter at the end of sampling.	xxx.xxx	kPa	x	
Flow rate RSD	Relative standard deviation of the flow rate during sampling.	xx.x	%		
Flow temp	Temperature in flow regulator.	xx.xx	°C		
Ext. temp	Temperature at sampling head inlet.	xx.xx	°C	x	
Atm P	Atmosheric pressure.	xxx.xxx	kPa	x	
Filter humidity	Humidity at filter.	xx.xx	% rel.	x	
Filter T	Temperature at filter.	xx.xx	°C	x	
Valve pos	Flow regulator position.	xxxxx			
Pneumatic status	Pneumatic status, see section A.2.	xxxxx		x	
Dark	No. of beta counts from the background.	xxx	cpm		
Blank	No. of beta counts from the clean filter at the start of the sampling.	xxxxxxx	cpm		
Blank time	Blank measurement time.	xxx	minutes		M
Collect	No. of beta counts from the sampled filter at the end of the sampling.	xxxxxx	cpm		
Collect time	Collect measurement time.	xxx	minutes		M
Short	No. of counts related to short-life beta activity in the sample.	xxxxx	cpm		D
Long	No. of counts related to long-life beta activity in the sample.	xxxxx	cpm		D
Nat res.	No. of counts related to residual beta activity in the sample.	xxxxx	cpm		D
Natural [1]	Raw data for calculation of short/long life beta activity.	xxxxx	cpm		

Name	Description	Format	Unit	QC	M/D
Natural [2]	Raw data for calculation of short/long life beta activity.	xxxxx	cpm		
Natural [3]	Raw data for calculation of short/long life beta activity.	xxxxx	cpm		
Natural [4]	Raw data for calculation of short/long life beta activity.	xxxxx	cpm		
Natural [5]	Raw data for calculation of short/long life beta activity.	xxxxx	cpm		
Natural periods	The number of raw data periods.	x			M
Blank T	Avg. chamber temp. during blank meas.	xxx.x	K	x	
Blank P	Avg. chamber press. during blank meas.	xxx.x	kPa	x	
Blank hum	Avg. humidity during blank meas.	xx.xx	% rel.		
Blank HV	Geiger voltage during blank meas.	xxx.x	V	x	
Collect T	Avg. chamber temp. during collect phase.	xxx.x	K	x	
Collect P	Avg. chamber press. during collect phase.	xxx.x	kPa	x	
Collect hum	Avg. humidity during collect phase.	xx.xx	% rel.		
Collect HV	Geiger voltage during collect phase.	xxx.x	V	x	
Beta status	Beta status, see section A.2.	xxxxx		x	
Total mass	Total collected dust weight on the membrane.	xx.xx	mg		D
Mass error	Error in total mass.	x.xxx	mg		D
Mass conc.	Dust concentration.	xxxx.x	$\mu g/Nm^3$		D
Filter samples	The number of samples done with the filter.	x			D
Filter pos	The position of the filter (0 or 1).	x			D

The parameters marked “x” in the QC column are included in the quality checks of the running instrument.

Some parameters can only be viewed from the Measure menu. They are marked with a “M” in the M/D column. The parameters marked with a “D” can only be viewed from the Data menu.

A.2 Buffer status codes

The buffer (section A.1) contains status codes for the pneumatic and beta system. Each status code consists of a 16 bit decimal value. This value should be zero (0) if the instrument was operating normally during sampling and measurement of the corresponding filter. The status codes have the following meanings:

Pneumatic status:

Status code		Interpretation
0001	SpanUnderPressure	Rel. PDrop > 0.45 during span test
0002	FlowSpanError	Span result not within ± 3 %
0004	FlowLeak	Pressure drop > 100 Pa during leak test
0008	LeakUnderPressure	Rel. PDrop > 30 kPa during leak test
0010	RegulatorMin	Flow regulator on lower dead-end
0020	RegulatorMax	Flow regulator on upper dead-end
0040	FlowMin	Flow rate < ee.MinFlow
0080	FlowPressureDrop	Flow pressure drop < 100 Pa
0100	FilterPressureDropMin	Filter pressure drop < ee.MinDrop
0200	FilterPressureDropMax	Filter pressure drop > 70 kPa
0400	FlowPressureDropOffset	Flow pressure drop offset > 250 Pa
0800	ExtTemperature	Ext temperature not connected
1000	AtmPressure	Atm pressure not connected
2000	FlowTemperature	Flow temperature not within ±10 degrees of GM temp

Beta status:

Status code		Interpretation
0001	GeigerDarkRange	Dark count < 10 or > 150
0002	GeigerTemperature	Temperature < 308K
0004	GeigerNoCount	Internal temperature: 1 = <308 K
0008	GeigerStability	Geiger stability more than 4 times theoretical value
0010	Aperture	Aperture relation not within ± 5 %
0020	GeigerHV	Voltage not within 604 ± 1 V
0040	Cards	All cards not ok
0080	BetaMeasurements	Beta measurements not done
0100	LoadError	Loading of filter failed
0200	MeasAborted	Measurement aborted
0400	CarouselPosError	Position could not be set
0800	CarouselLocking	Carousel could not be locked
1000	CarouselUnlock	Carousel could not be unlocked
2000	BetaShieldOpen	Beta shield does not open
4000	BetaShieldClose	Beta shield does not close
8000	LoadUnload	Filter load/unload failed

The current status of most of these parameters can be read from the system information.