OPERATING INSTRUCTIONS

GRAVIMAT SHC502
Gravimetric Dust Concentration Measuring System

Description
Installation
Operation

SICK
Sensor Intelligence.

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Notes on these instructions

These Operating Instructions contain basic information on safety, system features, planning, installation, commissioning and regular servicing of the device components. Short descriptions on the measuring procedures as well as the function of the complete system and its important parts are provided. They act as a support for the level of knowledge that is requir-ed for accurate installation and servicing of the measuring device. The comparison of characteristic features in the system varieties available should be facilitated during the planning phase, when deciding on the opti-mum configuration to suit the given conditions.

The content of the Operating Instructions does not constitute a part of any legal relationship. All obligations of SICK AG arise from the purchase contract concerned, which also contains the complete and solely applicable warranty provisions.

These Operating Instructions contain only the information required for a standard application and associated installation and relate to the technical data explained in the Appendix. For special applications, the SICK subsidiary will provide you with the necessary support. It is advisable to seek recommendation from SICK specialists in every case of application.

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Introduction

1.1 Safety symbols

The following symbols are used throughout these Operating instructions to indicate sections of text containing safety instructions which must be observed or other especially important information.

Danger
indicates possible damage to people, particularly from electrical equipment.

Danger
indicates possible hazards to people if the system components are not handled correctly.

Warning
indicates a danger to system components or possible functional restrictions.

Note
indicates important additional information on the system or its components.

1.2 Conditions of use

1.2.1 Use

It is assumed that installation planning, mounting, installation, commissioning, servicing and maintenance work will only be carried out by adequately trained staff. The measuring system may only be operated in the manner intended by the manufacturer.

The responsible qualified staff shall in particular ensure that:

- all system components are used only for their intended purpose,
- the application corresponds to the technical data and the information on possible use, as well as the installation, connection, environmental and operating conditions (to be obtained from the order documents, the device summary data, the type plates and delivery documents),
- the general mounting and safety instructions are observed,
- work is carried out in accordance with the local, plant-specific factors, taking into account hazards and rules due to operational factors,
- tools, and lifting or conveying equipment are correctly used,
- system components supplied with no protective system are fitted with protective devices by the operator,
- there is sufficient safety equipment and personal protective clothing and that this is used by staff.

1.2.2 Instructions for system safeguard

The GRAVIMAT SHC 502 is a sophisticated electronic measuring system which requires careful handling during all work, transportation and storage:

- Dry the gas path and extraction pump after the completion of each measurement!
- Never store the unit unprotected in the open!
- Transport and store only in the original packaging.
- Store in a dry place
- Never leave cable ends or plugs unprotected. Always insulate cable ends. When not in use, cable plugs must always be protected against moisture and dirt with protective covers or suitable packaging material. Corroded connectors lead to malfunctions!

1.3 Authorized users

It is essential that those responsible for safety ensure that:

- installation planning, assembly, installation, commissioning, servicing and maintenance work are carried out only by trained experts or qualified people and that this is checked by qualified senior staff. Qualified experts are people conforming to DIN VDE 0105, IEC364 or directly comparable standards. Qualified people have been authorized by those responsible for personnel and equipment safety, to undertake this work on the basis of their education, experience or training, and their knowledge of the relevant standards, instructions, accident prevention regulations and plant conditions. The most important factor is that such people should be able to recognize and avoid potential hazards promptly.
  Knowledge of First Aid and of local rescue equipment is required and assumed.
- the above-named people have accurate knowledge of operational hazards, for example, the risks due to hot, toxic or pressurized gases, liquid-gas compounds or other media.
- for work on power stations the ban on employment of unqualified persons (governed by DIN VDE 0105 or IEC 364) is observed.
- work on or in close proximity to hazardous system components by unqualified persons is forbidden.

1.4 Safety precautions, protective measures

1.4.1 Danger from items of electrical equipment

The GRAVIMAT SHC 502 is designed for use in industrial power stations. During installation, commissioning, operation and maintenance work, it is possible for;

- open or uninsulated components to be live at fatally high voltages,
- physical or material damage to be caused by unauthorized removal of the necessary covers, incorrect operation or insufficient servicing of the measuring system.

1.4.2 Preventative measures for safe operation

The operator must ensure that any malfunctions, shut down of the Gravimat SHC 502 or faulty measurements do not lead to dangerous or damage-causing operating conditions.

In order to prevent device malfunction, it is necessary that the prescribed servicing and inspection work is carried out regularly by qualified and experienced staff.

1.4.3 Detecting malfunctions

Any variation from standard operation is an indication of functional restriction and must be taken seriously. This includes, among other things:

- the response of the monitoring devices,
- excessive drifting of the measuring results,
- increased power consumption,
- higher temperatures in system components,
- unusually excessive vibrations,
- abnormal operating noises,
- the development of odours or smoke.

1.4.4 Avoiding consequential damage in the event of device malfunction

In order to avoid personal injury or material damage caused by malfunction or breakdown of the GRAVIMAT SHC 502, the operator must ensure that:

- the servicing personnel are trained to recognise and react correctly to faults in the device and any associated operational malfunctions,
- any necessary or accidental switching off of the GRAVIMAT SHC 502 does not lead to serious consequential damage.

1.5 Environmental information and instructions for disposal

The GRAVIMAT SHC 502 modules are easily disassembled and except for a few components of the printed electronic circuit boards, contain no toxic or environmentally hazardous materials. The principle materials are steel, stainless steel, synthetics, aluminium and wood, which consequently pose no difficulties for future disposal.

The printed circuit boards must be disposed of as hazardous waste or electronic scrap.

2.1 Application range, use of the device

The GRAVIMAT SHC 502 is a mobile measuring system for the gravimetric determination of the dust load of flowing gases in ducts. Dust-laden gas is extracted isokinetically (at the same speed) by the GS 5 filter head probe (internal filter probe). The dust is retained by a dust collector with a plane filter and subsequently weighed.

Fig. 2101 GRAVIMAT SHC 502

Gravimetric measurements to determine the dust load are necessary in the following situations:

- to check the dust emissions and compliance with limit values laid down by environmental legislation
- to check the function of dust-removing equipment
- for the verification of the operation of dust separators
- for the evaluation of emission patterns (e.g. with changes in patterns, increases in capacity, etc.)
- to check process parameters
- for the calibration of dust measuring devices in continual operation

2.2 Measuring principle

Using the gravimetric method the dust content is basically determined by means of:

- a timed extraction of a partial gas volume
- measurement of the extracted partial gas volume
- separation and subsequent weighing of the dust contained therein.

Isokinetic sampling

To avoid measurement errors the partial volume flow must be extracted isokinetically, i.e. at the same velocity as the main volume flow. In this way the occurence of sedimentation is avoided and the gas will contain the precise representative amount of dust at the measuring site.
For isokinetic extraction the velocity of the main volume flow is measured. The extracted partial volume flow is controlled in such a way, that the entry velocity in the extraction intake of the dust collector is the same as the velocity of the main volume flow.

Dust collection

All dust particles in the extracted partial volume flow are retained in the dust collector filter. The mass of the dust discharged is determined by the difference in the weight of the filter before and after the measurement.
The factors crucial to the measuring precision and the smallest measuring range of dust concentration connected therewith are:

- the correct configuration of the extraction and dust-retaining systems
- the correct preparation and subsequent handling of the measuring filter
- the resolution of the precision scales used

.
The GRAVIMAT SHC 502 uses an optimized retaining system (LC dust collector, see section 2.4.4) for the measurement of the smallest dust content, which is weighed complete with the extraction tube, filter and sampled dust. In this way unregulated dust loss when removing the measuring filter from the probe or measuring errors due to unrecordable dust deposits in the extraction tube are completely erradicated. Thanks to this solution, as well as the low weight of the LC dust collector, the smallest dust concentrations can be accurately and reliably detected with the GRAVIMAT 502.

Point measurement

With a point measurement in a dust-laden gas stream the dust concentration in g (dust) / m³ (gas) is determined at the respective measuring site.

Network measurement

Network measurements are necessary to get the representative concentration mean value across the duct cross-section. The duct cross-section is divided into various axes with several measuring points per axis. Through a dust collector probe across all the network points the mean value is determined (see VDI 2066 Sheet 1).

When distributing a sample to several dust collectors, the dust collectors must have identical extraction orifices at all network points to ensure precise extraction.
In the same way it is possible to analyse a network measurement in individual measurements, completely independent of one another.

Information on dividing up the duct cross-section and arranging the measuring points are contained in VDI 2066 Sheet 1.

2.3 Definitions of the measuring method (conformity)

The most important definitions of the measurement of stationary particle emissions are contained in the following directives:

VDI 2066 Sheet 1	(Basic principles)
VDI 2066 Sheet 3	(40 m^3/h - Filter head device)
VDI 2066 Sheet 5	(Grain size determination by means of an impactor)
VDI 2066 Sheet 7	(1 m^3/h- Plane filter head device)
ISO 9096	(corresponding international standard)
CENprEN 264	(Draft for European norm)
VDI 2066 Sheet 8	(Soot spot measurement)

For the calibration of automatic emission measuring equipment, e.g. dust measuring devices, additional regulations can be found in VDI 3950 Sheet 1.

Information on measurement planning, on the selection of representative measuring points in the measuring network, on the installation location and on the evaluation of the measurement are contained in VDI 2066 Sheet 1.

2.4 System components

2.4.1 Overview

The standard design GRAVIMAT SHC 502 (see Fig. 2301) consists of the following components:

- ▶ GS5 Filter head probe with multichannel hose
- ▶ Specially designed case with a set of dust collectors
  - Version with LC dust collector for low dust contents
  - Version with HC dust collector for high dust contents
- ▶ SHC-AE502 Evaluation unit
- ▶ Mounting components (installation support, probe bracket).

see section 8.1

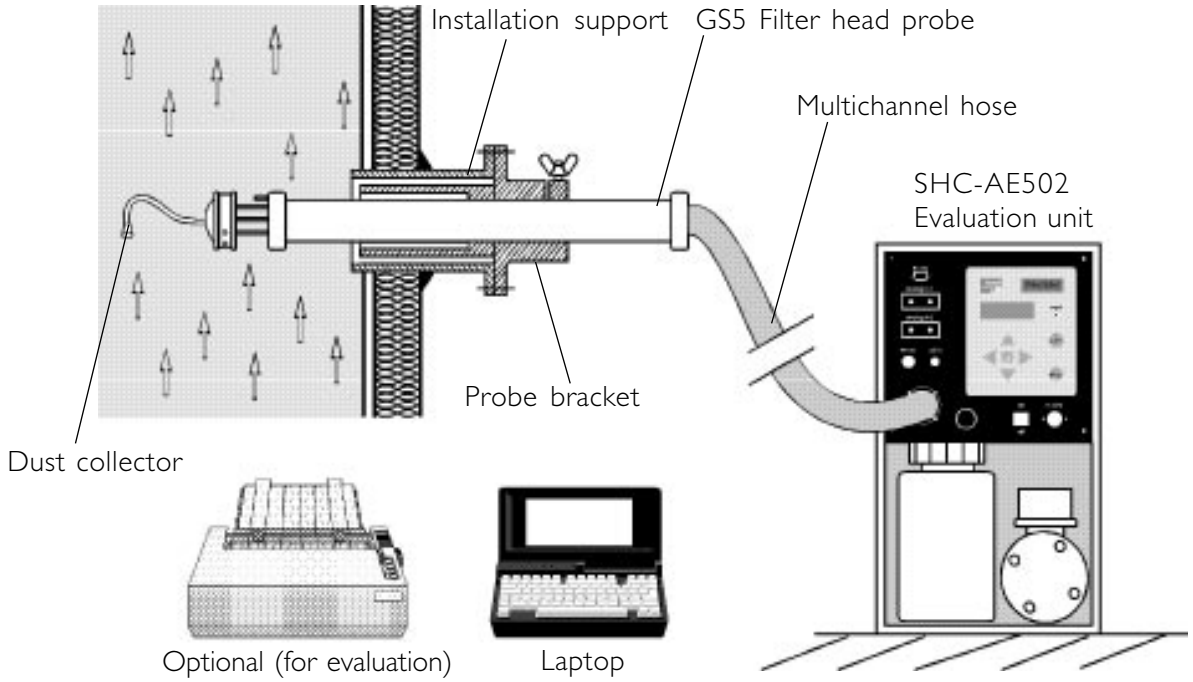


Fig. 2401 GRAVIMAT SHC 502 System overview

The GS 5 Filter head probe fitted with a dust collector is inserted into the duct. The dust collector picks up the extracted particles. Alongside the dust collector, the probe head also contains the measuring orifice for the gas velocity v and partial volume flow Q as well as the measuring sensor for the gas temperature T in the duct.

The filter head probe is connected to the evaluation unit via a multichannel hose with a connector.

The evaluation unit controls the isokinetic extraction and the registration of the measured values. The functional units necessary for this (see section 2.4.4) are housed in a robust flight case.
The input of measuring parameters and selection of the measuring program can be done by means of the SMP502 operator program via PC (Laptop) or via the operating keys on the front panel.

Note
The use of all functions is only possible with the SMP502 program.

2.4.2 GS 5 Filter head probe

The filter head probe consists of the following components:

- Probe head with integrated pick-up for the dust collector, with pressure measuring point for determining the gas velocity in the duct and the partial volume flow and with a Pt 100 temperature sensor for the precise measurement of the exhaust gas temperature at the extraction site
- Stainless steel probe shaft
- Multichannel hose with extraction conduit, pressure measuring conduit for transmission of the pressure signal to the pressure sensor in the evaluation unit and integrated temperature measuring conduit.

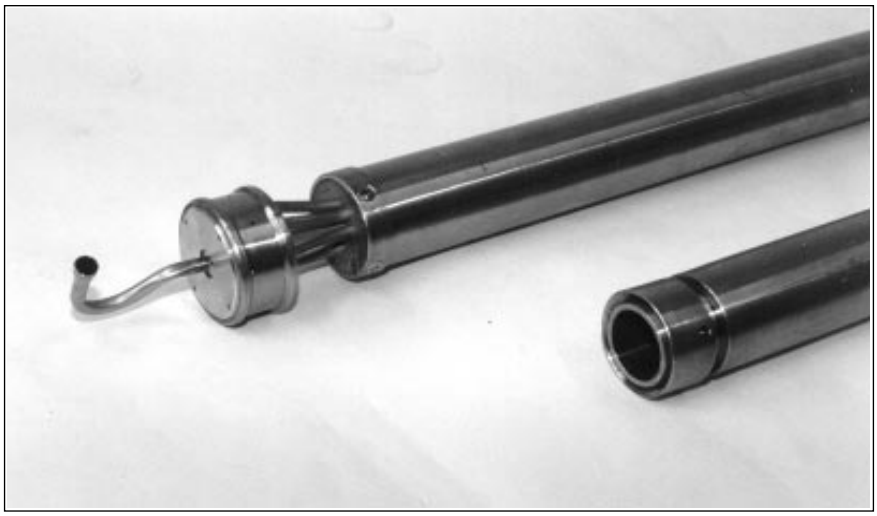
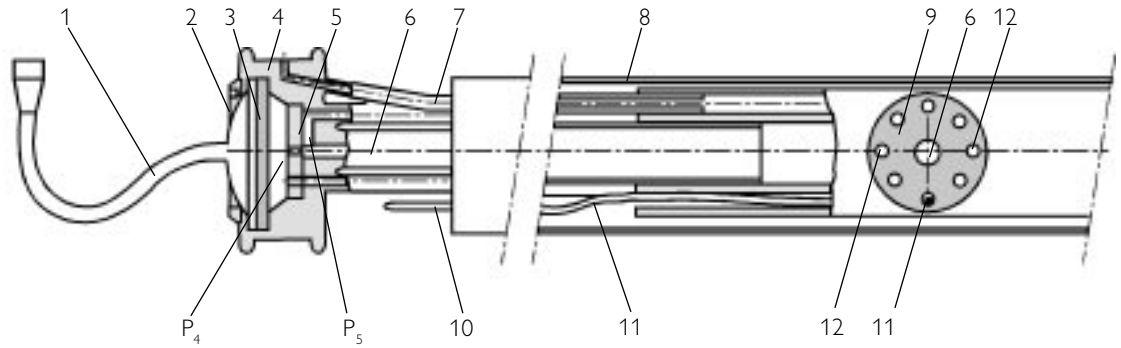


Fig. 2402 Filter head probe with extension

The principle design of the GS 5 Filter head probe is shown in Fig. 2403.



1 Dust collector
2 Screw plug
3 Support ring
4 Filter housing
5 Measuring aperture
6 Extraction conduit
7 Pressure measuring conduit
8 Probe shaft
9 Multichannel hose
10 Temperature sensor
11 Temperature measuring conduit
12 Purge air duct

Fig. 2403 GS 5 Filter head probe

For a description of the dust collector see section 2.4.4; For assembly see section 3.3.2

2.4.2.1 Probe head

The assembled dust collector (1) is inserted into the filter housing (4). A ring-shaped screw plug (2) presses the edge of the collector evenly over the filter membrane and the seam of a sealing washer. The filter membrane then lies on a support ring (3) which prevents it being destroyed by the pressure load. The support ring with a sealing washer can be used with gas temperatures up to 250 °C. For higher gas temperatures (up to 400 °C or up to 600 °C with the HT version) a support ring should be used without a sealing washer (see Chap. 8). When using the support ring without a sealing washer an additional error up to a maximum of 3% should be expected in the measurement of the partial volume flow.
Behind the support ring a measuring aperture (5) with the measuring points p_4 und p_5 is provided for measuring the drop in pressure across the aperture as a basis for the determination of the partial volume flow.

As well as the pick-up for the dust collector the probe head also simultaneously functions as a dynamic pressure sensor. For this the pressure measurement bore holes p_1, p_2, und p_3 on the cylindrical outer surface of the filter housing are provided for the analysis of the flow velocity in the duct and for the determination of the angle of flow in relation to the probe.
The sampling orifice on the dust collector is aligned parallel to the overall pressure bore hole (p_1) when mounting the collector (notch on the edge of the filter housing).

For measuring the gas temperature a Pt 100 temperature measuring sensor (10) is provided.
The probe head with the extended extraction conduit (6) and the five pressure measuring conduits (7) is secured to the probe shaft (8). The conduits (6, 7) and the temperature measuring conduit (11) flow into a multichannel hose (9) in the probe shaft.

With the installed measured value sensor, the filter head probe delivers all measuring signals necessary for controlling and adjusting the isokinetic sampling and for recording the extracted partial volume

2.4.2.2 Probe shaft

The stainless steel probe shaft (8) has a length of 1 m as standard. Other lengths are optionally available (see section 8.3). For larger penetration depths probe extensions can be screwed on.
There is a handgrip on the end of the probe shaft to make it easier to hold. A support spring prevents the multichannel hose becoming buckled.
A marking on the handgrip indicates the position of the extraction orifice in the duct (when assembling the probe check for agreement!).

see Chap. 8

see section 3.5

2.4.2.3 Multichannel hose

The multichannel hose carries the partial volume flow and the pressure and temperature measurement signals from the filter head probe to the evaluation unit.
The connection to the evaluation unit is via a connector, which ensures the correct coordination of the respective pressure measurement signals to the associated pressure sensors in the evaluation unit.
As standard the multichannel hose has a length of 5 m. A hose extension can be optionally connected.
For higher gas temperatures (comp. section 8.1) there are two spare channels in the multichannel hose for cooling air. The cooling air emerges in the probe shaft.

For data on cooling air see Chap. 8

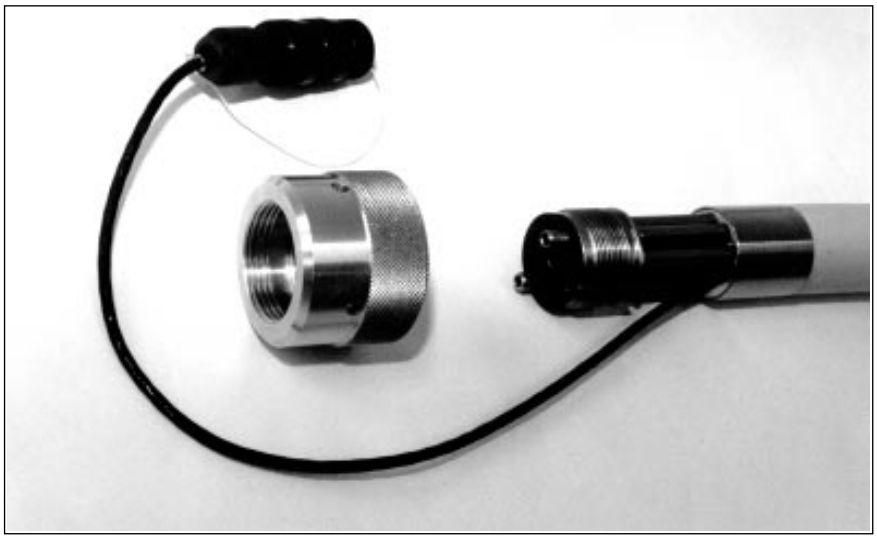


Fig. 2404 Multichannel hose with connector and plug for temperature sensor

2.4.3 Probe bracket

For the insertion of the filter head probe in the exhaust gas duct, a probe bracket and a corresponding installation support with the associated dummy plug are provided.
The cast-aluminium bracket guarantees a safe and simple guiding and fixing of the filterhead probe. The protection tube on the bracket prevents damage to the collector when mounting and maintaining the probe. The bayonet type connection makes it possible to mount the probe bracket quickly to a suitable installation support.
For existing installation supports at the plant the appropriate adapter supports can be supplied.

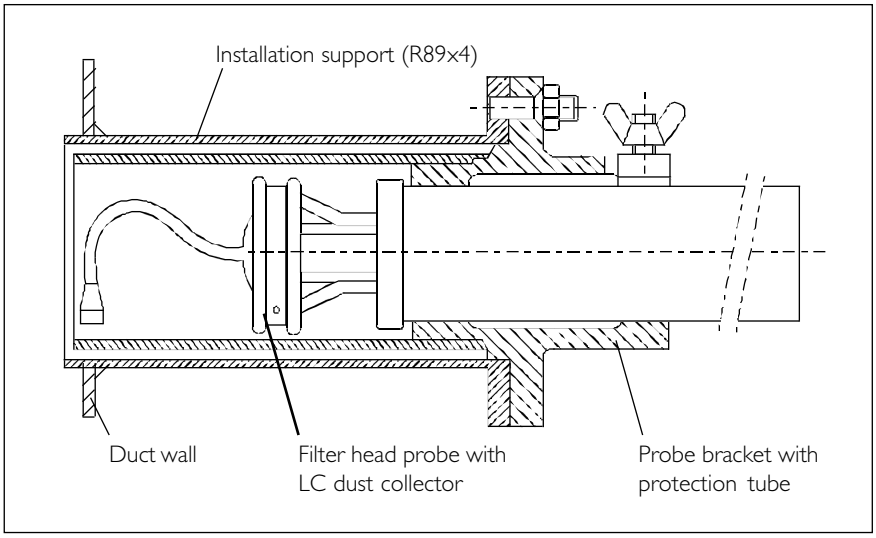


Fig. 2405 Filter head probe bracket before the start of a measurement

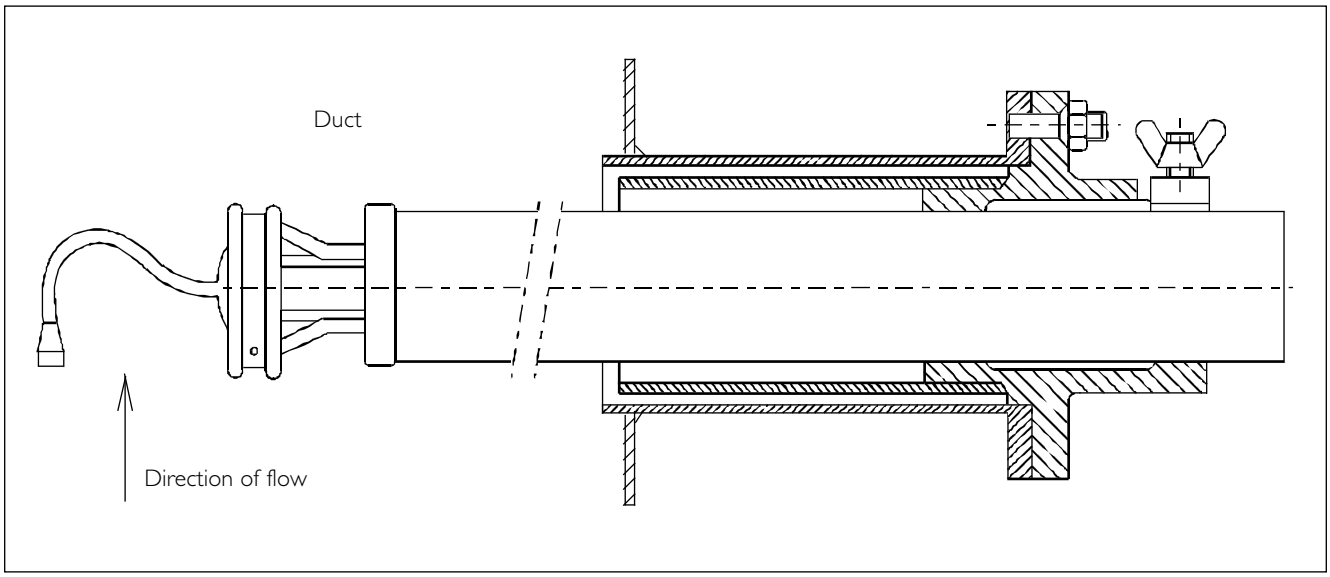
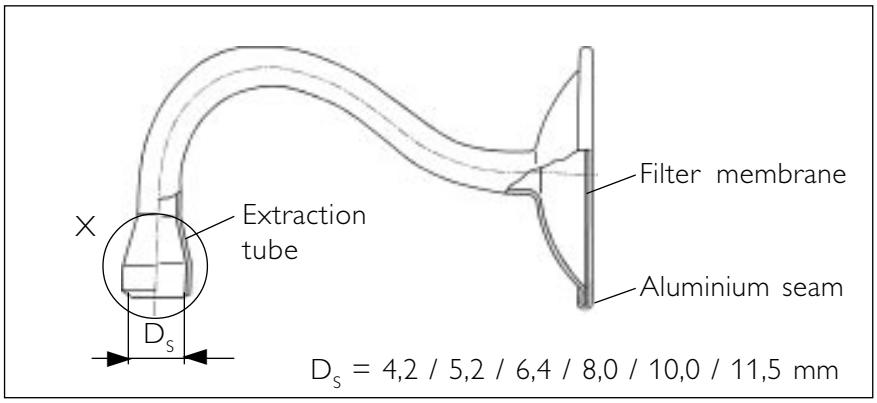


Fig. 2406 Filter head probe in measuring position

2.4.4 Dust collectors

2.4.4.1 LC dust collector

The LC (low concentration) dust collector is used to determine low to moderate dust contents (see section 8.1). The collector consists of a curved extraction tube and a convex filter plate.
On the flat edge of the filter plate the filter membrane is secured with a seam made from a ring of aluminium foil (see section 3.3.2).
For the adaptation of the sampling conduit of the complete measuring system to the flow velocity in the duct as a condition for isokinetic extraction, the collectors have different extraction diameters D_S.



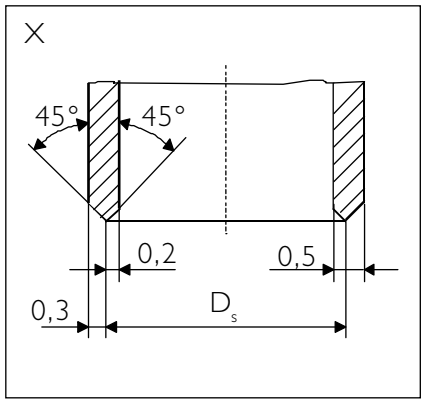


Fig. 2407 LC dust collector

As standard equipment 24 LC dust collectors plus the seaming equipment and a packet of aluminium foil rings are housed in a specially designed carrying case (see Fig. 2408). Each collector is marked with the sampling diameter Ds and a continuous registration number for the respective diameter.

Fig. 2408 Specially designed case with a set of LC dust collectors

Note
With the core plug a cavity can be made in the quartz padding, so that there is a better distribution of dust through the filter material and therefore an increase in the pick-up capacity.

2.4.4.2 HC dust collector

The HC (high concentration) dust collector makes it possible to determine moderate to high dust contents (see section 8.1). It consists of an aluminium cone with a substantially larger volume when compared to the LC collector and exchangeable extraction tubes with graduated orifice diameters. As with the LC collector, these extraction tubes it make possible to adapt the partial flow extraction to the main flow velocity in the duct.

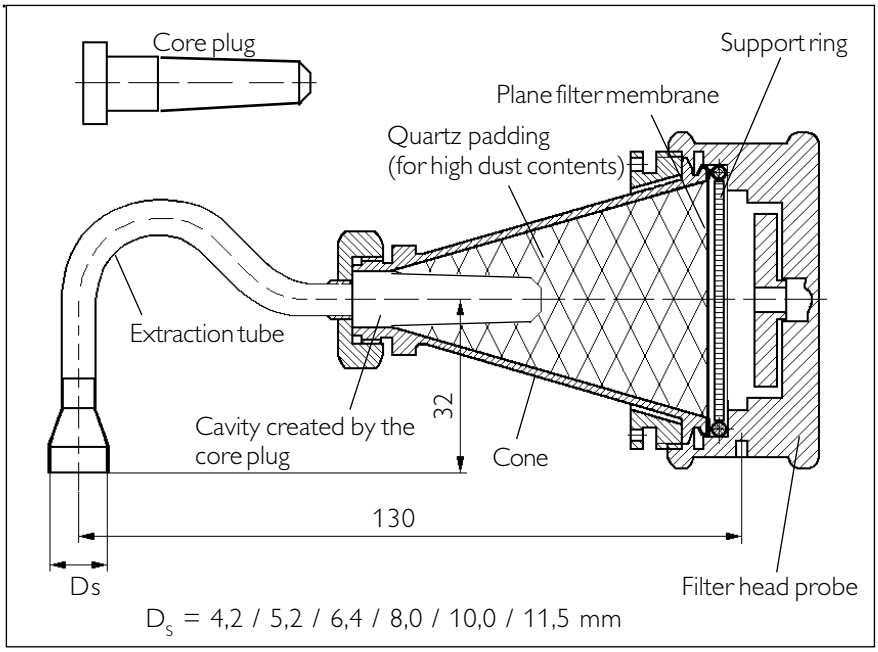


Fig. 2409 HC dust collector

Like the LC collector, the HC collector is equipped with a plane filter membrane with D=50 mm. The plane filter membrane is secured to the collector with a folded ring of aluminium foil.
In comparison to the LC collector, the HC collector provides a substantially higher capacity for the pick-up of dust with a filling of padding (ca. 10 times; max. 20 g, depending on the type of dust), without raising the filter resistance of the plane filter too much. According to the chosen extraction time and the extracted partial flow volume, dust concentrations up to 50 g/m³ are therefore measurable (depending on the type of dust).

The HC dust collector can also be used to determine lower dust concentrations (with or without padding). As a consequence of the higher empty weight (without extraction tube approx. 25 g, with extraction tube approx. 47 g) the achievable measuring accuracy is admittedly very dependent on the handling during weighing. Factors here include:

- accuracy of the available precision scales when weighing the whole collector
- possible dust loss if the filter membrane (and padding) is weighed separately and through dust deposits sticking in the extraction tube and cone if applicable.

As standard equipment 4 cones, 1 set of extraction tubes, 1 core plug, as well as screw plugs, seaming equipment and a packet of aluminium foil rings are housed in a specially designed carrying case.

Fig. 2410 Specially designed case with a set of HC dust collectors

2.4.4.3 Soot collector

By inserting a soot collector in accordance with VDI 2066 Sheet 8 in the filter head probe, the GRAVIMAT SHC 502 can be used for a soot spot measurement conforming to legislation.
The soot collector consists of the cone (as with the HC collector) and a special inlet nozzle, which is screwed onto the cone in place of the extraction tube. The inlet nozzle makes it possible to have a constant steady flow to the filter membrane. The angle of the cone is as specified in VDI 2066 Sh. 8.

For information on carrying out a soot spot measurement, see Section 4.2.6

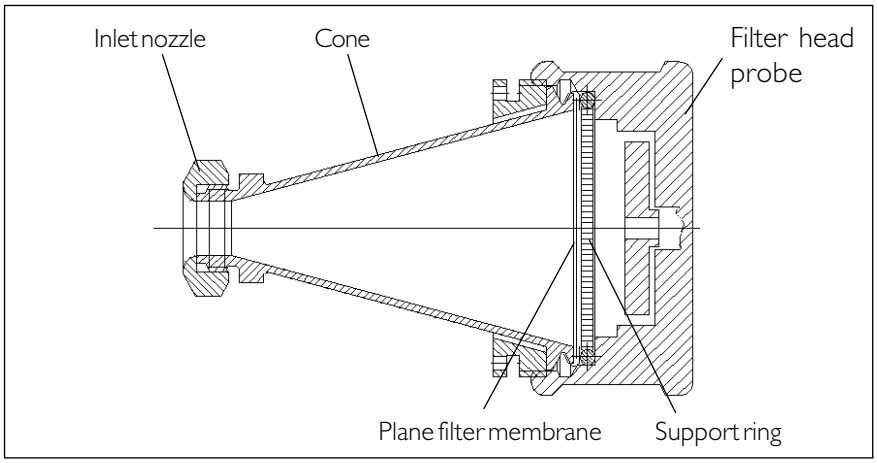


Fig. 2411 Soot collector

2.4.5 SHC-AE502 Evaluation unit

The evaluation unit contains all the components necessary for recording measured values, for automatic control of the isokinetic extraction and for operating the GRAVIMAT SHC 502. All parts are housed in a robust flightcase. The lid of the flightcase has space for accessories.
The evaluation unit consists of:

- electronic unit
- condensate separator
- control valve, stop valve
- extraction pump with sound-proofing

The flightcase is open during the measuring process. After the installation of the measuring device and the establishment of the necessary connections (see Chap. 3), the measuring program can be started (see Chap. 4). There are two possibilities for doing that:

Preferred method

- Parameter input, program selection and control of the measuring process via a PC (Laptop) and the SMP502 operating program (see section 4.2)
  With this method of operation the full range of functions is usable. The foil key on the front panel for preventing malfunctions is blocked (online-operation).
- Operation via the foil key on the front panel by use of the control program implemented in the evaluation unit
  In this case sone evaluation functions are not available. The log of measuring results can be read into a PC for further processing or a printer can be directly connected with a serial interface (offline-operation).

Fig. 2412 SHC-AE502 Evaluation unit

2.4.5.1 Electronic unit

The electronic unit consists of the following modules:

- front panel with
  - foil key for menu selection
  - illuminated LC-Display
  - analogue input (2x)
  - RS 232 interface
  - acoustic signal provider
- processor board with analogue input modules and 2 pressure sensors
- sensor panel with 4 pressure sensors
- power supply module for the processor board and valves with connection for the extraction pump and 2 fuses

Via the processor board it is possible to completely control the internal processes, consisting of valve control, keyed-in queries, activation of the LEDs as well as the measurement and processing of all analogue signals from the pressure sensors and the temperature sensor.

All device-internal alignment data and factory settings are saved in EEPROM.

An external PC (laptop) can be connected via an interface cable (accessory, see section 8.3) to the RS 232-interface on the front panel for operating the GRAVIMAT by means of the SMP502 operating program or by using a printer via the keypad with a serial interface for a measured value log. The analogue inputs are available for the connection of continually measuring dust measuring devices and/or a device for logging the standardization values (e.g. O_2 content or exhaust gas humidity).

The power supply comes from the mains connection. Adjustment to the local mains voltage (230 V AC oder 115 V AC) is carried out by exchanging the extraction pump (see section 3.5.4).

Note
In order to be able to put the GRAVIMAT into operation, the extraction pump of the device must be in contact (with a 7-pin plug).

2.4.5.2 Condensate separator

Exhaust gases from industrial plants have in general a high water vapour content. Due to the heat-loss along the partial gas conduit you get condensate deposits which can be very corrosive due to the absorption of gas components such as SO_2, SO_3, HCl etc. To protect the pump and the valves, the condensate formed is collected in the condensate separator.

2.4.5.3 Extraction pump

The pump is a sliding vane rotary pump with an asynchronous motor with auxiliary condensor. The pump housing is made of stainless steel. the rotor and rotary valve are made of graphite. The pump housing is considerably resistant to the effects of corrosive gases during operation .

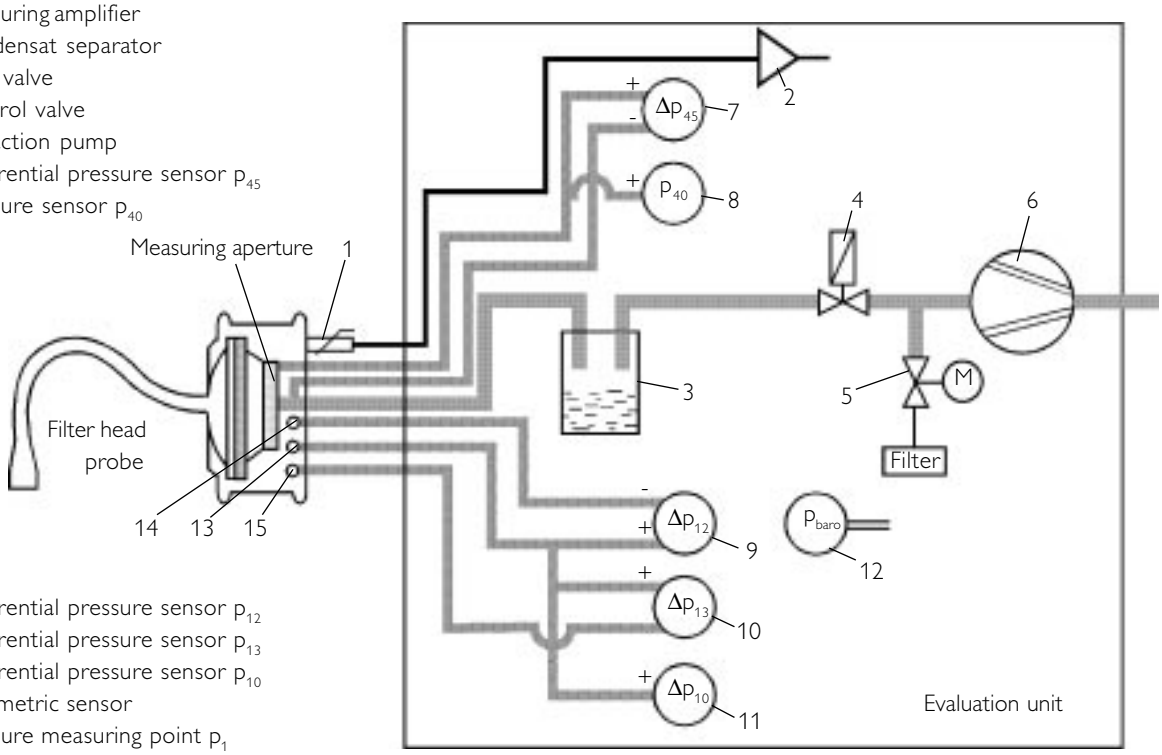
Warning
After the end of the measurement the extraction pump should be immediately cleaned of condensate residue with ambient air and dried, otherwise the life-span of the pump will be considerably shortened (condensate residues lead to corrosion).
The connection is made via a 7-pin connector which simultaneously guarantees the coordination of the available mains voltage.
The permitted mains supply is noted on the connection box of the suction pump (see section 3.5.4).

Warning
The extraction pump must be designed for the respective mains voltage! The necessary supply voltage should be stated at the time of ordering or in the technical questionnaire!

2.4.6 Basic functions of the GRAVIMAT SHC 502

The filter head probe and the evaluation unit are connected to one another via the multichannel hose. The connection of the filter head probe is made via a connector which guarantees an unchangeable coordination of the pressure measurement conduits to the respective sensors.

1 Pt 100 temperature sensor in 4 conductor circuit
2 Measuring amplifier
3 Condensat separator
4 Stop valve
5 Control valve
6 Extraction pump
7 Differential pressure sensor p_{45}
8 Pressure sensor p_{40}



9 Differential pressure sensor p_{12}
10 Differential pressure sensor p_{13}
11 Differential pressure sensor p_{10}
12 Barometric sensor
13 Pressure measuring point p_1
14 Pressure measuring point p_2
15 Pressure measuring point p_3

Fig. 2413 GRAVIMAT SHC 502 operating principle

The partial volume flow is channeled via the condensate separator (3) and the opened stop valve (4) on the extraction pump (6). The stop valve blocks the partial gas conduit before and after the extraction process in order to prevent disruptive backflows to the dust collector. Via the control valve (5) the partial volume flow is controlled by an artificial air supply so that extraction is isokinetic.

The extracted partial volume flow is determined by means of an aperture measurement. The differential pressure sensor p_{45} (7) (measuring range 0 to 25 mbar) measures the effective pressure of the aperture. Additionally the pressure p_{40} is measured in front of the pressure sensor (8) (measuring range +100 to -500 mbar) relative to the ambient pressure.

$P_{10} = P_1 - P_0 = P_1 - P_{Baro}$

The pressure p_{10} is measured by the differential pressure sensor p_{10} (11) (measuring range –70 to +70 mbar) relative to the surrounding pressure
With the barometric sensor (12) the surrounding air pressure is registered in the range from 770 to 1250 mbar.

For the calculation formula see Chap. 9

Via the pressure measuring points p_1 (13), p_2 (14) und p_3 (15) the differential pressures p_{12} und p_{13} are determined. With normal (symmetrical) streams both effective pressures are the same. they are different with diagonal streams. The quotient of these effective pressures provides the corresponding stream angle α in the range -22.5° to +22.5° with a standardized characteristic of the dynamic pressure transducer. From the sum of both effective pressures is determined by means of a second standardized characteristic curve (depending on α) of the dynamic pressure of the main volume flow.
From p_{10}, p_{12} and p_{13} the gas velocity in the duct and the angle of the stream are determined.

$P_{12} = P_1 - P_2$

$P_{13} = P_1 - P_3$

The Pt 100 temperature sensor (1) in the probe is connected to the evaluation unit via a 4 conductor circuit by means of a pin and socket connector. The connection cable between the Pt 100 and the pin and socket connector is provided in one channel of the multichannel hose.

2.4.7 Accessories and optional extras

For accessories see Chapter 8

SHC5-TU Flightcase
The SHC5-TU flightcase can be used to carry accessories. A laptop, printer, probe bracket, tools, spare parts, cable extensions and gloves can be housed inside it. The flightcase is not part of the standard scope of supply.

Precision balance
A precision balance is required for weighing the dust collector.
For weighing the LC dust collector a balance with a measuring range from 0 to 30 g in steps of 0.1 mg is recommended. For weighing the HC dust collector a balance with a measuring range ≥ 50 g is required.
A precision balance is not part of the standard scope of supply.

3.1 Planning the measuring point

Selecting a suitable installation site for gravimetric dust measurement requires accurate knowledge of the site. Smooth, uninterrupted flow patterns in the exhaust gas duct are prerequisite for representative measuring values, and in particular for official measuring requirements. These are most likely expected with long inlet and outlet sections.
In accordance with VDI 2066, Sheet 1:
The lengths of the inlet or outlet sections should amount to at least three times the "hydraulic diameter" (total length therefore at least 6 times the hydraulic diameter). With round and square duct cross-sections the hydraulic diameter and duct diameter are the same. Although these requirements can not always be met, the best possible site should be selected in existing plants.

Inlet and oulet sections

Hydraulic diameter

$$D=\frac{4A}{U}$$

A = Cross-sectional surface
U = Circumference

Further criteria for selecting as well as for determining nework point measurements are set out in VDI 2066, Sheet 1. In order to avoid planning errors the measuring location should be decided by experts (e.g. professional opinion of a suitable measuring point, according to §§ 26.28 BImSchG (German emissions legislation)).

Professional opinion of the measuring site

3.2 Preparations by the customer

The following conditions are required for carrying out gravimetric measurements with the GRAVIMAT SHC 501;

- measuring orifices in the exhaust gas duct with mounted installation supports (normally welded in), with an internal diameter > 62 mm,
- a sufficiently large and safe working platform with power supply and lighting should be provided if the measuring orifices are higher than 1.6 m above ground level.

For the number and alignment of measuring orifices see VDI 2066, Sheet 1.

The probe mount is secured to the installation support by means of a bayonet-type connection.
Should another installation support already be installed, the option of altering the probe mount by means of an adapter flange must be checked (see Fig. 3101 for connection dimensions).

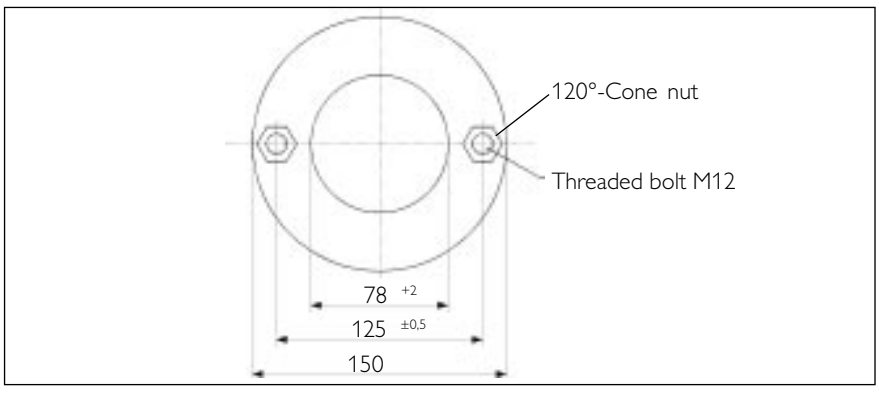


Fig. 3101 Adapter flange

3.3 Preparation of dust collectors

3.3.1 General

The respective dust collectors are to be selected, depending on the measuring task (determination of low or high dust contents or soot spot measurement). The collectors are to be prepared before each measurement. The following procedures are necessary:

- cleaning the dust collectors
- fitting of the collectors with the filter material
- drying the assembled dust collectors
- determining the empty mass of the collectors
- storage in desiccator

Warning

The preparation of the dust collectors requires the most meticulous care particularly for the detection of the smallest dust concentrations. The steps described below should only be regarded as foundation work.
A comprehensive description of the handling of dust samples can be found in the draft for the European norm CENprEN264.

Note for LC collectors:

Should the extraction diameter Ds of the LC collector to be used not be known before the measurement, then several collectors of different extraction diameters should be prepared (HC collectors are provided with the required extraction tube on site).

Cleaning

Clean the empty dust collectors (funnel and extraction tube or inlet nozzle for soot spot measurement with HC collectors) of dust and grease (i.e. in ultrasonic bath).

3.3.2 Fitting with filter material

3.3.2.1 LC dust collectors

Commercially available plane filter material with a diameter of 50 mm can be used as a filter diaphragm. The selection of filter material depends on the expected maximum temperature load and the necessary pore size. Capillary pore filter diaphragms are preferable for measurements of extremely low dust concentrations (less than 1 mg/m^3), or for higher accuracy requirements.
Alongside other advantages, these micro filters absorb only a very low amount of moisture (check maximum permitted temperature!).

The filter diaphragm is secured to the dust collector by means of a seam made of aluminium foil. The seam has to be shaped from a foil ring (Fig. 3301). The foil ring (1) is first concentrically clamped into the seaming device (2). Then the protuding edge is bent by sliding over the top part (3).

Then the bent seam (4) is laid in the recess of the component (5) together with the filter diaphragm (6) and the collector (7), as shown in Fig. 3302. The collector is then closed by bending the edge over using a rounded wooden or plastic spatula (8).

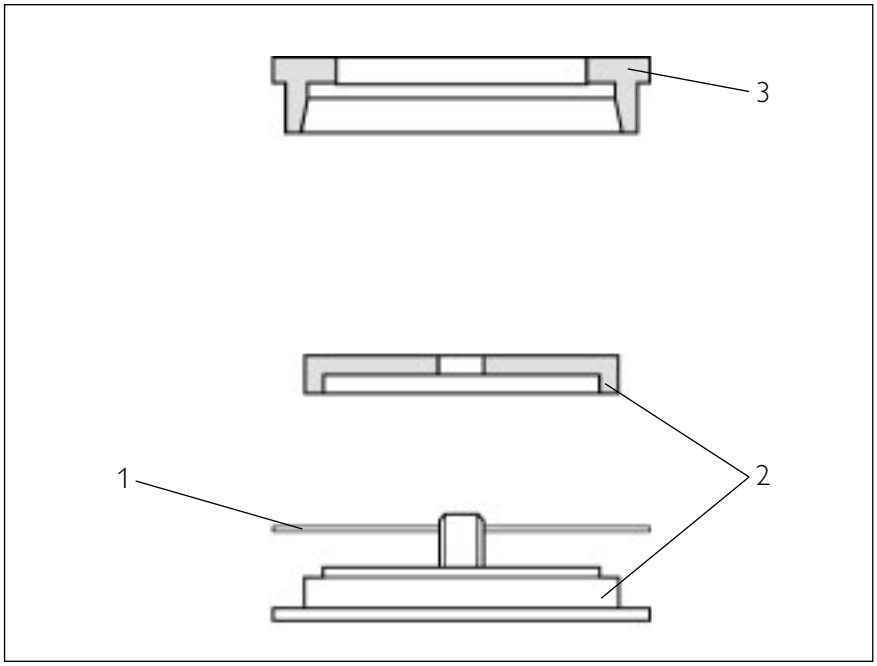


Fig. 3301 Making the seam

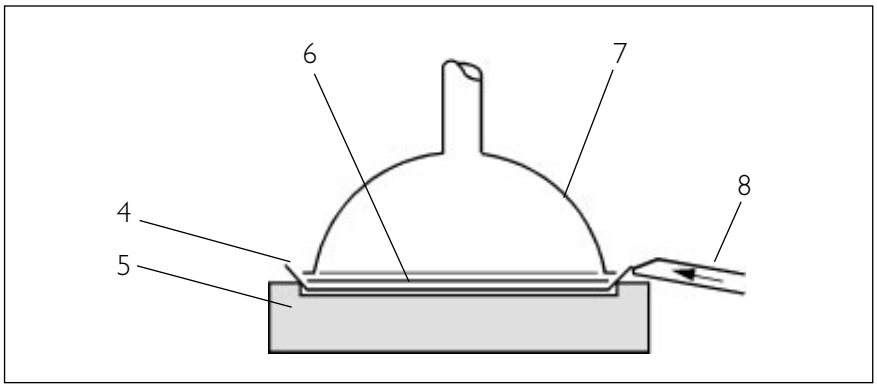


Fig. 3302 Securing the filter diaphragm

The thus prepared dust collectors are next dried in a warming cabinet, conditioned in a desiccator and then weighed (see section 3.3.3).

3.3.2.2 HC collectors

The preparation of HC collectors for dust concentrations > 50 g/m³ is carried out in accordance with VDI 2066 regulations, Sheet 3. The measuring filter here consists of an HC collector padded with quartz wadding and a filter plane tipped funnel. Quartz wadding is recommended as filter material, with an average fibre diameter of approx. 10 µm.

Assemble the filter material according to the following procedure:

- Core
  With the dummy plug in place, fill the funnel with approx. 3 g of quartz wadding. The filling should consist of linked balls of wadding. Pack and compress the quartz wadding as much as possible so that there arte no continuous channels.
- Sealing
  The plugged funnel is sealed as per section 3.3.2.1 with a plane filter diaphragm (diameter 50 mm) and an aluminium seam. The dummy plug is removed. The measuring filter is then complete.

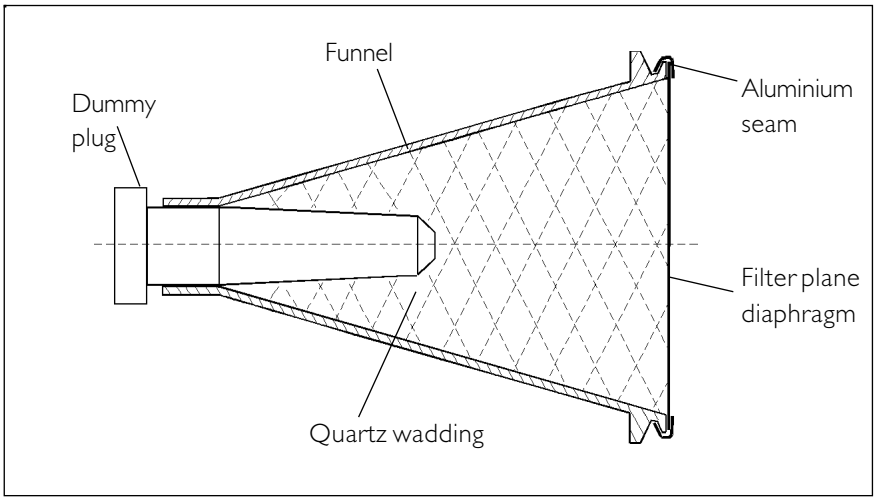


Fig. 3303 Preparing HC dust collector

3.3.3 Determining the empty mass of the prepared dust collectors

Drying

- ▶ Dry the prepared dust collectors in a drying oven for at least an hour. The drying temperature should be at least 20 K above the gas temperature at the measuring site.
- ▶ Then equilibrate the dust collectors for a period of at least 4 hours either in a desiccator or at least in an air-conditioned room. The collectors should be equilibrated in the same room, in which the weighing will take place.

Note for HC collectors:

If the necessary extraction diameter for the measuring process is known, the corresponding extraction tube can be screwed onto the measuring filter before drying and weighing it.

Weighing

The dust collectors are weighed individually immediately after being removed from the desiccator. In order to prevent false measurements, the measured value for each collector should be determined after the same period of time on the balance (e.g. always 10s after placing on the balance). Then the collectors are placed in the special carrying case.

Important

The balance must be set up in a vibration-free area (if necessary use a padded underlay).

Note

Particularly when determining small dust contents the zero point of the balance should be checked after each weighing. In such cases it is additionally meaningful to create a "norm" with a mass similar to the mass of the dust collectors, in order to detect possible drifting of the balance. This "balance norm" should be weighed after about every 4 weighings.

3 Preparation for measurement

3.4 Transporting

The measuring equipment is transported in the following units:

- Carrying case with probe and a max. of 2 extensions of 1.5 m
- Special carrying case with the prepared LC or HC dust collectors, seaming device, aluminium foil rings and plane filter material
- Evaluation unit in the flightcase
- Flightcase (optional) with probe mount, tools and other accessories.

Note

When transporting and storing the GS 5 filter head probe always insert the cap (see Fig. 3501) in the filter housing.

Fig 3401 Transport packaging for the GRAVIMAT SHC501 standard version

3.5 Installation of the measuring device

3.5.1 Installing the GS 5 filter head probe

The filter head probe should be taken out of the carry case at the measuring site. The probe bracket is pushed over the multichannel hose up to the probe head. Then the grip handle should also be pushed over the hose and screwed to the probe shaft. Place the temperature sensor on the connector in the notch when doing this!
When using two probe extensions (section 2.4.2.3) a hose extension (length 5 m approx. with cable for temperature sensor) should be used for safer handling (accessory, see Chap. 8).

The grip handle should be aligned in such a way that the marking on the filter head corresponds to the position of the pressure measuring site p_1. The direction of the whole pressure bore p_1 can be seen by inserting the face spanner in two 2 mm bores on the back of the filter head.

3.5.2 Inserting the dust collectors

The dust collectors prepared for the extraction process, or the cap (7) for the velocity/temperature measurement, should be inserted in the following way (see Fig. 3501):

- Loosen the screw plug (2) with the face spanner (1) and take it out; take out the cap (7).
- Mount the dust collector (3) on the support plate (4) in the filter head housing in such a way that the extraction orifice (5) points in the same direction as the marking (6) on the probe head.
- Screw the screw plug (2) in again so that the concentric pressure surface presses against the sealing washer on the support plate.
  (tighten gently with the face spanner)
- For velocity/temperature measurements as well as transporting and storage insert the cap(7) in place of the dust collector.

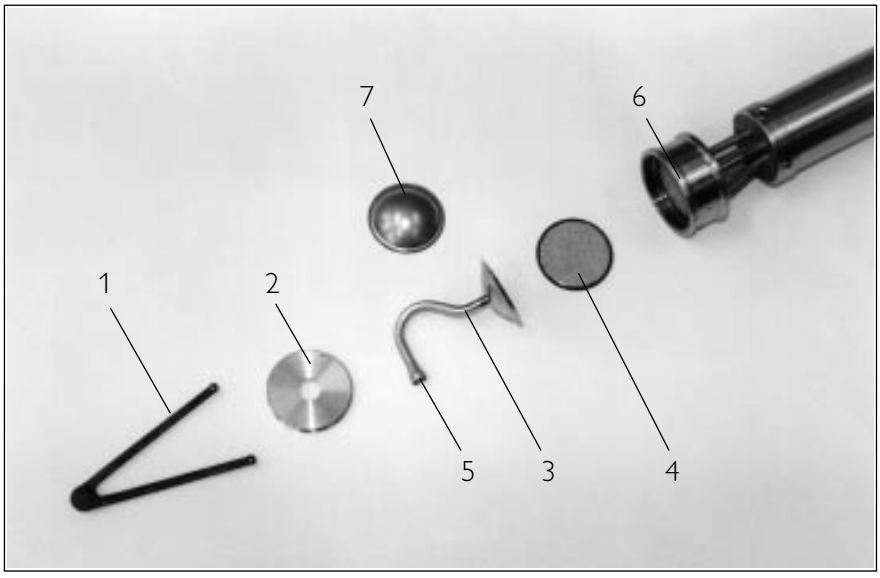


Fig. 3501 Insertion of the dust collectors

The insertion of the dust collector is shown for the LC collector.
The HC collector should be inserted in the same way, and the screw plug on the collector should be used.

3.5.3 Installing and connecting the evaluation unit

When setting up the evaluation unit the following points should be considered:

- The installation site should be sheltered from rain.
- Take heed of constantly sloping gas paths, so that the build-up of water pockets is avoided.

Important

The possible flow of condensate back into the probe after turning off the extraction pump must be absolutely avoided!

GS 5 Filter head probe

The connection of the filter head probe to the evaluation unit is carried out in the following way:

- Screw the safety lock nut (see Fig. 2404) on the connector of the multichannel hose up to the limit
- Put the safety lock of the multichannel hose on the connector of the evaluation unit in such a way that the sealing surfaces lie flat against one another.
- Screw the safety lock nut hand-tight in a clockwise direction; the nut must be easily moveable
- Put the plug for the temperature sensor in the socket and screw up.

Note

Check the thread and joint on the connector for damage or dirt, if necessary clean the thread with a wire brush, thread damage can be carefully removed with a triangular file.

Important

No tool is necessary to do up the nut if the threads are in the correct condition!

RS 232 Interface

The RS 232 interface can be connected via a connection cable to the serial interface of a laptop or to a printer for data logging.

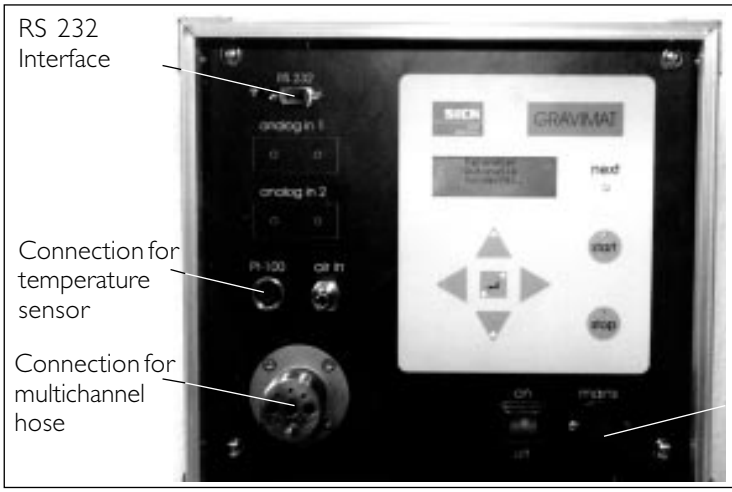


Fig. 3502 Connections to the evaluation unit

3.5.4 Adaptation to the available supply voltage

The evaluation unit is set in the factory for the supply voltage (115/ 230 V AC) specified at the time of ordering or in the technical questionaire. The adaptation is carried out by installing the relevant extraction pump (corresponds to coded connectors in the pump plug).

Warning
The evaluation unit may only be operated if the local supply voltage corresponds to the mains voltage setting!
When exchanging the extraction pump, it is essential that the operating voltage of the extraction pump and the local power supply are compatible!

Note:
The operating voltage of the extraction pump is noted on top of the terminal box of the pump motor and on the pump plug

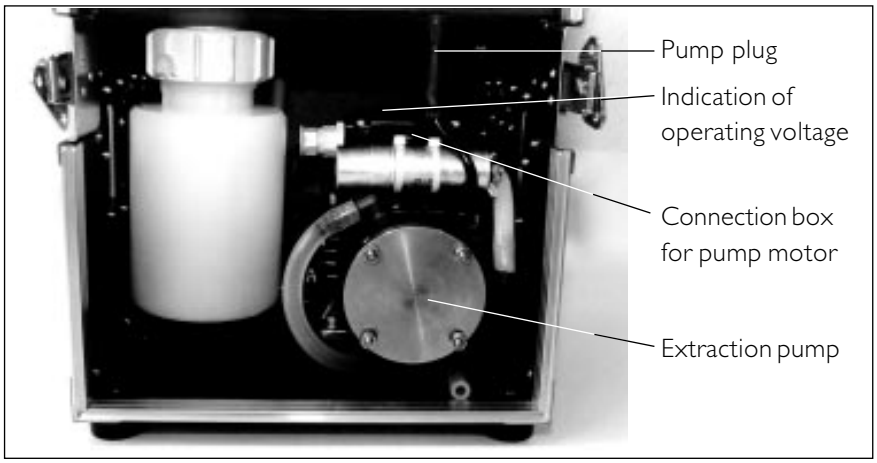


Fig. 3503 Extraction pump

3 Preparation for measurement

3.6 Function test before the start of a measurement

To check the correct functioning of the GRAVIMAT SHC501 the following test steps can be carried out before the start of a measurement:

▶ In the "Special functions / Manual operation" menu check the displays without the filter head probe connected:
Velocity = 0 m/sec
p_probe (p_{40}) = 0 mbar
Angle = 0 deg.
If the displayed values deviate from these, a zero-point calibration should be carried out ("Special functions / Calibration / Zero-point"; see section 6.3.1)

Note

There must be no air currents passing over the evaluation unit (wind, draughts, etc.)!

▶ With the filter head probe connected and the cap inserted, start an extraction procedure in the "Special functions / Manual operation" menu and select "volume" display and start the extraction (select "new measurement"). Regulate the isonetic value to MAX using the ▲ key and check the subsequent values.
When the device is functioning correctly the following values must be displayed during the the extraction:
extr. volume = 0 m^3/h
p_{40} = approx. -500 mbar
VDuct = 0 m/sec
Angle = 0 deg.

Note

There must be no air currents across the filter head probe!

If other values are displayed, the air-tightness of all lines should checked (see section 6.1.2) Or a malfunction check carried out as shown in Chap. 7.

4.1 General information

After completing all necessary preparation work as shown in chapter 3, the filter head probe should be inserted in the probe bracket mounted on the installation flange and locked (see figures 2405 and 2406).

The operation of the GRAVIMAT SHC 502 is preferably carried out by means of the SMP502 program via a PC (laptop), which is connected to the evaluation unit using the RS 232 interface. Alternatively it is also possible to operate the device via the keyboard on the front panel of the evaluation unit. In this case not all of the functions are available. Both possibilities are described in this chapter.

After turning on the power switch, the LC-display lights up and the main menu appears with:

- Parameters
- Evaluation
- Special functions

The LEDs on the keys indicate their readiness for operation. If the respective LED is not lit up, the corresponding key has no function.

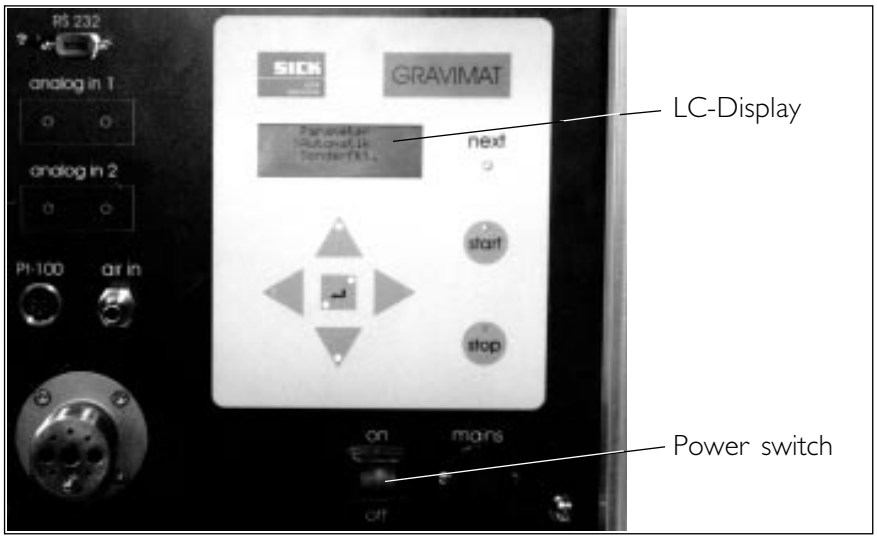


Fig. 4101 Evaluation unit front panel

4.2 Operation with the SMP502 program

In the work stages described below Windows activities are referred to. Also see the operating handbook for Windows.

4.2.1 General information

The SMP502 operating program runs under MS-Windows 3.11 (or higher).

Conditions

- IBM-compatible PC (laptop) with a 486DX processor of at least 8 MB (16 MB is recommended), 3,5" disk drive. The cycle frequency should be at least 66 MHz.
- Interface cable for connecting the RS 232 interface to the evaluation unit and the PC (accessory, see Chap. 8).

Installation

To install the program Disk 1 (supplied) should be inserted into disk drive A of the PC. The installation program is started in the program manager under "File/Set-up" by entering:

A:\Setup

If the laptop is included in the scope of supply, the program is installed in the factory in the C:\SMP502 directory.

As standard the directory C:\SMP502 is created for the program files. The program can however also be installed in another, freely selectable directory. After the definition of the directory the files are copied from the disk by clicking on the button area in the menu field (see Fig. 4201).

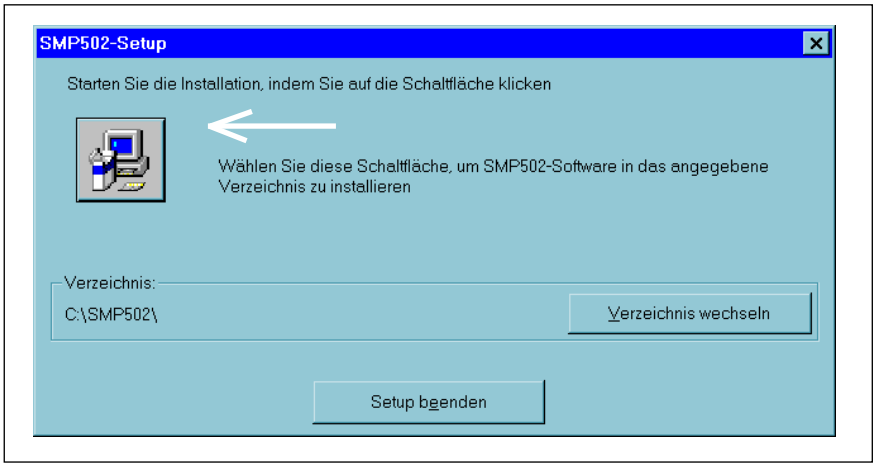


Fig. 4201 Setup menu

The SMP502 program can be called up automatically when starting Windows by moving the symbol in the program manager to the "Autostart" menu .

Program start

Starting the SMP502 program can be carried out by:

- Entering SMP502.EXE in program manager under "File/set-up"
- Clicking on the program icon in program manager
- Clicking on the symbol in program manager (automatically established during installation).

After starting the program the main menu appears on the screen.

Fig. 4202 Main menu

The illustrations in Section 4.2 were produced using Windows, German language version. When the SMP502 program is started under the English language version, all text will appear in English.

Establishing the connection

Before the start of the measurement or other work contact must be made between the laptop/SMP502 program and the evaluation unit via the menu point "Connection". The transference parameters are set at 9600 Baud, 1 Start bit, 8 Data bits, 1 Stop bit, no parity bits. The desired interface can be assigned by selecting the corresponding field (Fig. 4203).

Note

It is only possible to establish contact with the GRAVIMAT after initialization of the device.

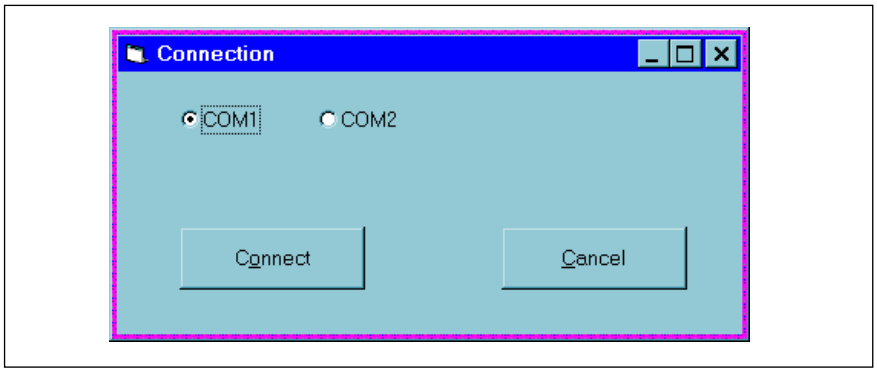


Fig. 4203 Interface selection menu

Initialization is completed when the screen displays the following:

→ *Parameters*
Automatic
Special functions

Warning

Interface icon (e.g. COM1) and connected plug on the laptop must correspond to one another.

The successful establishment of the connection is confirmed with the following message.

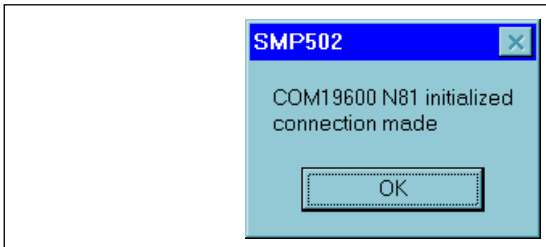


Fig. 4204 Confirmation that the connection has been made

After the successful establishment of the connection the following message appears on the screen of the evaluation unit:

```
<<<<<<<<<<<<<<<<<<<<
<          SHC 502          <
<           online          <
<<<<<<<<<<<<<<<<<<<<
```

The keyboard on the front panel of the evaluation unit is not available when using the SMP502 program except for the stop key.

4.2.2 Description of the program

4.2.2.1 "File" menu

With this menu the following functions are possible:

- ▶ New (standard settings)
  Erasure of menu inputs (parameter settings), erasure of all measured values and loading of the standard values (for values see "Parameters" menu)
- ▶ Load measured values
  Loading of measured values from previous measurements
- ▶ Protect measured values
  Saving of the measured values under a defined file name
- ▶ Reset measurement
  Erasure of all previous measured values plus the collector no. and the collector weight entered ("Parameters" menu).
  All other parameters are kept
- ▶ Device data Gravimat ⇒ File
  Copying of the device data in a file
- ▶ Device data File ⇒ Gravimat
  Copying of the device data from a file to the Gravimat

Loading and saving of files is carried out in the usual manner under Windows (selection of disk drive, directory, file name).

4.2.2.2 "Parameters" menu

All the settings necessary for the measuring process as well as the recording of data for the measurement can be carried out with the help of the "Parameters/Measuring parameters" menu. The possible input fields are shown in Fig. 4204. Switching between the fields can be done by means of the tab key or the mouse.

Information Fields

In these fields more precise information on the respective measurement can be given. The text is only necessary for printing out the protocol.

- Engineer
  The name of the measuring engineer should be entered here.
- Plant
  A code designation for the plant in which the measurement is taking place (e.g. power station XYZ), should be given here.
- Place
  The measuring site is entered here (e.g. 'Block A').
- Remarks
  Additional text (e.g. on the type of measurement) can be entered here.

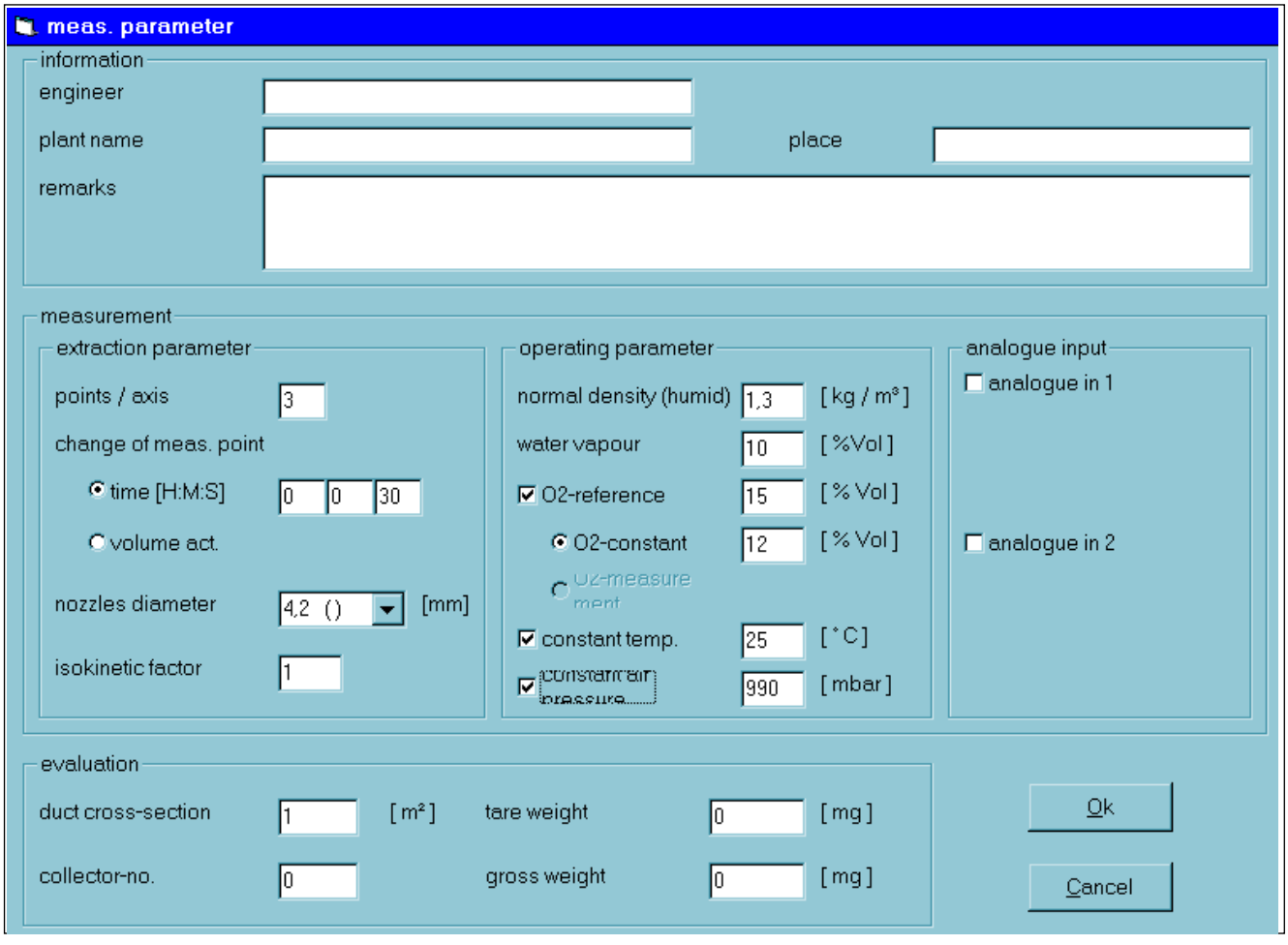


Fig. 4205 Measuring parameters menu

4 Measurement procedure

For designation of the measuring axes see section 4.2.2.3

Measurement Fields

▶ Sampling parameters

- Here the number of measuring points on one measuring axis (1 to 75) for a network measurement are entered. After processing the measuring points of an axis in automatic mode the measurement is interrupted and can be continued after changing the measuring axis. In this way all the measuring points can be processed in one measuring process using one dust collector. If a continually measuring device is being calibrated, a new measurement must be started for each point on the regression curve, i.e. a new measuring file should be created, as for each measurement a separate dust collector is required.
- Changing the measuring point
  The extraction time or the partial gas volume to be extracted per measuring point can be defined here. When the entered measuring time expires or the partial gas volume has been extracted, the change to the next measuring point is signalled acoustically. The measuring time for a measuring point should be entered in the format hours : minutes : seconds. The minimum time for a measuring point is 30 s, the maximum measuring time is 23h 59 min 59 sec.
  The total measuring time is accrued from the product of the number of measuring points per axis, the number of axes and the measuring time entered here. With measurements of long duration the amount of condensate formed should be monitored. If necessary the measurement should be interrrupted to empty the condensate separator or a larger container should be connected.
- Extraction diameter
  With an extraction process the extraction diameter of the dust collector (see section 2.4.4) used should be entered. The diameter is necessary for the determination of the nominal throughflow when performing an extraction process.
  The appropriate extraction diameter can be determined by a velocity/temperature measurement carried out beforehand (v/T measurement, see section 4.2.3). The operator can also use relevant experience and knowledge of the plant conditions to calculate the extraction diameter.

Values in m^3/h

Operating range of the extraction pump (0,6 - 2,4 m^3/h)

Extraction-Ø	Gas velocity in the duct in m/s								
in mm	5	10	15	20	25	30	35	40	45
4.2	0.25	0.50	0.75	1.00	1.25	1.50	1.75	1.99	2.24
5.2	0.38	0.76	1.15	1.53	1.91	2.29	2.67	3.06	3.44
6.4	0.58	1.16	1.74	2.32	2.89	3.47	4.05	4.63	5.21
8.0	0.90	1.80	2.71	3.62	4.52	5.43	6.33	7.24	8.14
10.0	1.41	2.83	4.24	5.65	7.07	8.48	9.90	11.31	12.72
11.5	1.87	3.74	5.61	7.48	9.35	11.22	13.09	14.96	16.83

Table 4201 Collector choice depending on the gas velocity in the duct

By clicking on the field with the mouse or by selecting the field with the tab key and then simultaneously pressing the keys Alt and U a selection field appears with all available extraction diameters.
If a vT-measurement has previously been carried out, the diameters which can be used for isokinetic extraction at all measuring points should be indicated by "(*) (=> recommended extraction diameter).
If high dust concentrations can be expected, the smallest of the collectors marked should be chosen.

- The isokinetic factor
  Under certain conditions it can be advisable to extract above or below the isokinetic level. By entering a factor not equal to 1 the nominal value for the extraction control is multiplied by this number and the extraction is appropriately controlled.

▶ Operating parameters see section 9.2

The respective plant parameters should be entered here.

- Normal density damp
  The values entered here are used for calculation until a new measurement is begun by erasing all parameters (Menu "File/ New").
- Water vapour
- O_2-reference value
  O_2-constant (actual value)
  These values are calculated as follows for protocol output:

$$C_{i.N.\ tr.\ (O2)} = C_{i.N.\ tr.} \cdot \frac{21 - O_2\text{-reference value}}{21 - O_2\text{-actual value}}$$

$C_{i.N.\ tr.}$ = Dust concentration under normal conditions dry

Constant values can be entered in the following fields.

- Constant temperature
  By entering the gas temperature measured in the duct isokinetic extraction can also take place even if the temperature gauge malfunctions.
- Constant air pressure
  If the barometer sensor malfunctions, in this field an externally measured value can be entered (standard setting 990 mbar).
  When restarting the GRAVIMAT an entered value will be reset to the standard value. After modifying the menu by deactivating this field the measured value from the barometer sensor will be used again.
  Alterations/resetting to standard or deactivation of this field are only effective when a measurement is started.

For the handling of the dust collectors before and after the measurement see sections 3.3 und 5.1

- Analogue inputs
  If a continually operating dust measuring device is being calibrated with the gravimetric measurement, the sizes to be calibrated (e.g. extinction, transmission) as well as an additional measuring device for determining the norm sizes (e.g. gas humidity) can be entered here. In the "Live Zero" field the Live-Zero-Value (0,2 oder 4 mA) of the device to be calibrated should be entered.

Evaluation Fields

- Duct cross-section
  The cross-sectional area of the duct should be entered here. It is needed for the determination of the main gas stream and the plant dust mass flow.
- Collector Nr.
  For a clear assignment of measured data and inserted dust collectors the identification marking of the dust collector should be given here before the measurement (1 ... 9999).
- Tare mass
  The tare mass of the dried and conditioned dust collectors with seam and filter, determined before the measurement, should be given. Input before the start of the measurement is recommended.
- Gross mass
  After the measurement the mass of the dried and conditioned dust-laden collectors should be determined and given here. Since the measurement and weighing are not, as a rule, carried out immediately one after the other, the data saved during the measurement should be loaded before entering the gross mass.

4.2.2.3 "Measurement" menu

In this menu the zero point calibration function and three different measuring forms can be selected.

Zero point calibration

Before the start of a measurement it is advisable to calibrate the pressure sensors to the exact zero point using this menu point (see section 6.3).

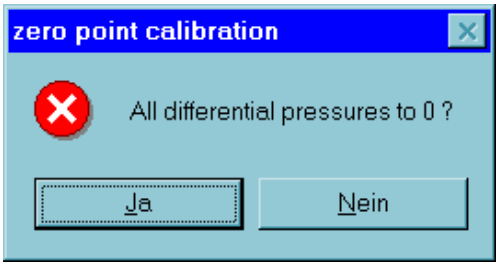


Fig. 4206 Zero point calibration menu

If a calibration is to be carried out, the switching field "Yes" should be confirmed. After successful calibration the following menu should be exited (Fig. 4207).

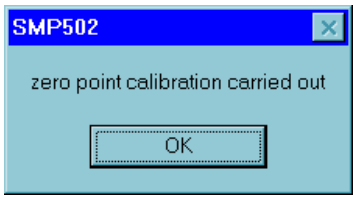


Fig. 4207 Menu for exiting zero point calibration

vT-Measurement

The velocity/temperature measurement (vT-measurement) should be carried out before an extraction process, in order to obtain information about the flow conditions in the duct. If the appropriate experience is already available, this is not absolutely necessary. During the vT- measurement there is no extraction, i.e. the pump is switched off and the stop valve is closed.
The input and display possibilities are explained below with the help of Fig. 4208.

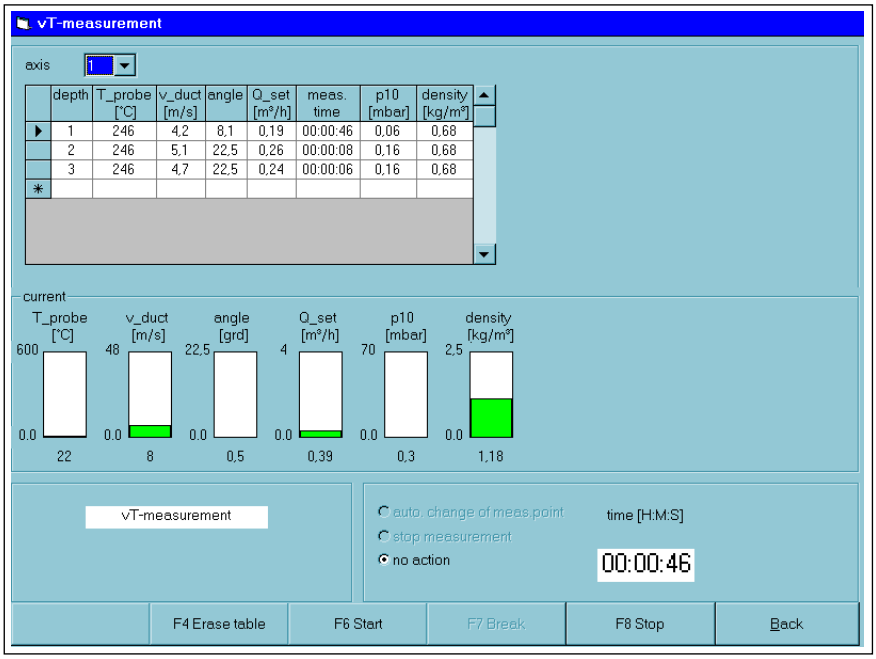


Fig. 4208 vT-measurement menu

- Axes
  In this field the number of axes is given. It is advisable to number the measuring axes consecutively, so that the assignment to the measuring sites in the duct is simplified.
  After the end of the measurement at a measuring point the value detected is automatically entered in the table. The number of lines depends on the selected number of measuring points on each axis (see section 4.2.2.2). The measuring point number is indicated in the "depth" field.
- Current
  During a vT-measurement the current measured values are displayed in this diagram as bars and in figures.
- Switching fields
  By operating the function keys on the indicated switching fields or clicking the respective switch field with the mouse the corresponding activity is triggered. The switching field "Stop" for ending the vT-measurement is activated be pressing the start key.

Non-simultaneous isokinetic extraction

Contrary to the following description of simultaneous isokinetic extraction, the determination of the velocity and the extraction are not carried out at the same time, but at two separate points in time. In this way it is also possible to extract isokinetically at the sites in the duct, where because of the geometry of the probe, measuring and extraction can't be done at the same time (e.g. in small ducts, on the side of the duct).

To perform this measurement the duct pressure and the velocity at the respective measuring point should be determined by means of a previous vT-measurement.

When subsequently calling up the non-simultaneous isokinetic extraction the measured values are taken over from the vT-measurement in the corresponding field of the extraction table (see Fig. 4209).

The control guarantees that extraction is done with the velocity preset in the table. Duct pressure and velocity are entered as preset constant sizes in the calculations.

By pressing the F2 selected measurements can be entered by hand :

T probe	(0 ... 400°C)
P10	(-70 ... 70 mbar)
v_duct	(0 ... 50 m/s)

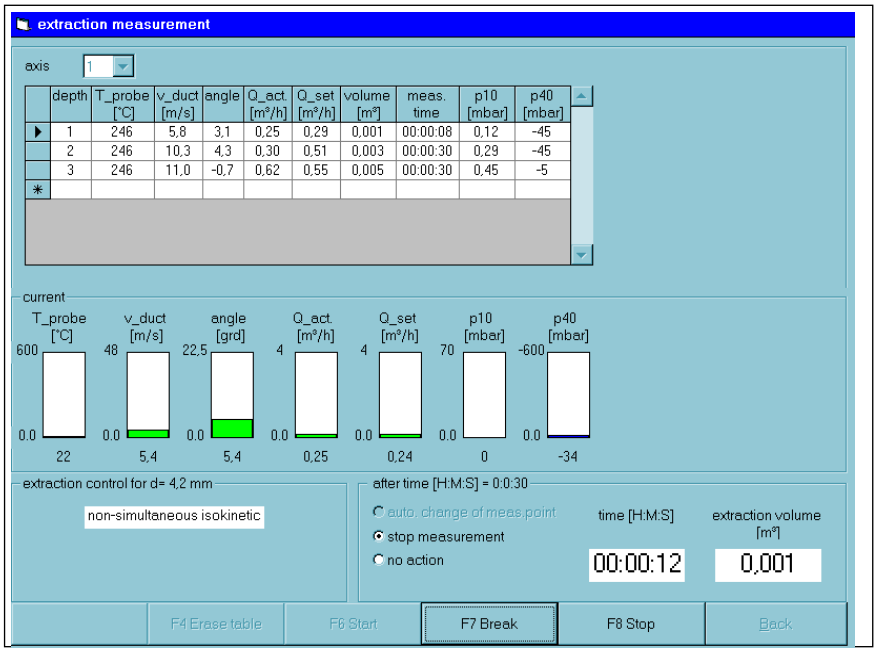


Fig. 4209 Non-simultaneous isokinetic extraction menu

4 Measurement procedure

For preparation see Chap. 3

The following procedure is advisable:

- ▶ v/T-measurement
- ▶ non-simultaneous extraction
  Carry out extraction separately for selected measuring points. The measuring process can be stopped after the processing of each measuring point. For this the "**Stop measurement**" field should be activated. The process for the next measuring point can be continued be pressing the F6 function key or the corresponding switch field.

The display of the measured values and the operation via the function keys and switching fields is carried out in the same way as with the vT-measurement (comp. Fig. 4208). The measured values are saved separately for each measuring point.

Simultaneous isokinetic extraction

With simultaneous isokinetic extraction the nominal value for the extraction control of the partial gas flow is ascertained from the measured values of the main gas flow (velocity, pressure, temperature) so that an exact isokinetic extraction can be carried out. The input of measuring axes, display of the measured values and operation via the function keys/switching fields(see Fig. 4210) is carried out in the same way as with the vT-measurement (see Fig. 4208).
Before the procedure a suitable dust collector should be inserted in the probe. The diameter of the inserted collector can be ascertained by a vT-measurement. The largest possible extraction diameter leads to the largest amount of extracted gas.

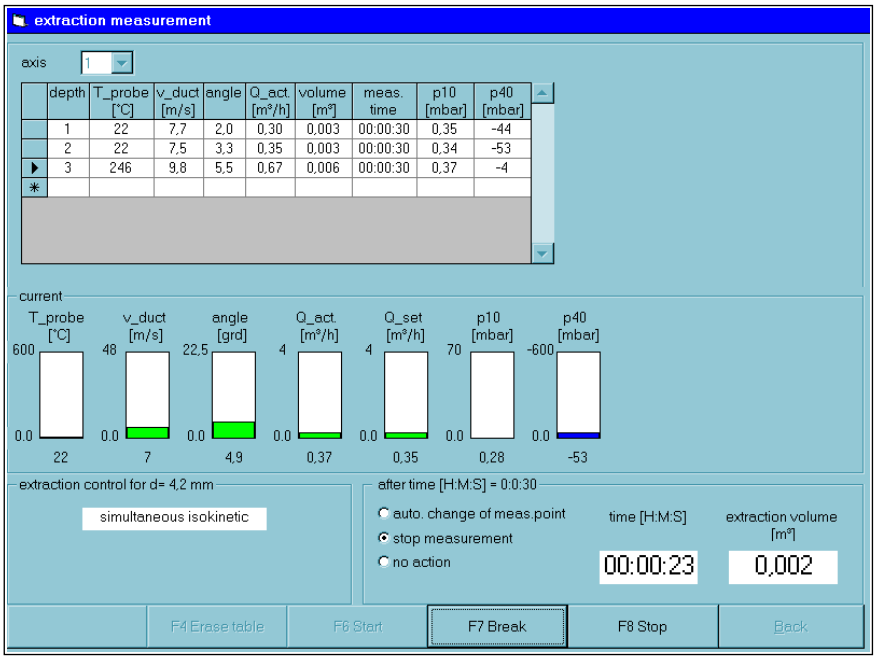


Fig. 4210 Simultaneous isokinetic extraction menu

With simultaneous isokinetic extraction there are two possibilities for ending a measuring process. In this way one of the following fields should be activated:

- ▶ automatic change of measuring point
  The measurement is ended after processing all measuring points on an axis.
- ▶ Stop measurement
  As for the non-simultaneous isokinetic extraction, the measuring process can be stopped after the processing of each measuring point. The measurement can be continued for the next measuring point be pressing the F6 function key or the corresponding switching field.

Soot spot measurement

This menu makes it possible to carry out a simple soot spot measurement in accordance with VDI 2066 Sh. 8. Before the start of the measurement a soot collector should be inserted in the filter head probe (see Section 2.4.4.3). The measuring process is basically the same as for a simultaneous isokinetic extraction measurement with the following alterations:

- ▶ Input of the sampling diameter (10 mm)
- ▶ 1 measuring point per axis

The input of the partial gas volume to be extracted (0.0874 Nm³) is automatically called up with the Soot Spot Menu and entered into the parameter menu.

The display of the measured values and operation via the function keys/switching fields is done in the same manner as with the other types of measurement (see Fig. 4211).

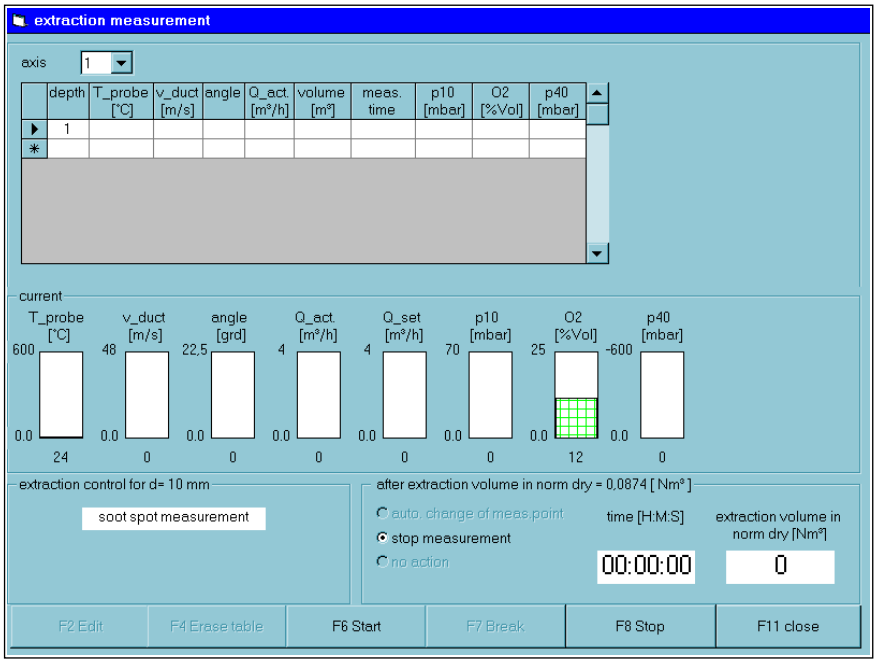


Fig. 4211 Soot spot measurement menu

4.2.2.4 "Service/Maintenance" menu

This menu can be used for drying all the gas paths, including the pump after completion of cleaning or maintenance work and for testing the basic system parameters. For this the following submenus should be selected:

- ▶ Drying or
- ▶ System check.

Drying

Here there is the option of drying all gas-carrying paths or the pump only, by selecting the appropriate switching field.

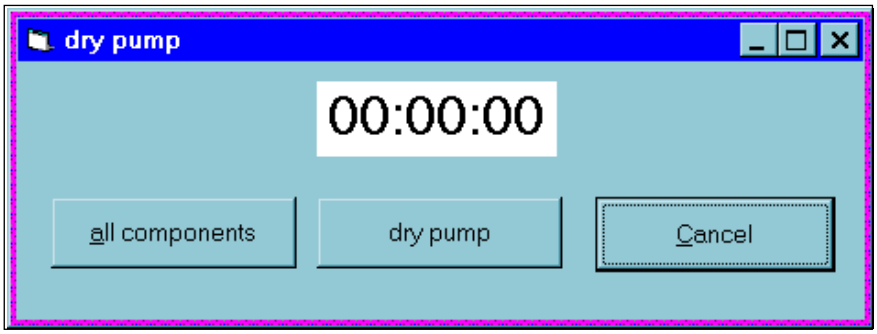


Fig 4212 Drying menu

System check

After selecting this menu, the values for the pressure sensors and temperature sensor, together with the functioning of the extraction pump, extraction valve, horn and LED NEXT, can be tested (see Fig. 4213).

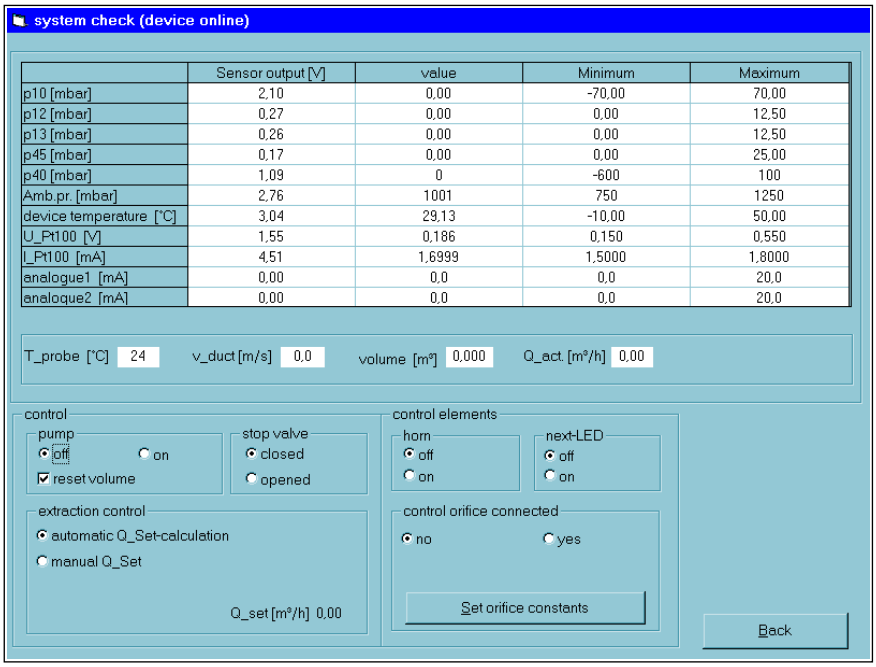


Fig. 4213 System check menu

In the menu field "Extraction control" a nominal value for the partial gas volume to be extracted can be entered by selecting the "manual nominal value input" field (in steps of 0.1 m³/h).

In the menu field "test aperture connected" the aperture value for the measuring aperture in the filter head probe can be corrected after checking with the test agent for the volume flow measurement (Accessories, see Chap. 7).

4.2.2.5 "Evaluation" menu

With this menu the measured and the calculated values for the measurement types

- vT-measurement
- non-simultaneous isokinetic extraction
- simultaneous isokinetic extraction
- protocol offline measurement

are displayed on the screen of the laptop (PC).
When switching to "table" the individual measured values for each measuring point are also displayed.

vT-Protocol

The values ascertained by the vT-measurement can be displayed within the "vT-Protocol" menu (Fig. 4214).

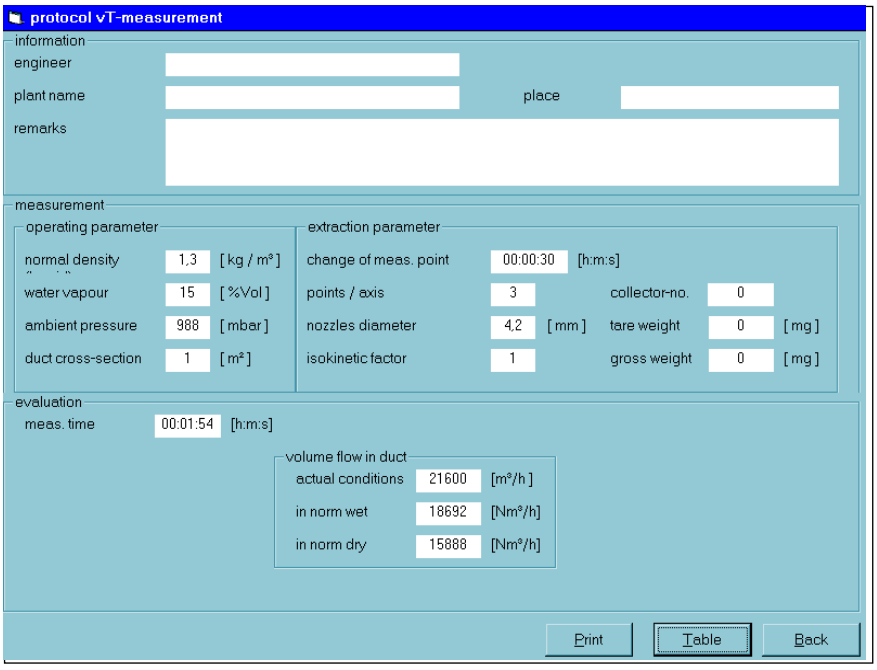


Fig. 4214 vT-Protocol menu

Extraction Protocol (non-simultaneous)

The values determined by the non-simultaneous isokinetic extraction can then be displayed on the screen with this menu (Fig. 4215).

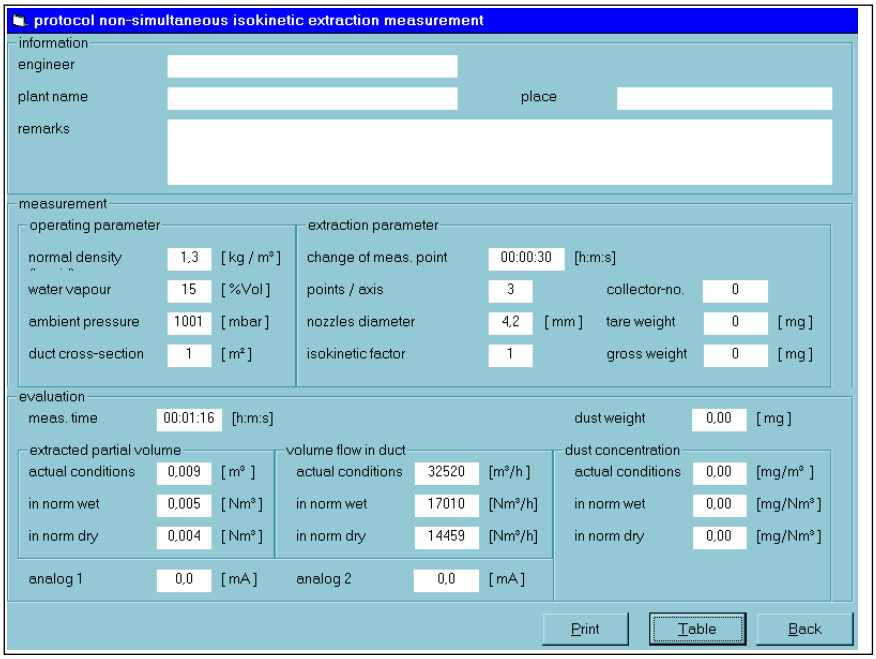


Fig. 4215 Extraction Protocol menu (non-simultaneous)

Extraction Protocol (simultaneous)

After a simultaneous isokinetic extraction the values detected can be displayed with this menu (Fig. 4216).

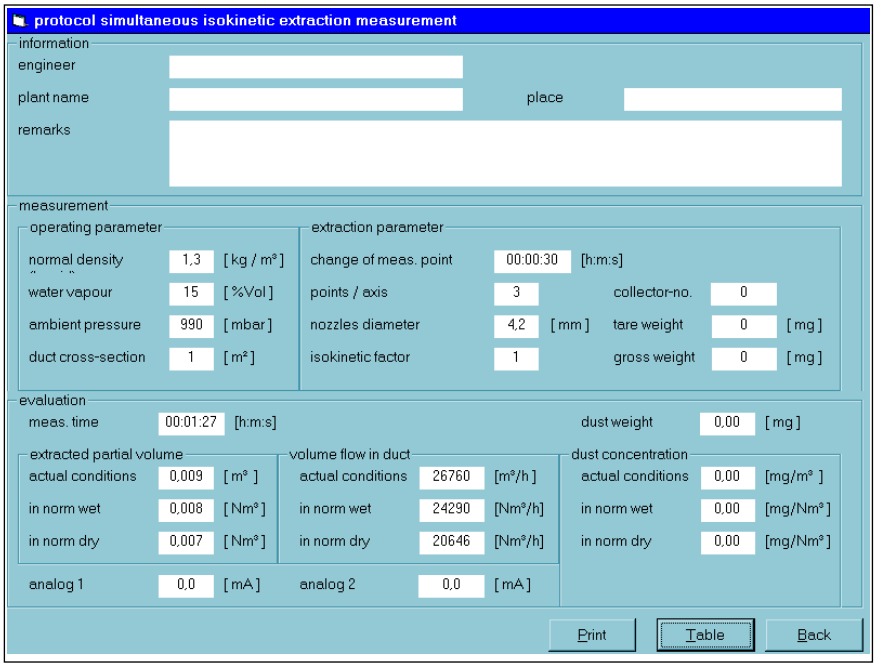


Fig. 4216 Extraction Protocol (simultaneous)

Offline measurement protocol

This menuis used for creating a protocol for measurements in offline mode (no computer connected, operation via the keyboard as shown in Section 4.3)

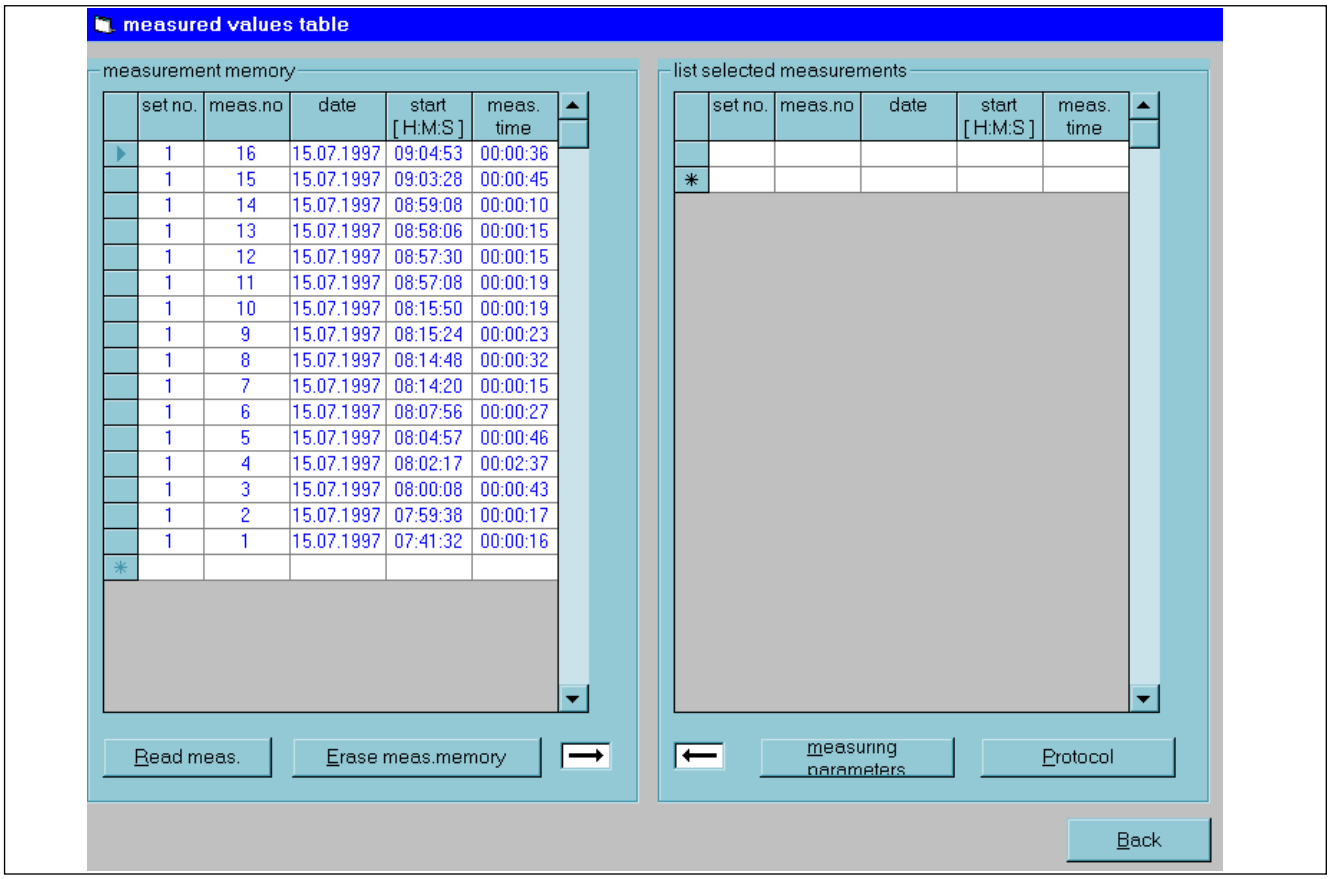


Fig. 4217 Offline measurement menu

In the left-hand menu (measured values memory), all measured values in the memory are displayed by clicking on the switching field "Read meas.". The measured values are arranged according to Set number, whereby all measurements with the same collector number, standard density and humidity are marked.
The values required for creating the protocol can be read from this overview. the values are shown again in the right-hand menu. In this way, false or incomplete measurements can be excluded.
Additions (e.g. input of the gross mass) can be made before producing the protocol by clicking on the "Measured values parameters" switching field in the parameters menu.
The measuring protocol is produced by clicking on the "Protocol" switching field.

4 Measurement procedure

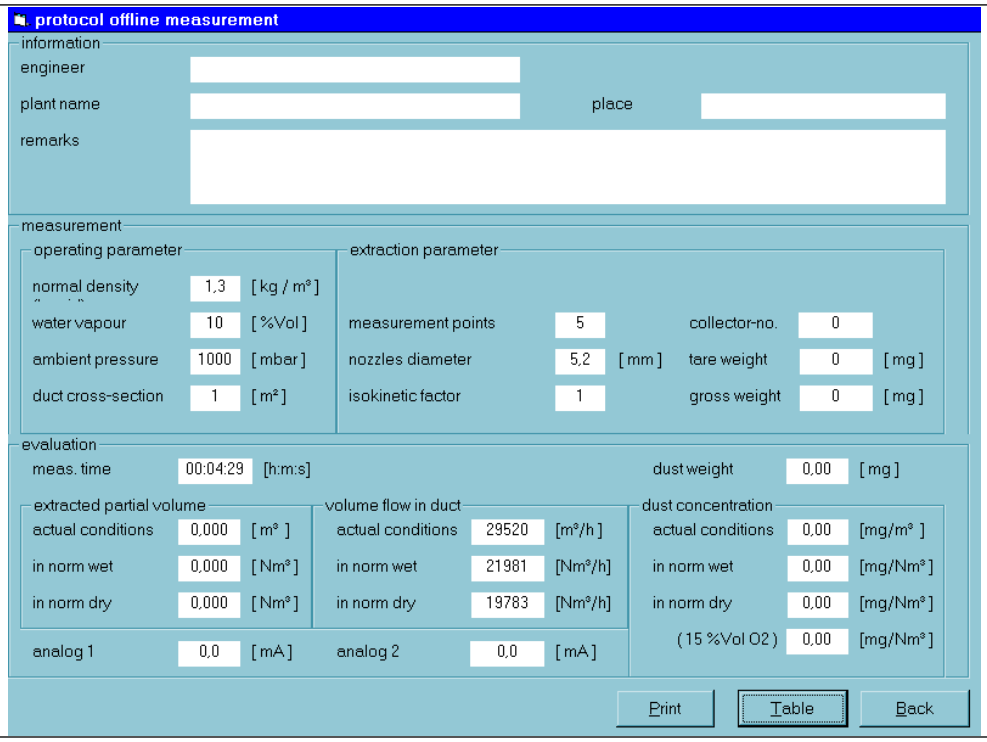


Fig. 4218 Offline measurement protocol

The measured values can be displayed in tabular form ("Table" switching field) or printed out ("Print" switching field).

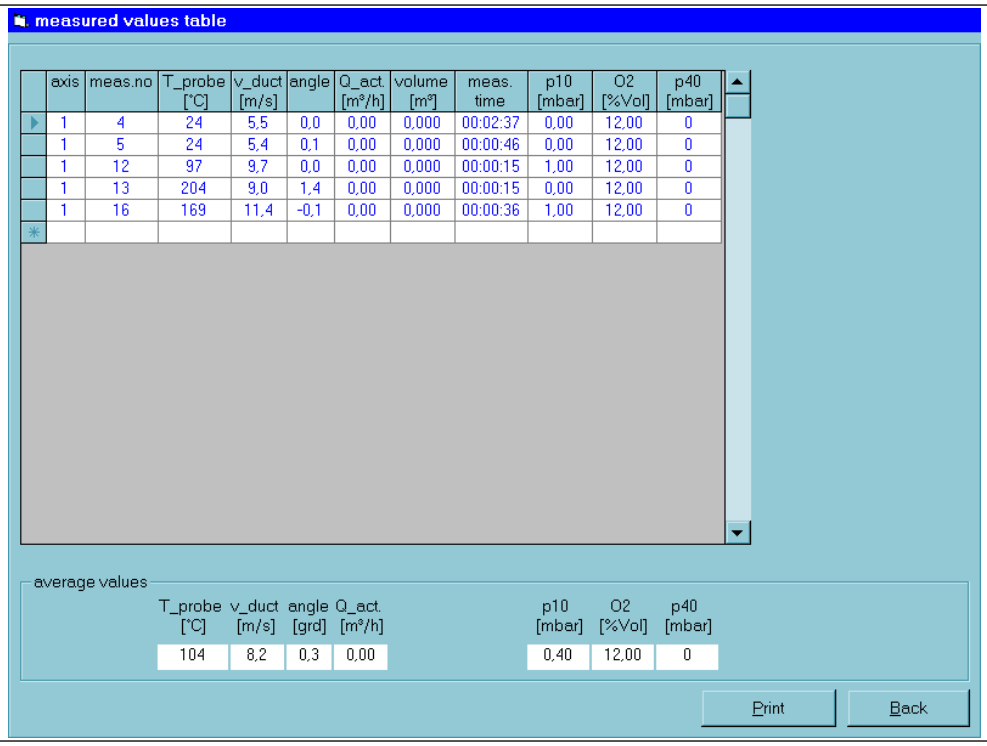


Fig. 4219 Display of the measured values in tabular form

Selection of the measured values required:

- ▶ Click on the "Read meas:" switching field
- ▶ Select the desired measured value in the measured value memory menu using the scrolling bar (indicator in the left-hand column moves to the corresponding row)
- ▶ Transfer the selected values to the selection list using the ⇒ switching field (bottom right)
- ▶ Add the parameters to the measuring parameters menu if necessary
- ▶ Click on the "protocol" switching field
- ▶ Define the type of output (Table or printout)

Notes

- ▶ Values added to the selection list can be erased again with the ⇐ switching field
- ▶ For each set number a separate protocol should be produced, as no calculation is possible if there are different standard densities, for example.

4.2.2.6 "Options" menu

The functions of language selection and horn on/off can be selected with this menu.

Language

After selecting this menu the desired language can be set by making the appropriate choice and then confirming it.

Fig. 4218 Language selection menu

Electronic horn
With the setting of this field the acoustic signal producer, which sounds 10 s before the end of a measurement, is activated and therewith indicates an impending change of measuring point.

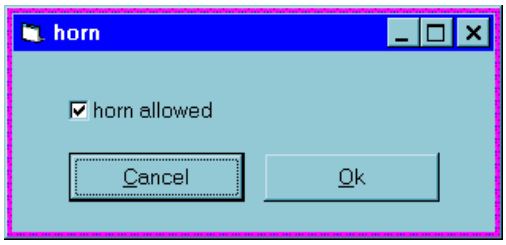


Fig. 4219 Electronic horn menu

4.2.3 Performing a vT-measurement

Procedure

- ▶ If necessary take the inserted dust collector out of the probe and put on the cap to seal the probe head (see section 3.5.1)
- ▶ Secure the probe bracket to the duct flange with the screws.
- ▶ Place the probe in the duct and pushed as far as the first measuring depth. At the same time align the probe in such a way that the pressure measuring bore p_1 or the marking on the grip points exactly in the direction of the axis length of the duct, against the direction of flow.
- ▶ Then lock the probe in the probe bracket with the winged nut (see section 2.4.3)
- ▶ Start the SMP502 program
- ▶ Make the connection to the evaluation unit
- ▶ Enter the required measuring parameters and the corresponding information for designation of the measurement in the "Parameters" menu
- ▶ Call up the submenu "vT-Measurement" in the "Measuring" menu and enter the necessary number of measuring axes

For settings see section 4.2.2.2

After pressing the F6 key or clicking on the switching field Start you are asked, whether previously determined measured values should be saved or overwritten (Fig. 4220).

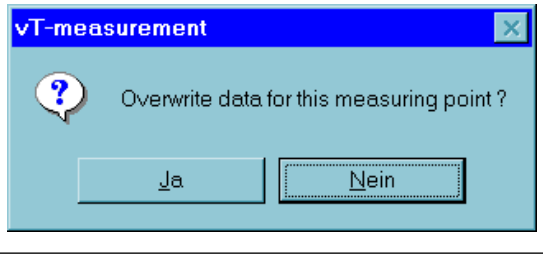


Fig. 4220 Menu field for data protection before the end of a measurement

After making the appropriate selection the measurement is begun. The measurement is ended by pressing the F8 key or clicking on the switching field Stop.
The shortest possible measuring period for one measuring point is 15 s. After the conclusion of the measurement the last valid average values remain in the approriate line of the table.

Then the probe should be moved to the next measuring point or placed in the next axis. After that the measurement can be restarted.

4.2.4 Performing non-simultaneous isokinetic extraction

To carry out an extraction process take the cap, if used, out of the probe and insert the dust collector prepared according to section 3.3. The place the probe in the duct and lock in in the same manner as described for the vT-measurement.
After starting the SMP502 program, the required parameters and the corresponding data for designation of the measurement should be entered in the "Parameters" menu.
Then, in the "Measuring" menu, call up the "non-simultaneous isokinetic extraction" submenu. The values determined by a previous vT-measurement are automatically written into the appropriate fields in the table.
After pressing the F6 key or clicking on the Start switching field you will be asked, as in the vT-measurement, whether previously detected measured values should be saved or overwritten (see Fig. 4220). After the appropriate selection the measurement begins by pressing the F6 key or clicking on the Start switching field.

Starting a measurement

The end of a measurement is signalled visually 10 s before the end of the selected measuring time by the illumination of an LED on the front panel of the evaluation unit. If the "tone permitted" function under the "Options" menu is switched on, the acoustic signal sounds at the same time.

Signal before the end of measurement

The measurement ends when the selected measuring time is over or by pressing the F8 key or by clicking on the Stop switching field.
After the conclusion of the measurement the last valid average values remain in the corresponding line of the table.
Then the probe should be moved to the next measuring point or inserted in the next axis. After that the measurement can be restarted.

Before returning to the main menu you are asked whether the pump should be dried (Fig. 4221).

Warning
The pump must be dried after every extraction process.

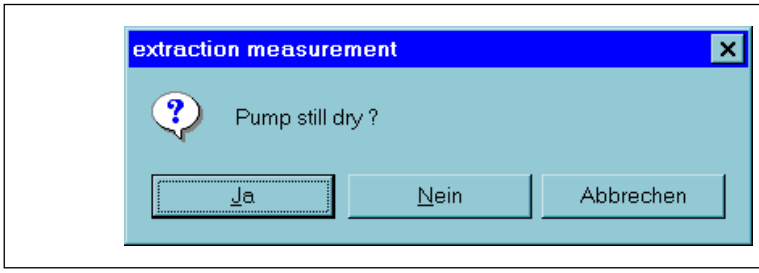


Fig. 4221 Menu field to dry the pump

4.2.5 Performing simultaneous isokinetic extraction

The necessary procedures and operator actions are the same as for non-simultaneous isokinetic extraction. The measured values required for isokinetic extraction are detected at the same time as the extraction itself takes place and processed for calculation of the nominal values for the partial gas flow.

4.2.6 Carrying out a soot spot measurement

The necessary procedures and operator actions correpsond to those described in Section 4.2.4. Variations to carrying out a dust measurement are as follows:

- a prepared soot collector should be inserted in the filter head probe in place an LC (or HC) dust collector
- the extraction diameter should be laid down in the "Measuring parameters" menu as 10 mm
- the extraction process should be ended when the partial gas volume to be extracted has been reached.

The soot particles contained in the extracted partial gas volume are separated in the plane filter. After completion of the measurement, the soot spot figure can be determined from the blackness of the plane filter by means of a separate light-optical evaluation.

4.2.7 Exit program

Before the SMP502 operating program can be exited, the following menu field appears. The appropriate switching field should be confirmed.

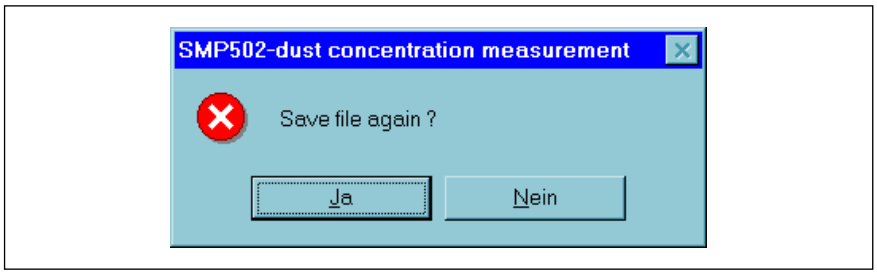


Fig. 4222 Menu field for data protection before exiting program

Warning

After completing all measurements and removing the filter head probe from the exhaust gas duct the gas paths should be immediately cleaned and dried. For this the dust collector or cap must be taken out of the filter head.

4.3 Keyboard operation

4.3.1.General information

Via the keyboard on the evaluation unit the following functions can be selected:

- Parameters
  Setting of the parameters for the measurement (Extraction diameter, collector number, normal density of the damp exhaust gas, gas humidity, constant temperature)
- Automatic
  Automatic, isokinetic extraction with selectable display of the extraction values (extracted partial gas volume, velocity and temperature of the exhaust gas in the duct, probe pressure p_{40}, angle between the probe and the flow)
- Special functions
  For function checking, calibration, language setting, manual operation code word, saving measured values.
  Special service functions are available by entering a code word.

For controlling the measuring process the following keys are available:

- Cursor keys field for menu selection and parameter setting
- Start key for beginning an extraction process
- Stop key for ending a measuring process as well as for the cancellation of an entry (Escape function)

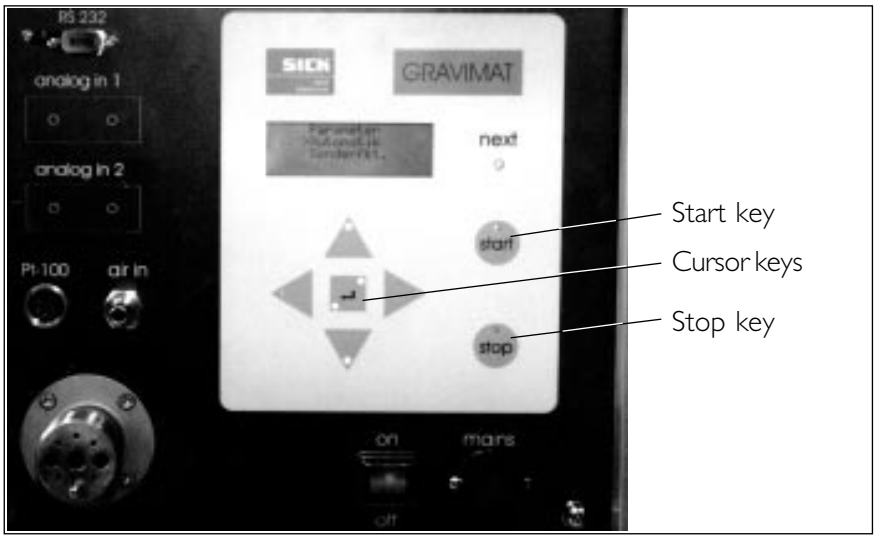


Fig. 4301 Evaluation unit keys

The following settings are possible with the cursor keys:

▶ ↵ key
- Confirmation of a selected menu point and transfer to the sub-menu
- Confirmation of a selected parameter and transfer to the editing mode
- Confirmation of an entry/selection and exit the editing mode.

▶ ▲ and ▼ keys
- Selection of a menu point in the main menu
- Return to the main menu from a sub-menu (▲ key) or cancellation
- Selection of the next higher (▲ key) or next lower (▼ key) figure in editing mode
- Setting of the partial volume flow in the "Manual operation" menu by:
  Selection of the "Volume flow" display and then changing the actual value while the extraction pump is switched on.

▶ ◀ and ▶ keys
- Selection of parameters, functions or measured values in the sub-menu
- Change of the cursor position between higher or lower value figures in editing mode.

Saving measured values

After ending the measurement be pressing the Stop keys the measured values are saved in the GRAVIMAT SHC 502 under a consecutive number from 1 ... 75. Pressing the Start key again allows the measurement to continue.
The last-saved number is shown on the LC-display on the left of the first line. Pressing the Start key increases the counter by 1.
In order to have the maximum possible memory space available, it is useful to erase the measured values of the previous measurement before starting a new measurement ("Special functions/Save measured values/Save" menu, see section 4.3.2.3).

Note
After switching on the GRAVIMAT the number saved last of all and the saving locations which are still free are shown on the LC-display (as long as there are no error messages).

Warning
Before starting a measurement it should be checked that the available memory space is sufficient for the number of measurements planned! When 75 measurements have taken place, the values of the last measurement are overwritten during a new measurement.

In order to have available the maximum possible saving space, it is advisable to erase the measured values from the previous measurement before beginning a new measurement ("Special functions/Save measured values/Erase" menu, see section 4.3.2.3).

4.3.2 Menu description

4.3.2.1 "Parameters" menu

For determining the optimal extraction diameter see section 4.3.3

For determining the normal density and gas humidity see Appendix section 9.2

The "Parameters" menu comprises the following setting possibilties:

- Diameter (extraction diameter of the dust collector)
- Collector no. (Number of the inserted dust collector for registering the probe)
- Normal density damp
- H_2O Humidity (Gas humidity)
- PT100 constant temperature (Entry of a constant temperature in place of the measured value from the temperature sensor)
- Protocol.

In this way the basis values necessary for isokinetic extraction are set.

With the "Protocol" menu point the setting can then be checked.

The selection is carried out according to the following diagram:

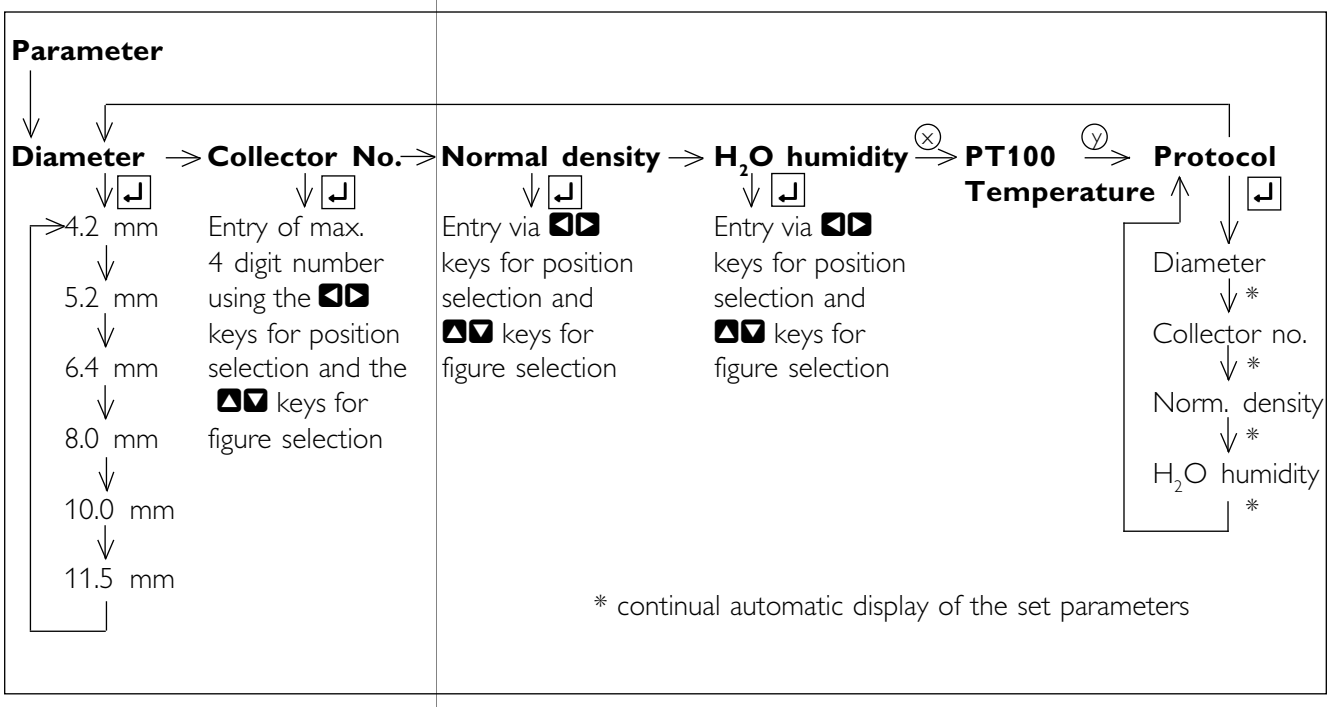


Fig. 4302 Operating process in the "Parameters" menu

By entering the gas temperature measured in the duct, isokinteic extraction can still be carried out even when the temperature measuring equipment is faulty (malfunction of the temperature sensor or similar). The steps necessary for this are illustrated in the following diagram.

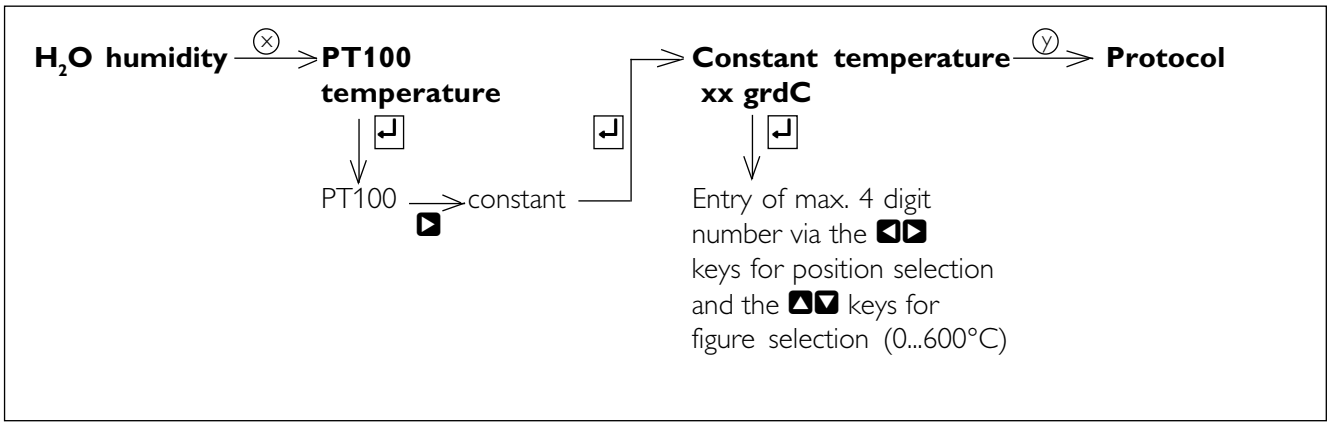


Fig. 4303 Partial process for "Input constant temperature"

Note
The operating processes shown in the figures 4302 to 4306 are in each case shown in only one direction. They can also be carried out in the reverse direction.

4.3.2.2 "Automatic" menu

With the "Automatic" menu all steps necessary for isokinetic extraction are performed.
The start and end of an extraction process is carried out by pressing the corresponding key (see section 4.3.3).
During the extraction process the extraction time and selectably the **current** measured or calculated values shown on the LC-display

- extraction time (in min:sec)
- extraction volume (partial gas volume in m³)
- velocity (gas velocity in the duct in m/s)
- temperature (exhaust gas temperature in °C)
- volume flow (partial volume flow in m³/h)
- p_probe (p_{40}) (probe pressure in mbar)
- angle (angle of the current in °)

After the "angle" parameter comes the menu point

- Dry pump.

In the subsequent menu point

- Measuring protocol

the **mean value** of the measured and calculated values can be called up after the end of the extraction process.

4.3.2.3 "Special functions" menu

With this menu the functions shown in the following overview can be selected as standard.

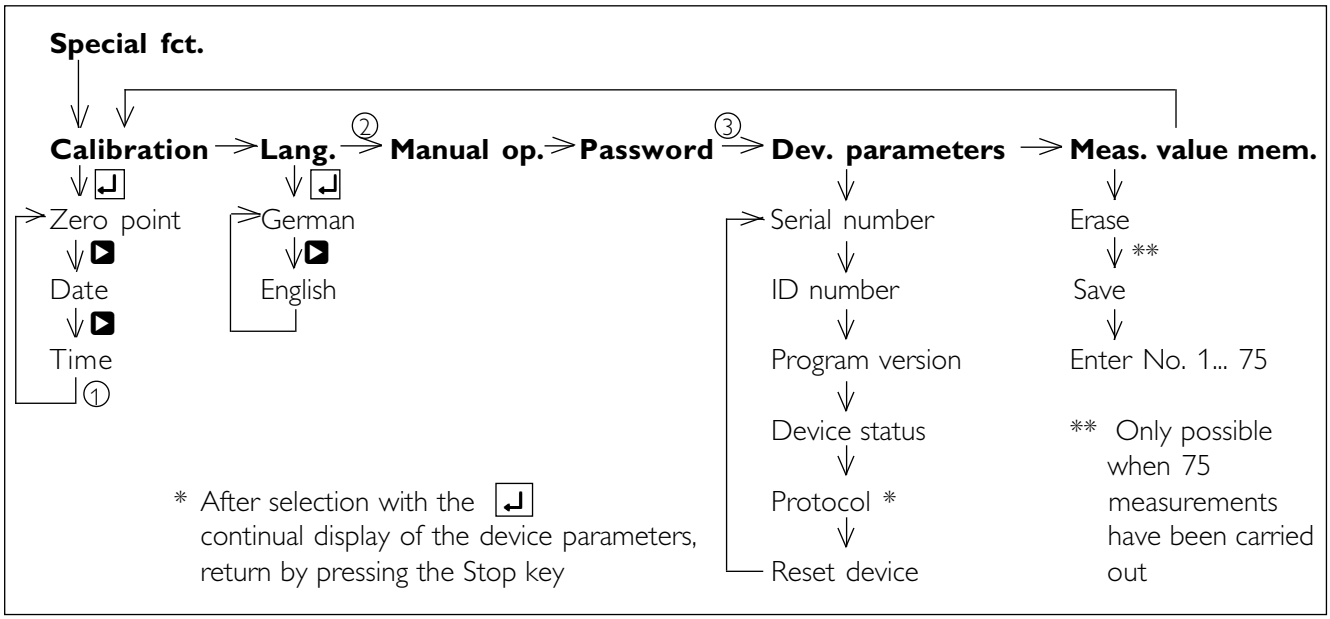


Fig 4304 Overview of special functions

After entering the level 2 password (only for service purposes) the following settings are also possible:

Calibration

Note ① After setting the time the aperture constants can be entered or corrected.

Service

Note ② After the menu point "Language"comes the menu point "Service" with the current values for:

- Pressure sensors (p_{10}, p_{12}, p_{13}, p_{40}, p_{45}, air pressure),
- Device temperature,
- Pt100 temperature sensor (current, voltage),
- Current inputs 1 and 2
- Volume flow
- Temperature

Control variable

Note ③ After the menu point "Password" comes the menu point "Control variable" which enables the setting of time constants (medium, slow, fast), minimum throughput, isokinetic factor.

Note

Settings and displays under the menu point "Manual operation" are described in section 4.3.4.

4.3.3 Extraction measurement

After selecting and entering the necessary basic parameters as per section 4.3.2.1, the extraction of a partial gas volume can begin.
The extraction process occurs according to the following diagram:

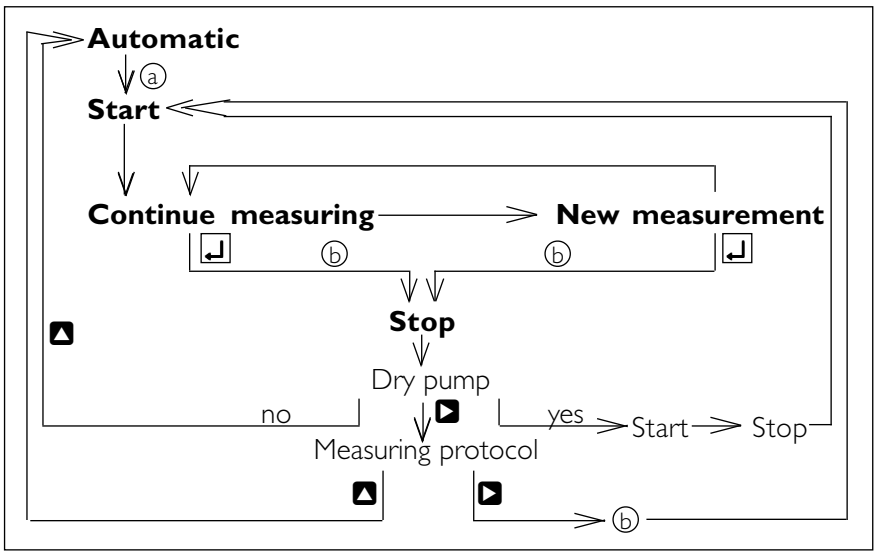


Fig. 4305 Operating process in the "Automatic" menu

Display of measured values
After selection of the "Automatic" menu the following measured values can be displayed in the manner shown:

Note ⓐ

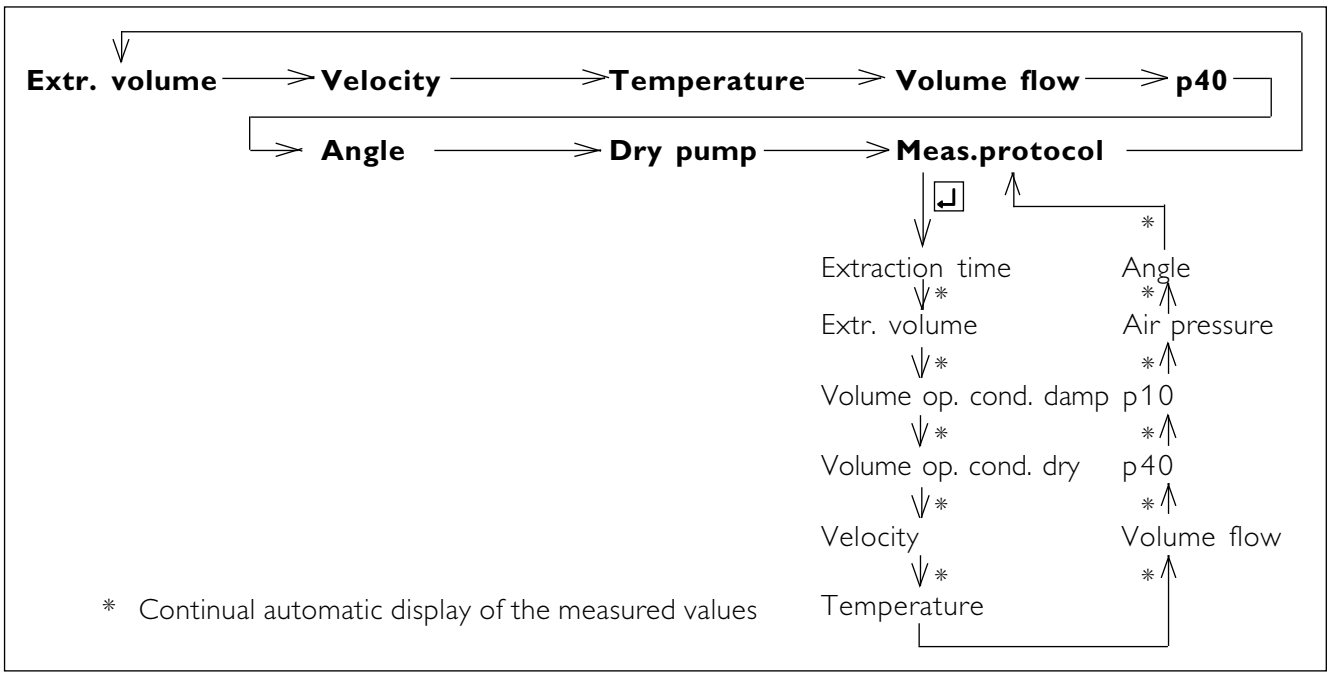


Fig. 4306 Measured value display in the "Automatic" menu

Note ⓑ

After the start of a measurement (continue measuring or new measurement) or after enquiring about the measuring protocol in the Dry pump submenu, the following values can be displayed in the order shown by using the ▶ or ◀ keys:

- Extr. volume
- Velocity
- Temperature
- Volume flow
- p40
- Angle

Through the subdivision into "Continue measuring"/"New measurement" the possibility exists for interrupting an extraction process (e.g. to change a dust collector or move the filter head probe to another measuring point) and then continue with the extraction ("Continue measuring") or begin a new extraction process ("New measurement").

Note

- Menu point "Continue measuring"
  The partial gas volume extracted in a previous measurement is used as a basis when continuing the extraction process.
- Menu point "New measurement"
  The counter in the measured value memory increases by 1 and the measured values of the subsequent measurement are saved to the allocated memory space. When the counter reaches 75 the measured values are not automatically saved on pressing the Stop key (see section 4.3.1).

During the extraction process the menu point Volume flow can be used to control whether the extraction is taking place isokinetically. The instantaneous "actual" extracted partial gas volume is compared with the nominal value for the pump control "nominal". If they are the same the extraction is isokinetic. If no agreement can be reached then it should be checked whether an unsuitable sampling diameter was used or possibly if there is a malfunction.

Warning

The nominal value must be within the operational range of the extraction pump (see section 4.2.2.2 Table 4201).
If necessary another sampling diameter should be entered in the "Parameters" menu and the corresponding collector inserted in the filter head probe.

Note

A small variation from the nominal value depends on the plant or system, as the plant parameters are measured in real time and the GRAVIMAT adapts continuously to the measured values.

4.3.4 Manual operation

The procedure for an extraction process under the "Manual operation" menu is carried out in the same manner as under the "Automatic" menu (see Fig. 4307).

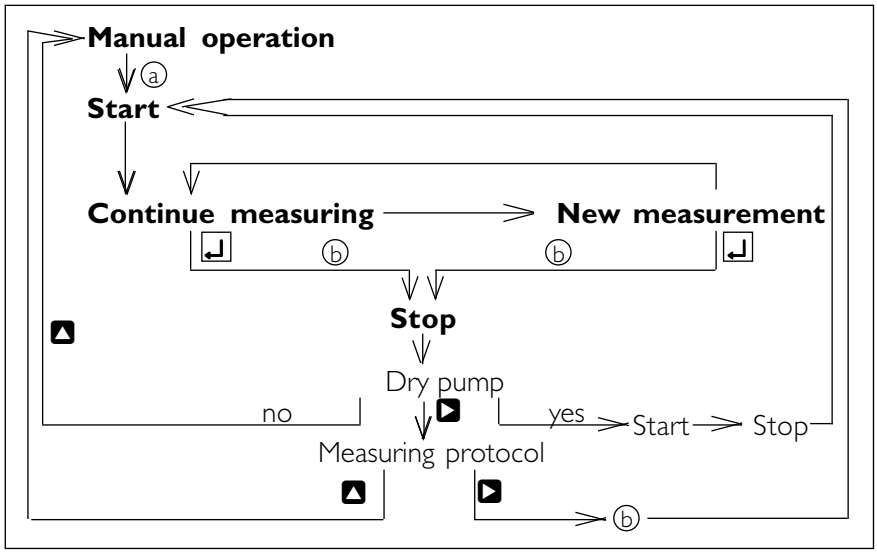


Fig. 4307 Operating procedure in the "Manual operation" menu

After pressing the Start-key a previous measurement can be continued as under the "Automatic" menu ("Continue measuring") or a new measurement can be started.

Warning

If the "New measurement" menu point is chosen, all average values from the previous measurement are irretrievably erased!

The measured values can be displayed in the same way as with an extraction measurement:

- ▶ After calling up the "Manual operation" menu (Note ⓐ)
- ▶ After the start of a measurement or after enquiring about the measuring protocol in the Dry pump submenu (Note ⓑ).

4 Measurement procedure

5.1 Determining the gross weight of the dust collector

5.2.1 Drying

The dust laden dust collector must be completely dried before each weighing process so as to eliminate faulty measurements caused by the influence of moisture. The drying process takes place in the same manner as described in section 3.3.3:

5.2.2 Weighing

The dust collectors should be weighed immediately after being removed from the desiccator. Provide a precision balance with the measuring range required for the type of dust collector used (HC or LC).
(LC dust collector - min. 20 g, HC dust collector - min. 50 g).
The dust-laden collectors should be weighed using the method described in section 3.3.3.

Note for HC collectors:
In case the only weighing machine available has a range of less than 100 g, the filter element (filter diaphragm and quartz wadding) can be weighed without the funnel and extraction tube. This is done by carefully removing the aluminium seam from the funnel as well as loosening the filter diaphragm and quartz wadding from the funnel. For this procedure it is essential that the net weight of the filter element is determined before measurement.

Warning
Adherent dust residues on the funnel and extraction tube should not be weighed when removing the filter element, due to the risk of false measurements.

Note
If the GRAVIMAT SHC 501 is only operated via the front panel on the evaluation unit, the dust concentration must be calculated separately from the empty mass and gross weight of the dust collector. For this the evaluation formulae are used (Appendix to the operating instructions).

5.2 Calulating the dust concentration

See VDI 2066, Sheet 1 for definitions

The dust concentration c is the ratio of the dust mass m contained in a determined volume v.

Dust concentration under operating conditions:

Dust load (dust content): mass flow of dust per volume flow of gas

$$c_{i.B.} = \frac{m}{V}$$

$$c_{i.B.} = \frac{m_{net} - m_{tara}}{V} \qquad (5.1)$$

$c_{i.B}$ = dust concentration under operating conditions
m_{tara} = empty weight of dust collector
m_{net} = gross weight of dust collector
V = extracted partial gas volume

Dust concentration under normal conditions

See Chapter 9, Appendix for calibration formula

$$c_{i.N.f.} = \frac{m_{net} - m_{tara}}{V_{i.N.f.}} \qquad (5.2)$$

$c_{i.N.f.}$ = dust concentration under norm. conditions wet
$V_{i.N.f.}$ = extracted partial gas volume under norm. conditions wet

$$c_{i.N.tr.} = \frac{m_{net} - m_{tara}}{V_{i.N.tr.}} \qquad (53)$$

$c_{i.N.tr.}$ = dust concentration under norm. conditions dry
$V_{i.N.tr.}$ = extracted partial gas flow under norm. conditions dry

Note:
Standard values calculated with the GRAVIMAT contain no calibration of the oxygen content. This must be done separately (see Chapter 9, Appendix).

Dust mass flow

$$\dot{M} = A_{duct} \cdot v_{ax} \cdot c \qquad (5.4)$$

$\dot{M}$ = main mass flow in duct
A_{duct} = cross-sectional surface of duct
v_{ax} = mean value of axial velocity components

For calculation of v_{ax}, see Appendix

Use the respective dust concentration for calculating dust mass flow under operating and normal conditions.

Note
The values required for determining the dust concentration and dust mass flow:

- volume flow op. cond. in exhaust gas duct (for wet gas)
- gas temperature in exhuast gas duct
- extracted partial voulme

are calculated by the GRAVIMAT SHC 501 from the "crude measuring values" of the 6 pressure sensors and the temperature sensor. Internal comparison of the pressure sensors, blend constants and gain is performed with the help of digital correction values, which are then saved to EEPROM.

See Appendix for formulae

The values measured or calculated by the GRAVIMAT can be selected using the front panel keys and displayed on the LC-Display. The mean values of the last respective measurement are saved.

Warning
When starting a new extraction measurement or determining velocity/ temperature patterns, the saved values from the previous measurement are overwritten. When analysing the dust concentration from several measuring processes, the data of each measurement must be logged.

The measured values are registered by:

- connecting a laptop to the RS 232 interface and saving the data in a file with the help of a terminal programme.
- printing out the values of each measurement process on a printer
- entering the values into the formula provided (see Operating Instructions, Appendix).

5 Measurement evaluation

6.1 Maintenance of the filter head probe GS5

6.1.1 Regular maintenance

The required maintenance work shown in the following table is partly subdivided into basic and intensive cleaning procedures. This maintenance work is to be carried out at regular intervals and if possible after every measurement of long duration.

Measures	Remarks
Removing of residual condensate	**Basic cleaning** Blow-drying the partial gas and pressure sensing conduits from the end of the multichannel hose using (compressed) air. Pressure > 500 mbar must be absolutely avoided. **Intensive cleaning** Removing and cleaning the support plate and the measuring aperture. **Warning** Do not damage the sharp edges of the aperture bores. Cleaning is carried out by purging or by blow-cleaning using water - air - alcohol - air. This sequence of work must be observed.
Removal of deposits	Dust deposits, corrosion and similar contaminates must be removed regularly from the probe, the filter head and the temperature sensor. To do so remove the support ring and aperture if necessary.
	Basic cleaning Cleaning with cloth and brushes using water and then alcohol.
	Intensive cleaning The same method as required for basic cleaning, but preceded by cleaning with a caustic agent (caustic solution: 25% HNO_3, 2% HF, rest H_2O). **Warning!** Observe work safety instructions for handling acids!
Inspection of rubber components	After temperature loads >200 °C the gasket in the filter head should be checked and replaced if necessary. The multichannel hose, in particular at its ends, has to be inspected for brittling and formation of cracks. If necessary, the damaged end should be cut off or the hose should be replaced (for advice on replacement, see Chapter 9).
Pt 100 temperature sensor	The temperature sensor should be checked for insulation resistance and replaced if necessary (including temperature sensor conduit).

Note:
Blow-drying can take place by using the extraction pump (menu "drying").
This is done by connecting a suitable hose to the pump outlet.

Measures	Remarks
Filter head probe safety lock	Check seal for contamination or tears. **Warning!** The seal must not be damaged! Cleaning can be carried out by washing and blow-drying with water - air - alcohol- air. This sequence must be observed.
	Check screw thread for dirt or damage. Clean screw thread with bristle brush if necessary. Any damage can be carefully removed using a triangular file.

6.1.2 Leak check

Note
The test agent (Accessories, see Section8.3) for the volume flow measurement can be used for simple testing for leaks in the gas paths and the temperature measurement (For instructions see the accompanying manual).

To check the tightness of sampling conduits and pressure measuring conduits the filter head probe should be connected to the evaluation unit.

Pressure measuring conduits for p_1, p_2 und p_3 (Determination of the gas velocity in the exhaust gas duct)

At the pressure measuring bores p_1, p_2 und p_3 on the probe head the following test pressures are produced by means of an injection with a shortened needle and pierced soft rubber screen or rubber suction foot:

Meas. variable	Value	Display in "Automatic" menu under
p_1	ca. 10 mbar	p_duct (p_{10})
p_2 and p_3	–10 mbar	v_duct or angle

The pressure displays must remain constant for this.

Pressure measuring conduits for p_4 und p_5 (Determination of the partial volume flow)

Set the "Manual operation/volume flow" menu, turn on the pump and close the control valve with the ▲ key. The extraction aperture should be sealed tightly on the inserted LC or HC dust collector (e.g. with the finger cone).

Tightness criteria:
p_{45} = 0
p_{40} between -200 and -500 mbar

If errors or implausible values come up in the tightness check the internal piping can be checked with the help of Fig. 6101. Loose hose connections should be replaced (comp. spare parts, section 8.4). To exchange the hose connections in the electronic unit the front panel should be removed.

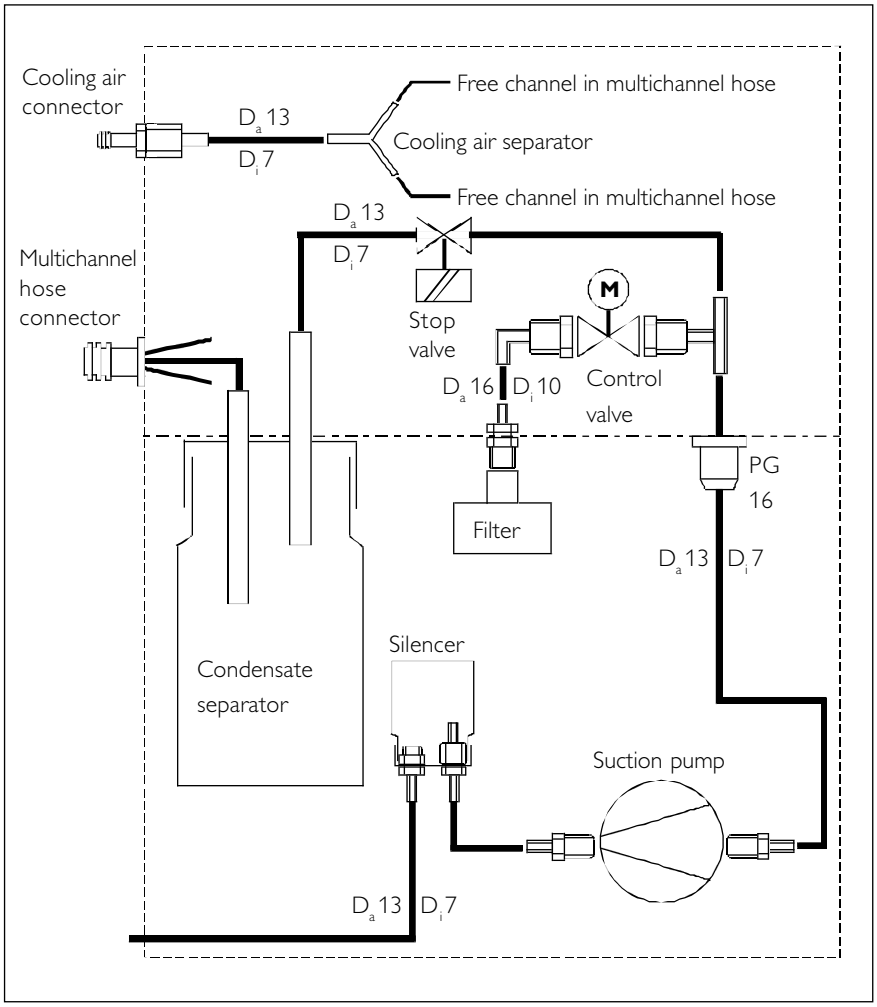


Fig. 6101 Evaluation unit internal piping

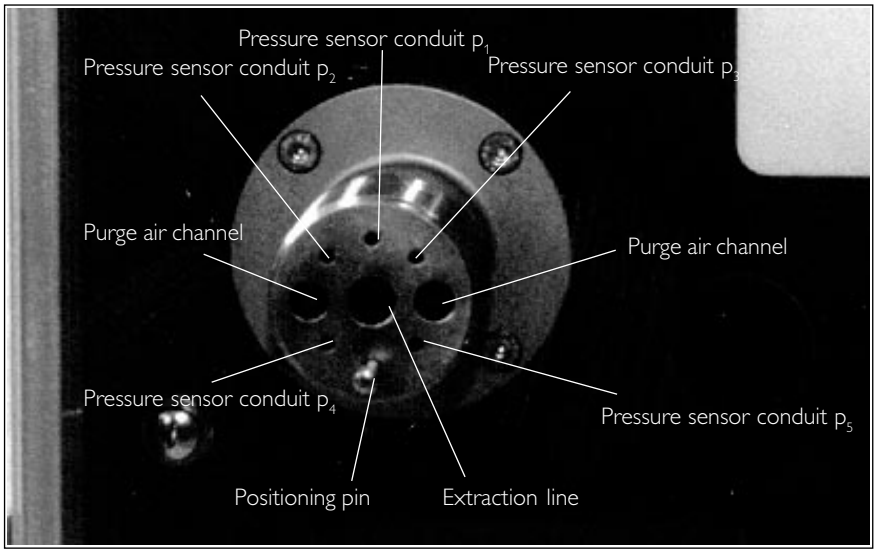


Fig. 6102 Connection piece on the evaluation unit for the connector on the filter head probe

6.2 Maintenance of the evaluation unit

Maintenance of the evaluation unit is essentially limited to cleaning work.

Condensate separator

The condensate separator must be emptied after each measurement. In order to do this the condensate separator must be unscrewed and removed from the Evaluation unit (see Fig. 6201).

Fig. 6201 Removed Condensate separator

Warning

The relevant legal stipulations are to be observed and adhered to when disposing of the collected condensate (the condensate should be treated as hazardous waste)!

Extraction pump

The pump must be carefully dried after each measurement. Allow the pump to run empty for a while (at least 10 min.).
The procedure happens in two stages:

- Rinsing with ambient air (stop valve open, control valve closed)
- Drying (stop valve closed, control valve open).

Additional work

- Clean the interior of the evaluation unit (pump area)
- Clean front panel

  Warning

  Do not clean the front panel with solvents (only water + harmless washing agent)
- Replace the filter in front of the control valve if the minimum partial volume flow is too great.

6.3 Calibration of the evaluation unit

Before the GRAVIMAT SHC 502 is despatched, the gain factors for the pressure sensors, temperature sensing equipment (sensor and gain) and orifice are calibrated in the probe head for determining the partial volume flow.
As a rule, calibration by the operator is not required. The unit only needs to be re-calibrated if the relevant parts have been replaced (or repaired at the factory).
In exceptional cases the following parameters may have to be calibrated:

- Zero point of the pressure sensors
- Aperture constants

Further parameters (e.g. conductance of pressure sensors) can only be checked and calibrated in the factory.
Changes in the sensor conductance occur very rarely and indicate that the sensors are defective or overloaded.

Zero point malfunctions can arise after long periods of operation through alterations, increased temperature fluctuations or overloading of the pressure sensors.

Note

It is recommended that a zero point calibration is carried out after switching on the device before every measurement (e.g. after changing a dust collector) (see section 4.2.2.3).

6.3.1 Zero point calibration

Zero point calibration may only be carried out if there is no differential pressure to the ambient air pressure at the sensors. That is the case if the probe is not properly connected.
Zero point calibration can only be carried out for the pressure sensors p_{12}, p_{13}, p_{45}, p_{40} and p_{10}. The calibration is performed in the menu "special functions / calibration / zero point". In the time required for this, approx. 5 seconds, there must be no pressure change on the pressure sensors connector.

Warning

It is a strict requirement for zero point calibration that all of the pressure conduits are depressurized. Non-compliance with this requirement (e.g. flow against probe by air currents) will result in a complete misalignment of the unit.

6.3.2 Aperture constants

The aperture value corresponds to the calibrated values of the probe (standard approx. 12-13 mm²). The aperture value can be determined with the GRAVIMAT.
The aperture constant can be corrected by selecting the "Service/ maintenance - System check" menu. For calibration, the help material for the tightness check or a precision gas meter can be used.

6.3.3 Setting time and date for protocols

The corresponding submenu should be selected under the menu "special functions / calibration". Each digit can be individually selected and altered.

Setting time

HH : MM : SS

HH :	Hours	from 00 ... 23
MM :	Minutes	from 00 ... 59
SS :	Seconds	from 00 ... 59

Setting date

DD : MM : YY

DD :	Day	from 01 ... 31
MM :	Month	from 01 ... 12
YY :	Year	from 00 ... 99

7.1 No measurement possible

Symptom	Possible cause	Remedy
Display and LEDs do not illuminate	• Faulty power supply • Pump plug not correctly inserted • Defective fuses	• Remove device from power supply • Check power supply cable • Test pump plug • Check fuses
Pump doesn't start after pressing the "Start" key	• Dried condensate deposits	• Remove device from power supply • Open pump cover • Clean the rotor and rotary valve and make them movable

7.2 Troubleshooting table

A self-test is automatically carried out after switching on the GRAVIMAT. The main menu appears if the device is functioning correctly.
If there is a malfunction, a fault code appears in the last line on the display.

Code	Possible cause	Action
0x0001 0x0002	CRC-error in reading the EEPROM	Set to standard factory setting by switching the device off and then back on (repeat as many times as necessary)
0x0010 0x0020 0x0040 0x0080	Error in reading the RAM range 1 Error in reading the RAM range 2 Error in reading the parameter range Error in last measurement (incomplete)	The values from the last measurement are erased (previous ones are saved).
0x0100	Error in the real time clock	Check the battery on the processor board

If the following messahes appear on the screen:
▶ SHC-Code Error (error in the hardware coding) or
▶ SHC-Device Error (error in the copy protection)
the electronic unit should be sent to the factory for repair.

7 Troubleshooting

8.1 Overview of technical data

Filter head probe GS5	
Measuring range	
▶ with LC dust collector	0.1 .....200 mg/m³
▶ with HC dust collector	50 ...50.000 mg/m³
Gas velocity in duct	2 ... 48 m/s
Partial volume flow	0.5 ...2.4 m³/h
Temperature range	Up to 250 °C without restriction Above 250 °C cooling air necessary overpressure 30 - 50 kPa, consumption 5 - 10 m³/h Up to 280 °C probe extension max. 1.5 m (only use with cooling air) Up to 400 °C without probe extensions, only use with cooling air Up to 600 °C special design filter head probe; use without extensions (only with cooling air)
Measurements	
▶ Probe head	Outer diameter 62 mm
▶ Probe shaft	Outer diameter 51 mm; length 1m (standard version) Special lengths 0.5 to 1.5 m on request
Weight	7.3 kg (with multichannel hose, length 5m)
Installation port required in duct (for installing probe mounts)	Minimum diameter 80 mm, preferably larger
Probe extensions	
Standard	Length 1.5 m; weight 2.75 kg
Special design	Length 0.5 ... 3 m: weight 0.95 to 5.5 kg
Carrying cases	
Standard	For filter head probe length 1m and max. 2 probe extensions length 1.5m
Measurements, weights	Approx. 1700 x 250 mm x 150 mm (L x W x H); 4.2 kg
Special design	For special length filter head probe and/or probe extensions
Probe mount	
with protective sleeve	Measurements 280 x 163 x 103 mm (L x W x H); weight 2.0 kg
without protective sleeve	Measurements 100 x 163 x 103 mm (L x W x H); weight 1.5 kg
LC dust collector	
Extraction diameters	4.2 / 5.2 / 6.4 / 8.0 / 10.0 / 11.5 mm
Empty weight	Approx. 16 g
Filter	Plane filter diameter 50 mm
Material	Stainless steel; for extraction diameter 6.4 mm also in titanium
HC dust collector	
Extraction diameters	4.2 / 5.2 / 6.4 / 8.0 / 10.0 / 11.5 mm
Empty weight	Funnel approx. 25 g; extraction tube approx. 22 g
Filter	Plane filter diameter 50 mm; approx. 3 g additional quartz wadding
Material	Stainless steel funnel; brass/stainless steel extraction tube

8 Technical Data

Dust collector case	
Measurements	365 x 315 x 145 mm (W x D x H)
Empty weight	2.5 kg
Evaluation Unit	
Displays	▶ 4 line LC-Display for measured values and parameters, illuminated ▶ LED function keys indicating readiness for operation
Interfaces	▶ Connector for filter head probe multichannel hose ▶ Cooling air connector (30 ... 50 kPa, 5 ... 10 m³/h) ▶ Pt 100 temperature measurement sensor connector ▶ RS 232, 9600, N, 8, 1
Sensors	Pressure sensors for ▶ Dynamic pressure p_{12} 0 ... 12.5 mbar ±0,2 % ▶ Dynamic pressure p_{13} 0 ... 12.5 mbar ±0,2 % ▶ Orifice pressure p_{45} 0 ... 25 mbar ±0,2 % ▶ Duct pressure p_{10} -70 ... +70 mbar ±0,2 % ▶ Probe pressure p_{40} -500 ... +100 mbar ±1 % ▶ Barometric pressure p_0 770 ... 1250 mbar ±1 % Pt100 temperature sensor -30 ... +700 °C
Extraction pump	rotary disk pump; typical extraction power 2 m³/h (without dust collector) configurable for 115 V AC or 230 V AC
Volume flow measuring accuracy	±1 % from maximum flow rate
Control valve, shut-off valve	24 V DC
Condensate separator	approx. 0.8 l volume; made of plastic
Fuse	T4 A
Power supply	115 /230 V AC, 50/60 Hz
Power consumption	approx. 400 W with extraction pump switched on
Protection class	IP 54 in opened condition (in closed condition IP 65)
Measurements	555 x 320 x 355 mm
Weight	24 kg
Ambient temperature	-10 ... +50 °C

8.2 GRAVIMAT SHC 501 standard design

Description	Quantity	Order number
GS 5 Filter head probe, length 1 m; with 5 m multichannel hose	1	7 040 187
Probe extension 1.5 m	1	7 040 024
Carrying case for filter head probe and 2 probe extensions	1	7 040 002
Probe mount with protective sleeve	1	7 040 001
Special LC case with 24 dust collectors	1	7 040 009
Special HC case	1	7 040 183
AE-SHC501 Evaluation unit	1	7 040 185

8.3 Accessories, optional extras

Description	Order number
DN 80 Installation flange with tube length 200 mm, with cover; material St 37	7 040022
R3" Adapter flange, with cover	7 040023
Probe mount without protective sleeve	7 040095
GS 5 Filter head probe special length (between 0.5 and 1.5 m)	7 040188
GS 5-HT Filter head probe for up to 600 °C, length 1 m	7 040189
Probe extension 0.5 m	7 040102
Probe extension 1.0 m	7 040104
Special length probe extension (between 0.5 and 3 m)	7 040190
Special length carrying case	7 040184
SHC 500 Hose extension, complete, length 5 m	7 040169
Titanium LC dust collector, extraction diameter 6.4 mm	7 040227
AE-SHC501 Evaluation unit, 115 V AC	7 040186
RS 232 interface cable	7 040012
SHC-5 Transport kit	7 040027
Leak testing kit	7 040202
Spare parts set	7 040070
On request	
Toshiba Laptop	
Portable ink jet printer, with battery pack	
Precision balance with RS 232-interface	

8.4 Consumable parts

Description	Order number
Support plate, diameter 46 mm, with sealing washer	7 040 005
Ring plug screw for LC collector	7 040 046
Ring plug screw for HC collector	7 040 106
Aluminium foil rings, pack of 100	7 040 026
Filter for pump	7 040 058
K21 seal for safety lock hose connectors	7 040 220
Filter material	
Paper no. 604 (Schleicher & Schüll), for up to 150 °C, pack of 100	7 040 036
Glass fibre no. 8 (Schleicher & Schüll), up to 250 °C, pack of 200	7 040 037
MN 85/90 BF (Machery-Nagel), up to 500 °C, pack of 25	7 040 039
Quartz fibre MK 360 (Munktrell), up to 950 °C, pack of 25	7 040 040
Polycarbonate 0.4 µm (Oxyphen), up to 180 °C, packof 100	7 040 041

8.5 Spare parts

Designation	Order number
GS 5 Filter head probe	
Support plate, diameter 46 mm, with sealing washer	7 040 005
Support plate, diameter 50 mm, without sealing washer, for up to 400 °C	7 040 074
Measuring orifice with sealing washer	7 040 193
Ring plug screw for LC collector	7 040 046
Ring plug screw for HC collector	7 040 106
Cap for filter head	7 040 065
Multichannel hose (by the metre) *	7 040 003
PT 100 measuring sensor with line **	7 040 192
Plug for temperature sensing line	7 045 641
Nut for multichannel hose safety lock	7 040 194
K21 seal for safety lock hose connector	7 040 220
GS 5 Filter head probe safety lock hose connector	7 040 221
Probe grip	7 040 044

* Replace only by using a special tool, see Appendix
** without plug

Designation	Order number
Dust collector	
Empty case for LC dust collectors	7 040051
Empty case for HC dust collectors	7 040191
Seaming equipment	7 040080
Stainless steel LC dust collector, extraction diameter 4.2 mm	7 040028
Stainless steel LC dust collector, extraction diameter 5.2 mm	7 040 029
Stainless steel LC dust collector, extraction diameter 6.4 mm	7 040 030
Stainless steel LC dust collector, extraction diameter 8.0 mm	7 040 031
Stainless steel LC dust collector, extraction diameter 10.0 mm	7 040 032
Stainless steel LC dust collector, extraction diameter 11.5 mm	7 040 033
Funnel for HC dust collector	7 040 105
Extraction tube for HC dust collector, extraction diameter 4.2 mm	7 040 109
Extraction tube for HC dust collector, extraction diameter 5.2 mm	7 040 110
Extraction tube for HC dust collector, extraction diameter 6.4 mm	7 040 111
Extraction tube for HC dust collector, extraction diameter 8.0 mm	7 040 112
Extraction tube for HC dust collector, extraction diameter 10.0 mm	7 040 113
Extraction tube for HC dust collector, extraction diameter 11.5 mm	7 040 114
Dummy plug for HC dust collector	7 040 108
Inlet nozzle for soot collector	7 040 107
Hose connector for multichannel hose extension	7 040 223
Evaluation Unit	
Complete front panel for AE-SHC501	7 040201
Sensor board	7 040198
Condensate separator	7 040969
Shut-off valve with connection cable	7 040195
Control valve with connection cable	7 040196
Pump 230 V AC, with cable and plug	7 040117
Pump 115 V AC, with cable and plug	7 040118
Evaluation unit hose connector	7 040222

8.6 Scale diagrams

8.6.1 Filter head probe

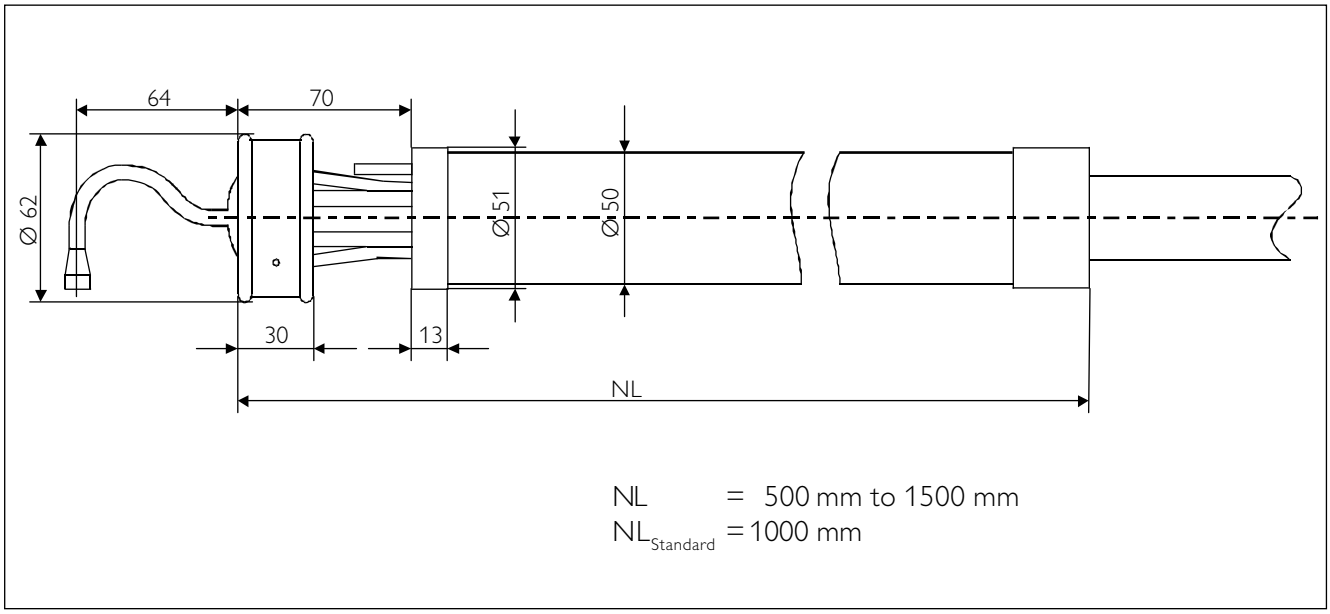


Fig. 8601 Filter head probe with LC dust collector (without hand grip)

8.6.2 AE-SHC501 Evaluation unit

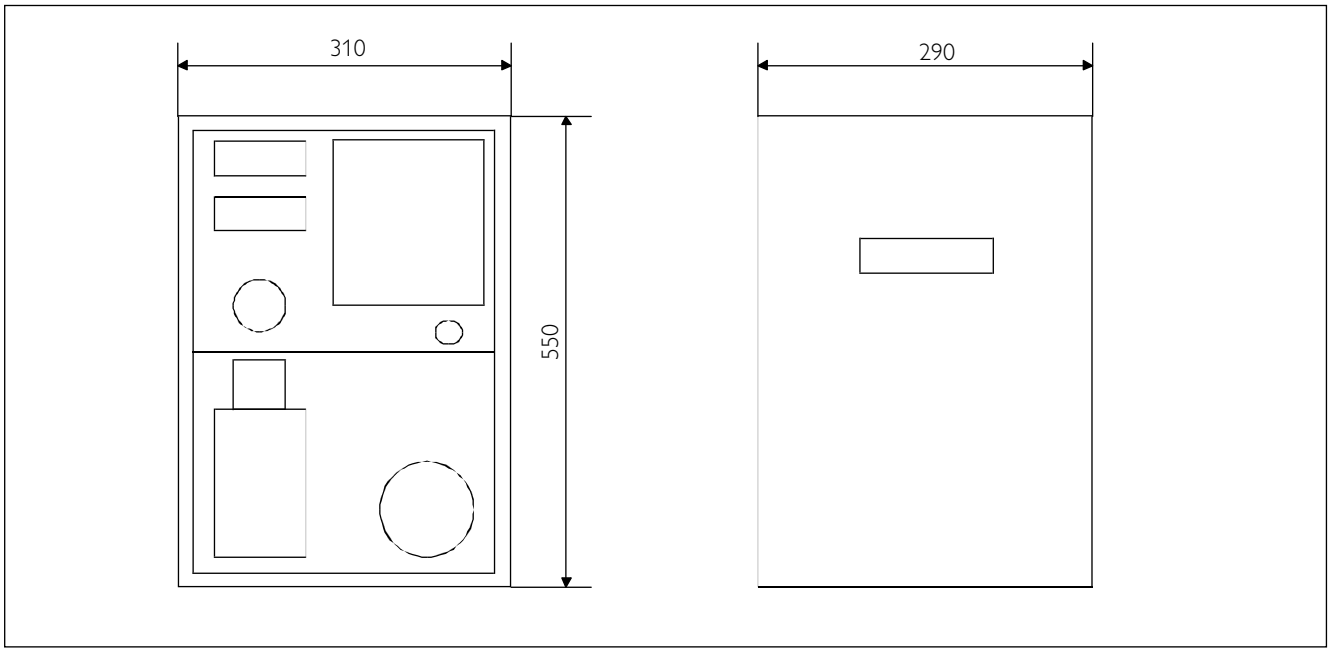


Fig. 8602 Evaluation unit

9.1 Formula overview

The partial volume flow and extracted partial gas volume are calculated with the GRAVIMAT SHC 501 from the "basic measuring values" of the 6 pressure sensors and the temperature sensors based on sequential formulas.

Dynamic pressure

$$p_{Dyn} = \frac{p_{12} + p_{13}}{2 \cdot \beta}$$

$\beta = f_1(\alpha)$ dynamic pressure correction value depending on the angle of flow (detected in wind channel)

Angle of flow

$\alpha = f_2(p_{12}, p_{13})$ characteristic curve detected in wind channel

Angle α is only determined within the range -22.5° to +22.5°.
If greater values appear, the program uses the violated limit values.

Main gas flow velocity (Axial component) in the duct

$$v_{ax} = \sqrt{\frac{2 \cdot p_{Dust}}{\rho}} \cdot \cos \alpha$$

with the gas density ρ in the duct

$$\rho = \rho_N \cdot \frac{T_N}{T} \cdot \frac{(p_0 + p_{10})}{p_N}$$

ρ_N = gas density under normal conditions (standard density)
p_N = standard pressure (1013 mbar)
T_N = standard temperature (273.15 K)
T = operating temperature of the gas in K
p_0 = ambient air pressure in mbar
p_{10} = static pressure in the duct in mbar

9 Appendix

Dust concentration under normal conditions

Normal conditions wet

$$c_{i.N.w} = c_{i.\,B.} \cdot \frac{T}{T_N} \cdot \frac{p_N}{p}$$

$c_{i.N.w}$ = dust concentration in normal conditions wet
$c_{i.N.w}$ = dust concentration under operating conditions
T = operating temperature of the gas in K
T_N = standard temperature (273.15 K)
p_N = standard pressure (101323.2 Pa)
p = absolute operating pressure in Pa

Normal conditions dry

$$c_{i.N.d} = c_{i.\,N.d} \cdot \frac{100}{100 - F}$$

$c_{i.N.d}$ = dust concentration under normal conditions dry
F = gas humidity (in volume percent)

Normal conditions dry O_2 calibrated

$$c_{i.N.O2} = c_{i.N.d} \cdot \frac{21 - O_2\,(ref.)}{21 - O_2\,(meas.)}$$

O_2(ref.) = reference value of oxygen content according to BImSchV (German emissions legislation)
O_2(meas.) = measurement value of oxygen content

Partial mass flow

$$\dot{m} = A_{orifice} \cdot \sqrt{2 \cdot p_{45} \cdot \frac{\rho_N \cdot T_N}{p_N} \cdot \frac{(p_{40} + p_0)}{T}}$$

$\dot{m}$ = partial mass flow
$A_{orifice}$ = orifice constant in m²
p_{45} = differential pressure of meas. orifice in Pa
ρ_N = gas density under normal conditions wet
T_N = standard temperature (273.15 K)
p_N = standard pressure (101323.2 Pa)
p_{40} = probe pressure in Pa
p_0 = ambient air pressure in Pa
T = operating temperature of the gas in K

Actual partial volume flow op. cond.

$$Q_{act.} = \frac{\dot{m}}{\rho}$$

$Q_{act.}$ = actual partial volume flow
$\dot{m}$ = partial mass flow
ρ = gas density

Nominal partial volume flow op. cond.

$$Q_{set} = \frac{\pi}{4} \cdot D_S^{\,2} \cdot v_{ax}$$

D_S = extraction diameter of dust collector in m
v_{ax} = main gas velocity (Axial component) in the duct in m/s

Extracted partial gas volume

$$V = \int_0^{t_{extr.}} Q \, dt$$

V = extracted partial gas volume
$t_{extr.}$ = total extraction time of all measuring points

9.2 Physical composition

Standard density ρ_N

The standard density depends on pressure and water vapour content, as well as the relevant saturation temperature of the water vapour (=dew point temperature of gas).

In most cases the measured gas is wet flue gas or humid air. The standard density of dried air amounts to 1.296 kg/m³. 1.33 kg/m³ is a good mean value for dry flue gas.

The standard density of humid air and wet flue gas can be taken from the following diagram.

9 Appendix

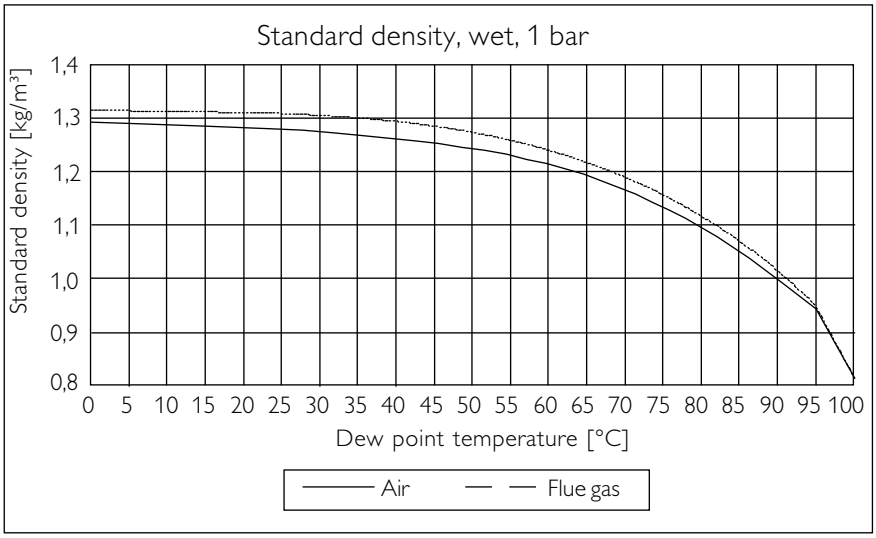


Fig. 9201 Standard density in humid air and wet flue gas

The characteristic curve is strictly valid for 1 bar measured gas press-ure, however pressure differences of up to 50 mbar can normally be ignored (density error <1%).

Water vapour/dew point

The water vapour content of the measured gas depends on the saturation temperature (= dew point temperature). The characteristic curve (following diagram) applies to measured gas pressure of 1 bar.

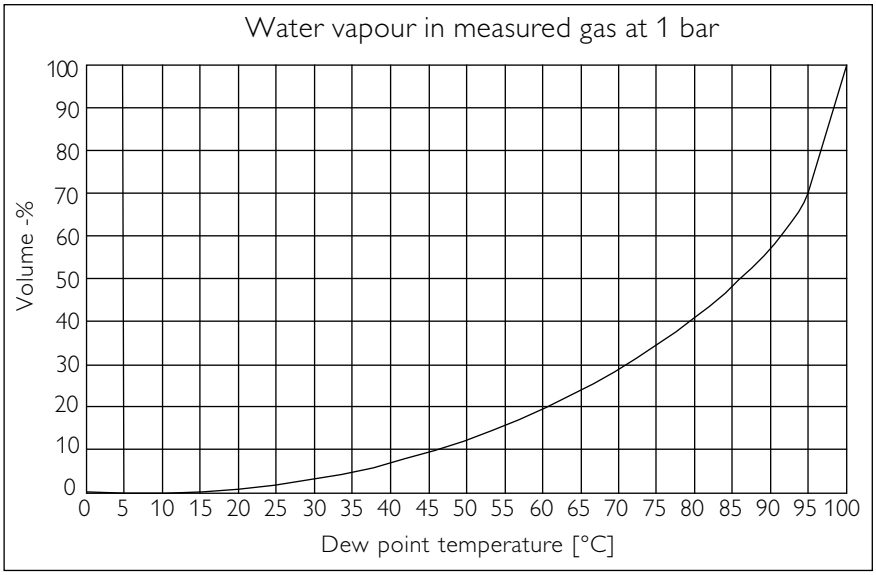


Fig. 9202 Characteristic curve for measured gas pressure 1 bar

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