testo ASET15 1

User Manual

Content

1 Declaration of Warranty

Manual Version History:
Version: V1.1
Date: September 2016

1.1. Type of Designation

This user manual refers to the instrument type and version as listed below. It replaces all previously dated user manuals for this instrument.

Type: testo ASET15-1

1.2. Manufacturer

Testo SE & Co. KGaA
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Germany

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1.3. Warranty

Testo SE & Co. KGaA warrants that this product adheres to the specified properties for a period of twelve (12) months from the date of delivery.

Excluded from the warranty are all parts subjected to normal wear as any fuses, batteries or other consumable parts. Also excluded are: Defects resulting from abnormal use, in particular outside the intended purpose; lack of maintenance; improper use or malicious damage. Warranty is void if actions are carried out which are not described in the documentation nor authorized by Testo SE & Co. KGaA.

Testo SE & Co. KGaA does not provide any warranty on finished goods manufactured by others. Only the original manufacturer's warranty applies.

There are no user-serviceable parts inside testo ASET15-1 and some very sensitive parts. Do not open your testo ASET15-1, as you may damage it. Warranty is voided if the case is opened and warranty-seal is broken.

Parts repaired or replaced as a result of repair services are warranted to be free from defects in workmanship and material, under normal use, for 90 days from the date of shipment.

2 Precautions

2.1. Foreword

This manual guides you through the installation, starting up, operation and maintenance procedures of the testo ASET15-1. In detail you will find information about the system as

- safety
- functionality of the testo ASET15-1, technical information and specifications
- installation of the testo ASET15-1 and accessories
- handling, operation, maintenance and troubleshooting

Follow the instructions provided by this manual for safe and proper operation of the testo ASET15-1 Air Supply / Evaporation Tube.

Before installing and operating the testo ASET15-1, the operator or service has to read carefully this manual. For improper function, damages or injuries caused by ignoring the instructions by this manual no liabilities are accepted.

2.2. Liabilities

Testo SE & Co. KGaA accepts no liability to improper function or injury caused by

- neglecting the instructions provided by this manual or instructed person.
- improper installation, operation, application, or maintenance.
- operation by untrained staff.

- any technical modification not carried out by Testo SE & Co. KGaA or an authorized service partner.
- use of not genuine spare parts.

2.2.1. Liability to Content

The content of this manual is generated with most accurateness. Testo SE & Co. KGaA does not guarantee completeness, correctness and being up to date. Testo SE & Co. KGaAreserves the right to revise the content of the manual at any time and without notice.

Follow the guidelines below to ensure proper operation of the instrument:

- Read this instruction manual before installation and operation.
- Always use genuine replacement parts supplied by Testo SE & Co. KGaA.
- For operating the testo MD19-3E Rotating Disk Diluter integrated in the testo ASET15-1, refer to the testo MD19-3E user manual.

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3 Safety

3.1. Risk Types

The following diagram shows typical risks that could cause damage or injury while handling the testo ASET15-1 Air Supply / Evaporation Tube.

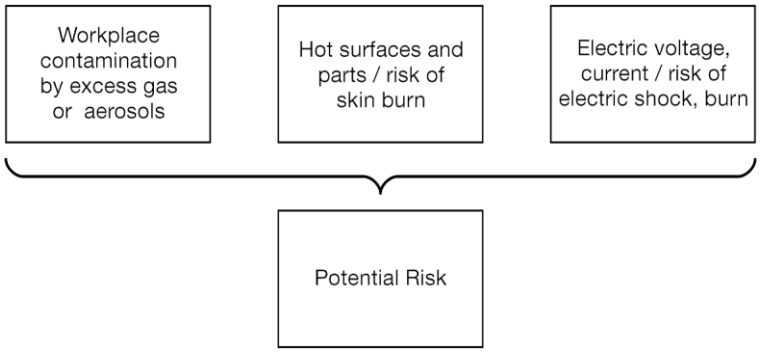

Fig.3.1 : risk types

3.1.1. Aerosol Contamination

Toxic aerosols may escape from the device, if the excess and measuring gas ports are not properly connected to the sensors downstream or an offtake.

3.1.2. Hot Surfaces – Burn Hazards

The evaporation tube is heated up to 400°C/752°F. Therefore, the pipes and other parts on the rear side of the device may be hot and must not be touched. Always ensure good air circulation around the heated parts. Do not use the device if the fan for gas cooling on the rear side of the device does not work properly.

3.1.3. Electrical Safety

When in operation any electrical equipment can produce dangerous voltages. Failure to observe the warnings may result in serious injury or damage. It is, therefore, mandatory that only suitably qualified personnel use this instrument. Satisfactory and safe operation of this instrument calls for proper handling in transportation, storage, installation as well as careful control and maintenance.

3.1.4. Mechanical Shock

Parts of the Instrument are thermally insulated by a quartz glass tube that may be damaged when exposed to intense mechanical shock. The device should be handled with care.

3.2. Labels and Explanations

When operating the testo ASET15-1, the user always is operating under certain risk factors as electricity, hot surfaces, and the aerosols which are processed by the dilution and conditioning system. Therefore the testo ASET15-1 includes several safety features. Nevertheless, some precautions still need to be taken to ensure safe and reliable operation. Listed labels, Caution and Warning are explained in general, and the further specific labels refer to type of hazard and danger.

Caution

Caution means be careful. If you do not follow the manual instruction you might cause an instrument or accessories damage, but no human injury. Also Caution refers to important information about installation, operation and maintenance.

Warning

Warning means that improper operation could cause a serious human or instrument damage or injury with consequence of irrevocable instrument damage.

Electric Shock

Hazardous voltage. Contact may cause electric shock or burn. Turn off and lock out system power before servicing.

Electric Ground

This sign indicates that the mains connector and cabinet ground are connected to protective earth PE.

Skin Burn

Hot surface. Do not touch. To avoid possible skin burns, wear heat protection gloves or turn heating off and allow surfaces to cool down before servicing. Ensure good air circulation around labeled parts.

Aerosol

Aerosols containing invisible nanoparticles and toxic exhaust gases are handled. Some aerosols may escape from the testo ASET15-1 if the excess gas and measuring gas ports are not thoroughly connected to an offtake and the aerosol sucking sensors.

4 System Overview

4.1. Dilution and Conditioning

4.1.1. Principle

testo ASET15-1 Air Supply / Evaporation Tube is an accessory for the testo MD19 which is the Rotating Disk Diluter with external diluter head for performing the primary dilution as close as possible to the aerosol source.

This combination complies with the method of ThermoDilution according to the regulation for nanoparticle measurement UN-ECE R83 and R49. ThermoDilution with testo MD19 and testo ASET15-1 separates sampling, dilution and conditioning of the aerosol into the following steps:

- Primary dilution of combustion engine emissions from tail pipe or CVS with the testo MD19-diluter. testo ASET15-1 generates the primary dilution air for the testo MD19-diluter with a calibrated and controlled flow of 1.5 l/min.
- Removal of volatile particles in the Evaporation Tube where the temperature can be adjusted up to 400°C (recommended heating temperature according to GRPE-draft = 300 °C). No recondensation takes place in the cooling down zone assuming the measuring gas is below the dew point after primary dilution.
- Secondary dilution in an adjustable dilution factor range from 1 to 11 in a mixing assembly whose construction minimizes thermophoretic losses. The primary diluted measuring gas from the primary testo MD19-3E diluter with a flow of 1.5 l/min and the evaporation tube is diluted with secondary dilution air generated in testo ASET15-1. Its flow is adjustable in a calibrated range of 0...15 l/min corresponding to a dilution factor range of 1...11. The total measuring gas flow, up to 16.5 l/min enables the user furthermore to connect nanoparticle instrumentation, which consumes higher measuring gas flows than can be drawn from the testo MD19-diluter, whose diluted measuring gas flow is limited to 5 l/min.

4.1.2. ThermoDilution

Fig. 4.1 shows a schematic plot of the mass concentration of a volatile compound against the temperature of the surrounding gas. In a dilution tunnel both the concentration and the temperature of the substance are reduced (path A → B). During dilution, the compound passes its dew point and nucleates into nanodroplets (curve N). Subsequent secondary dilution (B → D) will reduce the number concentration of the droplets, but is unable to evaporate them, because of a hysteresis effect between nucleation and evaporation.

A strategy to avoid the mere formation of nanodroplets is direct sampling from the hot exhaust in combination with hot dilution (A → C). Given a sufficient dilution factor, the volatiles will not nucleate during subsequent cooling (C → D) even though the same final state is assumed as through dilution tunnel and secondary dilution (A → B → D). However, in some applications e.g. measurement on CVS tunnel, direct sampling is not possible, and nanodroplets already exist in the gas sample (B). In those cases the diluted gas sample (D) has to be heated above the evaporation point of the compound (C → D, crossing curve E). Like with hot dilution, the compound remains in vapor phase upon subsequent cooling (C → D). The combination of diluter and heater (B → D → C → D) is known as ThermoDiluter. Hot dilution is realized in Testo rotating disk diluters. Together with Testo rotating disk diluter testo MD19-3E the testo ASET15-1 forms a complete ThermoDiluter system.

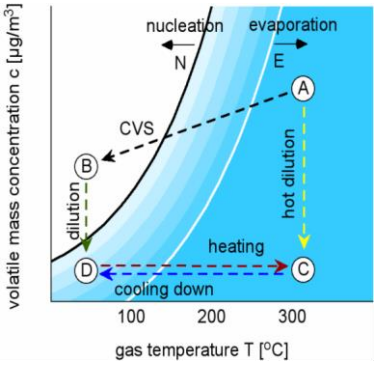

Fig.4.1: volatile mass diagram

4.2. Definitions

Air Supply	primary and secondary dilution air supply part of testo ASET15-1
Evaporation Tube	thermally insulated stainless steel tube with electronically controlled heater on the testo ASET15-1 rear side for heating up the primarily diluted measuring gas.
Raw gas	undiluted aerosol from the emission source
Measuring gas	primary or secondary diluted aerosol from the emission source (combustion engine or CVS).
Primary dilution	Takes place in testo MD19-3E rotating disk diluter before the measuring gas enters into the evaporation tube.
Secondary dilution	Dilution of the primarily diluted and thermally conditioned measuring gas at the outlet of the evaporation tube.

4.3. Abbreviation, Units and Symbols

testo ASET15-1	Air Supply Evaporation Tube; 15 = 15 l/min air supply; 1 = version 1
CVS	Constant Volume Sample – fullstream dilution tunnel in vehicle test benches
DF	Dilution Factor in secondary dilution: DF = $(Q_{AS} + Q_{MD})/ Q_{MD}$
PCRF	Particle Concentration Reduction Factor
LED	Light Emitting Diode – used as signal lamps at the front of the testo ASET15-1
l/min (STP)	Standard liter per minute: unit for gas volume flow at Standard Temperature and Preasure (STP: 1013,25 hPa, 0°C)
testo MD19-3E	Type designation for Testo rotating disk diluters
Q_{MD}	primary diluted measuring gas flow from the testo MD19-3E primary diluter
Q_{AS}	secondary dilution air flow from the air supply part of testo ASET15-1
Q_{MG}	secondary diluted measuring gas flow to the connected instrumentation
Q_{EX}	excess secondary diluted measuring gas gas flow

4.4. The System

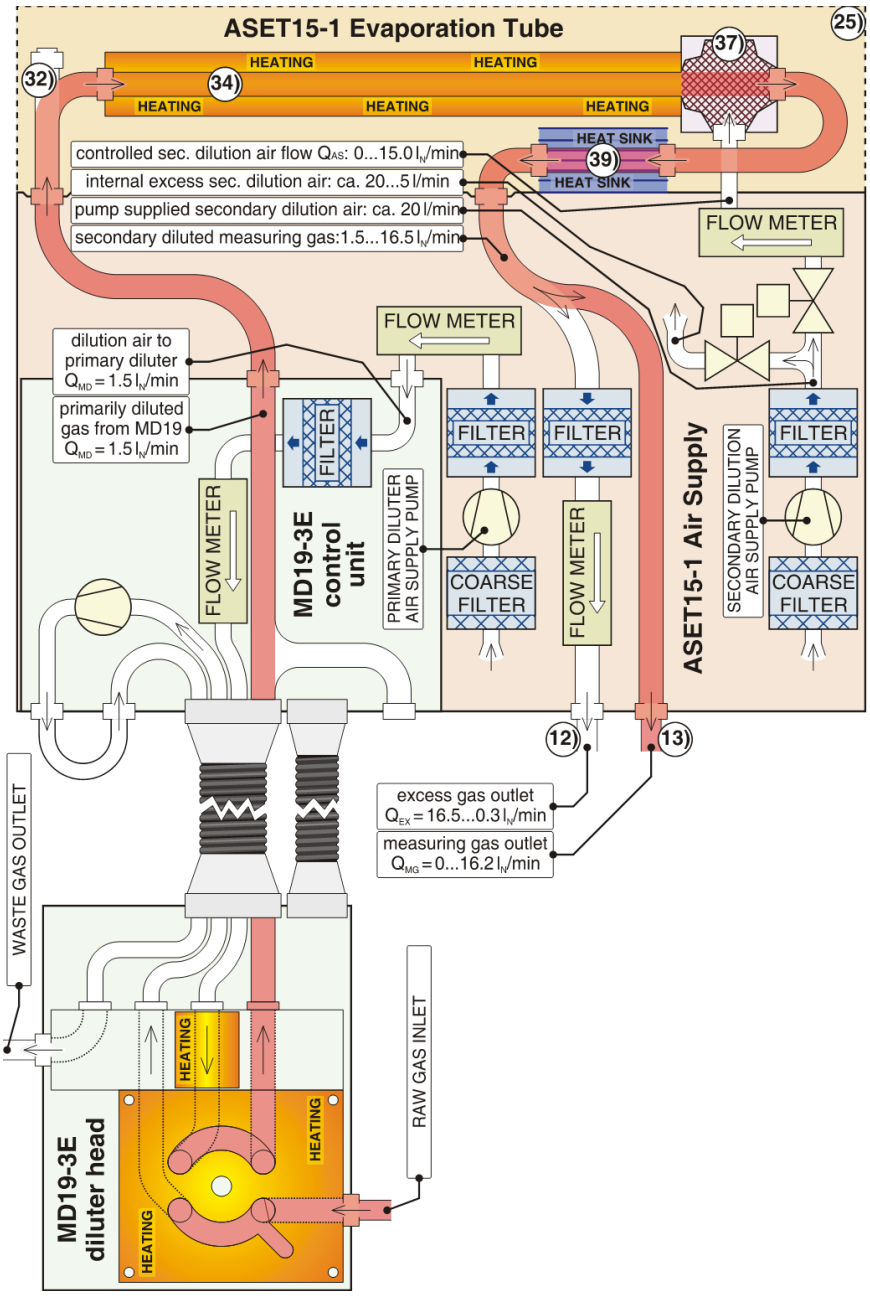

Fig.4.4 : function principle – pneumatic diagram of testo ASET15-1 with integrated testo MD19-3E

12 Excess measuring gas output
13 Measuring gas output
25 Safety cage to inhibit skin contact to the hot parts situated at the rear or the unit
32 Additional evaporation tube inlet port
34 Thermally insulated evaporation tube
37 Secondary dilution mixing chamber
39 Heat sink

The testo ASET15-1 is power supplied by one phase electricity. An internal pump feeds filtered air to the integrated testo MD19-3E, where raw gas is added and therewith primary dilution is carried out.
The testo ASET15-1 Air Supply / Evaporation Tube with integrated testo MD19-3E Rotating Disk Diluter can be combined with the testo CU-2 digital control unit and therewith

remote controlled via Ethernet. The components are mounted in standard 19" cases and can easily be integrated in a test bench equipped with 19" racks and Ethernet connections.
Fig. 4.2 shows all pneumatic components of the ThermoDilution system consisting of the testo ASET15-1 and the testo MD19-3E. The pathways of dilution air, raw gas and diluted measuring gas are visible.
No external dilution air is needed. Ambient air is drawn and filtered inside the case of the testo ASET15-1 and fed to the testo MD19-3E where it is needed to dilute some raw gas. The primarily diluted gas then returns to the testo ASET15-1. In the evaporation tube volatile particle components are transformed into the gas phase. Finally a certain adjustable amount of secondary dilution air is added in order to reduce the gas temperature, to enhance the measuring gas flow, and to achieve particle concentrations within the range of the particle sensors set downstream the dilution system.

4.5. Control Elements and Connections

4.5.1. Important Remarks

The testo ASET15-1 and testo MD19-3E are constructed for dilution and conditioning of exhaust or flue gas from combustion processes in diesel engines, light oil burners or wood or coal combustion. It may also be used for gases or aerosols emerging from other processes.

Electric Shock
When in operation, any electrical equipment can produce dangerous voltages. Ignoring these warnings may result in serious injury or damage of the equipment. It is mandatory that only suitably qualified personnel are allowed to work on this instrument. Satisfactory and safe operation of this instrument necessitates proper handling in transportation, storage and installation as well as careful control and maintenance.

Skin Burn
Parts of the testo MD19-3E diluter head are heated up to 160°C / 320°F. Also the outer surface of the testo ASET15-1 evaporation tube becomes a hot surface when the temperature inside is increased up to 400°C / 752°F. Always use heat protection gloves when handling hot parts.

Aerosol
Diluted or undiluted aerosol may escape from the system if the gas return port of the testo MD19-3E is are not thoroughly connected to an offtake or if the additional evaporation tube inlet port 33) of testo ASET15-1 is open. If some gas escapes at the excess gas port 12) it is filtered and contains no particles but may contain diluted gaseous toxic exhaust components.

4.5.2. Front View

In Fig. 4.3 all ports and operating elements situated at the front side of testo ASET15-1 with integrated testo MD19-3E are shown. The testo ASET15-1 elements are described below the figure while the testo MD19-3E controls are explained in the testo MD19-3E operations manual.

Fig.4.3 : front view of testo ASET15-1 with integrated testo MD19-3E

1 Air supply control elements: primary dilution air feed and secondary dilution
2 Evaporation Tube control elements (conditioner parameters)
3 Remote control LED green: remote dark: local
4 Secondary dilution air supply ON/OFF switch
5 Sec. dil. air supply LED green: OK red: flow error dark: OFF
6 testo MD19-3E air supply ON/OFF switch
7 testo MD19-3E air supply LED green: OK red: flow error dark: OFF
8 10 turn potentiometer for secondary dilution air supply setting
9 High excess gas flow LED yellow: excess gas flow > 1.5 l/min
10 Sufficient excess gas flow LED green: excess gas flow = 0.3...1.5 l/min
11 Low excess gas flow LED red: excess gas is critically low: < 0.3 l/min
12 Excess measuring gas output
13 Quick coupling for measuring gas output to sensor(s)
14 Heating current too high LED red: current too high (short circuit)
15 Heating current OK LED green: current within range
16 Heating current too low LED red: current too low (interrupt)
17 Evaporation tube heating ON/OFF swich
18 Actual evaporation tube temperature (red)
19 Evaporation tube temperature setpoint (green)
20 Temperature controller status field
21 Temperature controller control field

4.5.3. Gas Connectors

The excess gas port 12) and measuring gas port 13) of testo ASET15-1 can be connected to an offtake and to the subsequent sensor(s) using the connectors shown in Fig. 4.4.

Fig.4.4 : excess and measuring gas connectors

22 Female gas coupling for connecting a 6 mm ID tube to excess gas port
23 Male gas plug for connecting a 6 mm ID tube to measuring gas port (delivered with testo MD19-3E Rotating Disk Diluter)

Connecting any device to the front aerosol output of the testo MD19-3E would affect the flows inside and therewith the dilution properties of the system. The testo MD19-3E is internally connected to the testo ASET15-1 and no additional connection is needed. The gas plug 23) out of the testo MD19-3E delivery is used to connect any measuring instrumentation to the testo ASET15-1.

4.5.4. Rear View

Fig. 4.5 and 4.6 show all testo ASET15-1 elements and connections which are situated at the rear side of the unit. The hot parts are covered by a safety protection cage which has been removed in Fig. 4.6.

Fig.4.5 : rear view of testo ASET15-1 with safety cage mounted

24 Safety cage fixation nuts
25 Safety cage to inhibit skin contact to the hot parts situated at the rear side of the unit
26 Digital/analog interface of the integrated testo MD19-3E rotating disk diluter
27 Digital/analog interface to connect the testo ASET15-1 to the CU-2 digital control unit
28 Fuse of the integrated testo MD19-3E:5A slow
29 Fuse of testo ASET15-1: 5A slow
30 Mains switch
31 Mains connector
32 Additional evaporation tube inlet port (closed)

Skin Burn

Hot surfaces are inside the heat protection cage. Always ensure good air circulation around the rear of testo ASET15-1 when it is in operation. Always wear heat protection gloves or turn heating off and allow surfaces to cool down before removing the heat protection cage.

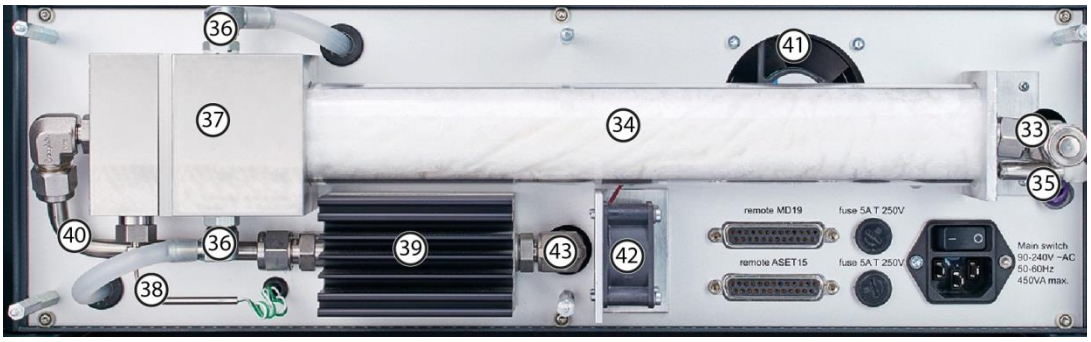

Fig.4.6 : rear view of testo ASET15-1 with safety cage removed

33 Evaporation Tube inlet
34 Thermally insulated evaporation tube
35 Electrical cable of the heater
36 Secondary dilution air inlet
37 Secondary dilution mixing chamber
38 Temperature sensor of the evaporation tube
39 Heat sink

40 Connection between mixing chamber and heat sink 39)
41 Fan for cooling the components integrated in the testo ASET15-1
42 Heat sink cooling fan
43 Measuring gas outlet connection to front panel

Aerosol
Never operate the testo ASET15-1 with open additional evaporation tube inlet port 32). This port is only used for calibration issues. Any air or aerosol flow on this port will influence the dilution conditions in the device. If the port is open during operation, the environment of the unit may be contaminated by escaping aerosols.

5 Installation and Setup

Note: Numbers – e.g. 8) = secondary dilution setting potentiometer – refer to the operating elements illustrated in chapter 4.5.

The testo ASET15-1 Air Supply / Evaporation Tube is a secondary dilution unit and cannot be operated without an inserted primary testo MD19-3E Rotating Disk Diluter.

5.1. Integrating testo MD19-3E into the testo ASET15-1

The testo ASET15-1 without any primary diluter integrated is shown in Fig. 5.1. The testo MD19-3E Rotating Disk Diluter can be plugged into the testo ASET15-1 housing if the pneumatic ports at the rear side of the plug-in are equipped with the quick couplings shown in Fig. 5.2 .

Fig.5.1: testo ASET15-1 without integrated testo MD19-3E Rotating Disk Diluter

The control unit of the primary diluter is plugged into the testo ASET15-1 housing and fixed with six screws located at the top and the bottom of the testo MD19-3E front panel. To remove the testo MD19-3E from the testo ASET15-1 these screws have to be solved and the unit can be pulled out.

Fig.5.2: Plug-in unit rear view with suitable quick couplings testo MD19-3E

5.2. Gas/Aerosol Connections

5.2.1. Quick Couplings at the front of testo ASET15-1

testo ASET15-1 is equipped with two quick coupling elements to connect the device to an excess gas offtake (male coupling 12)) and to the subsequent sensor(s) (female coupling 13)). One female excess gas coupling 22) is included in testo ASET15-1 delivery and one male measuring gas plug 23) is delivered with testo MD19-3E rotating disk diluter. Both coupling elements are also available from Testo SE & Co. KGaA.

Fig. 5.3 shows how the male plug of a tube is disconnected from the female quick coupling. Pushing down the button at the top of the quick coupling will release the plug which can be pulled out then.

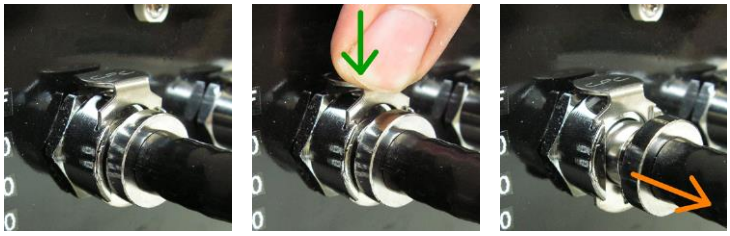

Fig.5.3: handling of quick coupling at the front side

The plug catching ring will remain down when the plug is disconnected from the coupling. When a plug is pulled in, the ring and button will jump up and automatically lock the plug. If the plug cannot be inserted, the fixation ring might be in the wrong position. Push down the release button and insert the plug again.

The excess gas connection 12) meets the same standard but male and female connectors are exchanged.

5.2.2. Connect a Sensor to the Measuring Gas Inlet of the Evaporation Tube

The connection of a sensor e.g. a particle counter (CPC) to the additional evaporation tube inlet port 32) might be of interest to measure the loss of volatile particles in the evaporation tube by evaporation. To prepare the connection of the sensor proceed as follows:

- Dismount the safety cage 25) by loosening the 5 nuts 24).
- Remove the closing cover from the additional evaporation tube inlet port 32).
- Mount the short stainless steel tube to the additional inlet using the Swagelock stainless steel nut and the two PTFE ferrules. All these parts are included in the accessories.
- Remount the safety cage before you connect your sensor to the steel tube.

Drawing measuring gas on the inlet to the evaporation tube reduces the flow in the evaporation tube and influences therefore the setting of the dilution factor as explained in chapter 6.3.3.

6 Operating Instructions

6.1. Start Up

Instructions in the following chapters are given for operation with an integrated testo MD19-3E rotating disk diluter mounted in the left half of the testo ASET15-1 rack case.

For starting up some measurements using the dilution system consisting of the testo MD19-3E and testo ASET15-1 follow these steps:

- Connect the connector 31) at the rear side of the testo ASET15-1 case to mains supply. The mains switch 30) should remain switched off. Details of the power supply are described in chapter 7.
- Prepare the testo MD19-3E Rotating Disk Diluter to be ready for operation according to the testo MD19-3E manual. Connect its diluter head via pneumatical and electrical connection to the control unit which has to be integrated into testo ASET15-1.
- Connect the nanoparticle instrumentation to the measuring gas output 13) using the gas connector plug 23) for tubes with inner diameter 6 mm.
- Connect the waste gas output of the testo MD19-3E to the exhaust or a separate offtake.
- Connect the excess measuring gas output of the testo ASET15-1 12) to an exhaust suction system

  The two gases must be independently connected to the exhaust suction. The pulsation of the testo MD19-3E pump might have an influence on the flow regulation in the Air Supply of the testo ASET15-1.

  The tube connected to testo MD19-3E pump outlet can fill with liquid from condensation if the diluter head is connected to undiluted engine exhaust which is cooled down on its way to the control unit.

- Ensure the raw gas pump switch on the testo MD19-3E front panel and the testo MD19-3E air supply switch 6), the dilution air supply switch 4), and the evaporation tube heating switch 17) on the testo ASET15-1 front panel are all in OFF position.
- Switch on the mains switch 30) at the rear side of the unit.
- Switch on testo MD19-3E dilution air supply 6) at the testo ASET15-1 front panel. The testo MD19-3E air supply LED 7) indicates if the electronically controlled dilution air flow is within its specified tolerance of +/- 3 % (green) or not (red).

6.2. Evaporation Tube Heating Up Procedure

The temperature inside the evaporation tube 34) is measured in the gas stream and indicated on the actual temperature display 18) at the top of the temperature controller which is shown in Fig. 6.1. The evaporation tube heating is activated and deactivated using switch 17). Heating only makes sense if dilution air is supplied to the primary diluter and measuring gas passes the evaporation tube. Nevertheless there is no risk of damage by overheating even if no gas passes the evaporation tube.

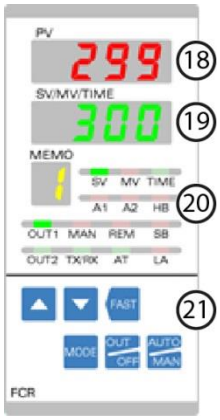

Fig.6.1: TemperatureController

- If the actual temperature display 18) shows oFF, press OUT/OFF in the control field 21) during 2 sec to switch on the temperature controller.
- Press MODE and then ▲ and/or ▼ to change the temperature setpoint. If the desired value is indicated by the setpoint display 19), safe by pushing MODE again.
- Switch on the evaporation tube heating with toggle switch 17) to connect the controller power output to the heater.
- The green heating current OK LED 15) indicates that supply voltage (24 VDC) is applied to the heating and the current is within its tolerance.
- If one of the red heating current LED's 14) or 16) lights, the current is too low or too high, probably caused by a defective heating element or an interrupt in the electric circuit. The evaporation tube should be switched off immediately and the device has to be checked and repaired by the manufacturer or a local service provider.
- Wait until the measured gas temperature 18) agrees with the set value 19) within +/- 2 °C. During the heating up phase the heating current OK LED 15) lights continuously green. The LED starts blinking in intervals of a few seconds when the measured gas temperature approaches the set value. When the set value is reached the heating on/off-duty cycle stabilizes on a ratio depending on the adjusted temperature. Heating up times are approximately 2.5 min from ambient to 200 °C and 4 min to 300 °C.

Due to attachment of low volatile substances on its inner surface, the evaporation tube may produce particles itself if operated at temperatures above the previous operation point. In this case, the attached volatile material evaporates, and may re-nucleate being measured by the connected instrumentation. When the evaporation tube temperature is increased, it is recommended to run the testo ASET15-1 with stopped rotating diluter disk but active testo MD19-3E dilution air supply to rinse the tube with filtered air until no undesired particles are detected anymore. This process may last up to 20 minutes.

6.3. Flows and Control LED's in Air Supply Part

Note: All flows mentioned in this manual are standard volume flows in [l/min] which means liters per minute at standard conditions: 1013,25 hPa / 0°C.

testo ASET15-1 in its pneumatic function is an adjustable diluter where two calibrated flows Q_{MD} and Q_{AS} are mixed in the secondary dilution mixing chamber 37). Fig. 6.2 shall help to understand the setting of the secondary dilution air in the air supply part of testo ASET15-1.

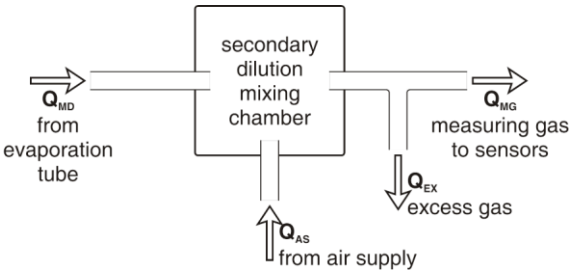

Fig.6.2: secondary dilution flows

Measuring gas flow Q_{MD} (standard 1.5 l/min) from the testo MD19-3E Rotating Disk Diluter enters the secondary dilution mixing chamber. Secondary diluted measuring gas flow Q_{MG} is drawn from the instrumentation connected on the measuring gas output 13).

It is evident that Q_{AS} must be adjusted to a value where $Q_{MD} + Q_{AS} > Q_{MG}$ and therewith $Q_{EX} > 0$ to ensure no gas is sucked backwards through the excess gas tube and added to the measuring gas.

6.3.1. Signal LED Information

The excess flow $Q_{EX} = Q_{MD} + Q_{AS} - Q_{MG}$ is internally measured and examined in relation to three criterions signalized with tree control LED's:

- The sufficient excess flow LED 10) lights green if Q_{EX} is within the minimal excess range 0.3 ... 1.5 l/min.
- The high excess flow LED 9) lights yellow if $Q_{EX} > 1.5$ l/min. This means the excess gas flow exceeds the minimal excess flow range. Depending on Q_{EX} a certain backpressure can arise. At 16.5 l/min excess gas (i.e. maximum secondary dilution and no measuring gas drawn by a sensor) this backpressure can reach up to 16 mbar.
- The low excess gas flow LED 11) lights red if $Q_{EX} < 0.3$ l/min. The excess gas flow is nearly zero and could even get negative due to slight flow changes. There is a certain risk of ambient air sucked backwards through the excess gas tube and mixed to the measuring gas.

6.3.2. Flow Settings and Dilution Factors

The primarily diluted flow Q_{MD} is adjusted and calibrated to a standard flow of 1.5 l/min. This amount of filtered dilution air is fed to the inserted primary diluter testo MD19-3E. It is added there by some raw gas and returns then to the testo ASET15-1 for further conditioning.

Q_{AS} can be set on the scaled 10-turn secondary dilution air potentiometer 8) or via analog input signal. The reading on the potentiometer from 1.00 ... 11.00 and the input signal range 0 ... 10 V DC correspond to a flow Q_{AS} of 0 ... 1 5 l/min.

With Q_{MD} = 1.5 l/min the potentiometer reading corresponds directly to the secondary dilution factor.

Examles:

pot. setting = 2 $Q_{AS} = (2-1) \cdot 1.5\,\text{l/min} = 1.5\,\text{l/min}$

dilution factor $DF = \frac{Q_{AS}+Q_{MD}}{Q_{MD}} \rightarrow DF = \frac{1.5+1.5}{1.5} = 2$

pot. setting = 5 $Q_{AS} = (5-1) \cdot 1.5\,\text{l/min} = 6.0\,\text{l/min} \rightarrow DF = \frac{6.0+1.5}{1.5} = 5$

6.3.3. Influence of Instrumentation Connected to the Additional ET Inlet Port

If a sensor is connected to the additional evaporation tube inlet port 32) and draws a certain amount of measuring gas, the flow in the evaporation tube is reduced and therewith the dilution is affected. To calculate the secondary dilution factor, the flow drawn from the evaporation tube inlet port has to be known. If this flow cannot be determined otherwise, it can be calculated as the difference between the excess gas flow measured with and without the drawing sensor.

The excess gas flow can be measured on pin 5 of the testo ASET15-1 interface connector 27), according to the pin assignment which is described in chapter 7.2.

1...5 VDC relates to 0...5 l/min excess gas flow. This means that a flow change of 1 l/min causes a voltage difference of 1.25 VDC, or 1 VDC corresponds to 0.8 l/min:

$\frac{\Delta U}{\Delta Q} = \frac{(5-1)\text{V}}{(5-0)\text{l}_\text{N}/\text{min}} = 1.25\,\frac{\text{V}}{\text{l}_\text{N}/\text{min}}$ respectively $\Delta Q = \Delta\text{U} \cdot 0.8\,\frac{\text{l}_\text{N}/\text{min}}{\text{V}}$

Example: A sensor S1 is connected to the additional evaporation tube inlet port 32).

A constant measuring gas flow Q_{MG} is drawn from the measuring gas outlet 13) at the front panel. The testo ASET15-1 potentiometer 8) is set to 2.

If S1 is sampling, the voltage at pin 5 is U_{ON} = 2.13 V

If S1 is not sampling, the voltage is U_{OFF} = 2.50 V

$Q_{S1} = \Delta Q = \Delta\text{U} \cdot 0.8\,\frac{\text{l}_\text{N}/\text{min}}{\text{V}} = (2.50 - 2.13)\text{V} \cdot 0.8\,\frac{\text{l}_\text{N}/\text{min}}{\text{V}} = 0.3\,\text{l/min}$

pot. setting = 2 $\rightarrow$ $Q_{AS} = (2-1) \cdot 1.5\,\text{l/min} = 1.5\,\text{l/min}$

dilution factor $DF = \frac{Q_{AS}+Q_{MD}-Q_{S1}}{Q_{MD}-Q_{S1}} = \frac{1.5+1.5-0.3}{1.5-0.3} = 2.25$ instead of 2.

Air Supply Local Operation

Start up the system following chapter 6.1 and heat up the evaporation tube.

- Start the instrumentation connected to the testo ASET15-1 therewith the measuring gas flow desired for the pending measurements is drawn from the measuring gas output 13).
- Set the secondary dilution air supply potentiometer 8) on its mechanical zero position to set the secondary dilution factor to 1.0 which actually means no secondary dilution.
- Switch on the secondary dilution air supply 4). The secondary dilution air supply LED 5) lights red first and turns to green after a few seconds to indicate the secondary air supply pump working properly.
- If the connected sensors draw less than 1.2 l/min, the sufficient excess measuring gas flow LED 10) lights green as soon as the flows are stable. The testo MD19-3E raw gas pump can be switched on and the measurements can start if the primary diluter is ready and no secondary dilution is required e.g. due to too high concentrations in the measuring gas or for reducing thermophoretic losses according to appendix A.3.
- If a higher amout of measuring gas is drawn, the low measuring gas flow LED 11) lights red indicating that the excess gas flow is below 0.3 l/min or could even be negative which would mean air was sucked backwards through the excess gas port 12) and mixed in an undefined way with the measuring gas.
- In this case enhance the secondary dilution flow Q_{AS} by adjusting the secondary dilution air supply potentiometer 8) until the light signal changes to the green flow OK LED 10). Increase the flow 0.1...0.3 potentiometer units over the limit where the green LED starts to light to find the ideal measuring gas flow setting.
- The secondary dilution can be used to increase the total dilution factor as well as to reduce thermophoretic losses. If it is set as high as more measuring gas is conditioned and provided than needed by the connected sensor(s), a certain back pressure can arise in the measuring gas stream due to the filter in the excess gas tube. Therefore the high excess gas LED 9) lights yellow if more than 1.5 l/min pass the excess gas port. This back pressure can reach up to 16 mbar at maximum secondary dilution and zero measuring gas flow.

The total particle concentration reduction factor PCRF is the product of the primary dilution factor set at the testo MD19-3E, the secondary dilution factor set at the testo ASET15-1 and the inverse of one minus the fraction which is not lost due to thermophoretic losses.

Example: testo MD19-3E primary dilution factor: 30
testo ASET15-1 secondary dilution factor: 3
thermophoretic loss (see appendix A.3): 10% = 0.1

$$PCRF = 30 \cdot 3 \cdot \frac{1}{1-0.1} = \frac{30 \cdot 3 \cdot 1}{0.9} = \frac{90}{0.9} = 100$$

Note: When switching OFF the secondary dilution air supply switch 4), wait at least 10 seconds before restarting in order to avoid short peak flows in the order of 20 l/min on the measuring gas output 13)

6.4. Remote Operation

Remote communication with testo ASET15-1 is possible with analog and digital inputs and outputs at the digital/analog interface 27) at the rear side of the device. The signals on this connector are described in chapter 7.2.

Besides the remote interface of the integrated testo MD19-3E Rotating Disk Diluter is connected to the corresponding plug 26) at the rear side of the testo ASET15-1 case. The function and pin assignment of this connector are the same as the ones of the connector at the rear side of the testo MD19-3E stand alone case which are described in the testo MD19-3E user manual.

7 Electrical Connections

7.1. Mains Supply

Connect the power cord plug to a grounded power socket. The IEC mains connector 31) on the rear side of the testo ASET15-1 case includes the mains switch 30). The fuse holders 28) and 29) for integrated testo MD19-3E Rotating Disk Diluter and testo ASET15-1 itself are located on the rear side of the laboratory case, besides the mains switch / mains connector. The one phase power cord delivered with the instrument is equipped with a country-specific plug and protective earth.

Mains supply voltage: 90 ... 240 VAC, 50/60 Hz, max. 600 VA
Fuse type testo MD19-3E: slow switching fuse 250 V, 5 A, t, 5 x 20 mm
Fuse type testo ASET15-1: slow switching fuse 250 V, 5 A, t, 5 x 20 mm

Warning
In case of a blown fuse, replace it only with the specified type of fuse. If the fuse is repeatedly blown, the dilution unit must be sent to the manufacturer or to an instructed service station for checking and repair.

Electric Shock
Make sure that the protecting ground pin of the country specific plug is correctly connected to the protecting ground contact of your socket. If the plug is replaced, ensure the yellow/green ground wire of the cable is properly connected to the new ground pin or the case is otherwise connected to protective earth which is usually indicated by the ⏚ sign.

7.2. Analog/Digital Interface

The 25 pole D-Sub connectors at the rear side of the testo ASET15-1 case and the pin assignment of the testo ASET15-1 remote interface 27) are shown in Fig. 7.1.

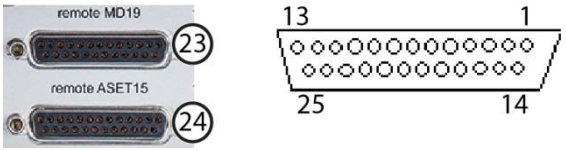

Fig.7.1: testo MD19-3E and testo ASET15-1 remote interfaces

The digital inputs and outputs are standard 5 V logic levels.

- Digital inputs: High level: > 3.0 VDC low level: < 0.7 VDC
  The load resistance of the device is R_{in} > 10 kΩ
- Digital outputs: High level: 5.0 +/- 0.2 VDC low level: < 0.7 VDC,
  The source resistance of the device is R_{out} < 3.5 kΩ

The analog signals are 0...10 VDC signals.

- Analog inputs: The load resistance of the device is R_{in} > 1.0 MΩ
- Analog outputs: The source current of output signals can be I_S ≤ 5 mA.

D-sub pin	signal description	local equivalent or signal	analog / digital	in- / output	signal range
1	evaporation tube actual temperature	disp. 18)	A	O	0...10 VDC = 0...400°C
2	evaporation tube temperature setpoint	disp. 19)	A	I	0...10 VDC = 0...400°C
3	analog ground		A		0 VDC for analog inputs / outputs
4	evaporation tube current I_{heat} too high	LED 14)	D	O	0 VDC: OK 5 VDC: I_{heat} too high

D-sub pin	signal description	local equivalent or signal	analog / digital	in- / output	signal range
5	excess gas mass flow		A	O	1...5 VDC= 0...5 l/min
6	secondary dilution air setpoint	pot. 8)	A	I	2.5...10 VDC= 0...15 l/min
7	not connected				
8	not connected				
9	secondary air supply pump ON/OFF	switch 4)	D	I	0 VDC: OFF 5 VDC: ON
10	not connected				
11	actual testo MD19 -3E dilution air flow (1.5 l/min)		A	O	fixed value within 3.2...3.8 VDC
12	remote operation	LED 3)	D	I	0 VDC: local 5 VDC: remote
13	digital ground		D		0 VDC for digital inputs / outputs
14	secondary dilution air supply flow error	LED 5)	D	O	0 VDC: OK 5 VDC: error
15	evaporation tube current I_{heat} too low	LED 16)	D	O	0 VDC: OK 5 VDC: I_{heat} too low
16	evaporation tube heating ON/OFF	switch 17)	D	I	0 VDC: OFF 5 VDC: ON
17	primary dilution testo MD19-3E air flow error	LED 7)	D	O	0 VDC: OK 5 VDC: dil air error
18	actual secondary dilution air flow		A	O	2.5...10 VDC= 0...15 l/min
19	low excess gas flow	LED 11)	D	O	0 VDC: OK 5 VDC: Q_{EX} too low
20	not connected				
21	not connected				
22	not connected				
23	not connected				
24	primary dilution testo MD19-3E air ON/OFF		D	I	0 VDC: OFF 5 VDC: ON
25	analog ground		A		0 VDC for analog inputs / outputs

7.3. Remote Control

Switching the device to remote operation is done by connecting a digital HIGH-signal to pin 12 of the interface connector 27). Remote operation is indicated by the green lighting remote control LED 3). Switches and potentiometer on the front panel are inactive and all additional functions are controlled by digital and analog signals listed in chapter 7.2.

The 25 pole D-Sub connector 26) is used for the remote control of the primary dilution unit. For details plesase refer to the user manual of the testo MD19-3E Rotating Disk Diluter.

8 Maintenance and Calibration

8.1. Evaporation Tube

Chemical compounds in the primary diluted measuring gas can be deposited on the inside surface of the evaporation tube. Depending on their evaporation temperature they can be origin of nucleation particles in the heating up process. As already recommended in chapter 6.2 such artifact particles should be removed by feeding filtered particle free air through the primary diluter when the temperature in the Evaporation Tube is increased to a higher set value and start the measurement not before no particles are measured in the instrumentation.

The best procedure to clean the Evaporation Tube is to heat it up to the max. temperature of 400°C and feed filtered particle free air. Leave the temperature at 400°C until no particles are detected by the instrumentation anymore. Depending on the degree of pollution this procedure can last up to 60 minutes. Do this procedure before or after longer measuring programs.

8.2. Parts with Limited Lifetime

Filter media and moving parts like air supply pumps inside the testo ASET15-1 have limited lifetimes due to ambient air pollution and mechanical abrasion. Insufficient flows due to these components are indicated by the testo MD19-3E air supply LED 7) and the secondary dilution air supply LED 5).

- If the testo MD19-3E air supply LED 7) remains red for longer than a few seconds after the pump is switched on it indicates insufficient dilution air flow either caused by a testo MD19-3E air supply pump defect or an overloaded testo MD19-3E air supply filter. The testo MD19-3E air supply pump typically reaches 10'000...15'000 hours operating time.
- The secondary dilution air supply LED 5) remains red if the secondary dilution air flow is not reached. This might be caused by a pump defect or overloaded secondary dilution air filters.
- The secondary dilution air pump reaches 5'000...10'000 hours operating time.

Pump maintenance and filter replacement should be done by Testo SE & Co. KGaA and/or an instructed local service provider.

8.3. Storage, Acclimatization

Fast ambient temperature changes may result in condensed water on and inside the instrument. This may cause serious damage of electronic parts, e.g. the controller or safety devices.

- Do not store the instrument outdoor, the storage environment must be clean and dry.
- After long time storage or transport with cold ambient conditions or thermal fluctuation, the instrument requires to adapt slowly to the local ambient conditions before starting up.
- If condensed water has been formed, wait at least 12 hours before installation and starting up.
- Avoid mechanical damage and agitation.
- Storage temperature range: -10°C to +60°C.

8.4. Operation Environment Requirements

Caution

Read this section carefully before setting up testo ASET15-1 Air Supply / Evaporation Tube. Testo SE & Co. KGaA is not liable if the instrument is damaged, caused by the operation environment not meeting the requirements.

Caution

The testo ASET15-1 Air Supply / Evaporation Tube is designed to be installed in a laboratory, test stand or a temporary test set-up. The instrument is not intended to be used outdoor or in a dusty or wet environment.

IP protection degree	IP 20. testo ASET15-1 is protected against accidental contact to dangerous parts of the instrument. It is not protected against intrusion of sand, dust or water. Avoid operation in dusty or wet environment for safe and reliable operation.
operating temperature range	The operating ambient temperature range is +10°C to +40°C if free air circulation around the device is ensured.
humidity range	The ambient relative humidity range (RH) is 0% to 80%, max. 80%@30°C, linearly degrading to 50%@40°C, non condensing.
shocks and vibrations	Avoid operation under any kind of shock or vibration.

9 Appendix

9.1. Extent of Delivery

testo ASET15-1 delivery consists of the following items:

item #	description	
1	testo ASET15-1 Air Supply / Evaporation Tube	
2	testo ASET15-1 accessories box, containing:	
3	user manual to testo ASET15-1 Air Supply / Evaporation Tube	
4	IEC power cord	for Switzerland
	or	for Germany, France, Italy, Korea, etc.
	or	for USA, Canada, Japan, etc.
	or	for United Kingdom, etc.
5	1 female gas coupling for connecting a 6 mm ID tube to the excess gas port	
6	1 Swagelok nut 8 mm OD SS-8M2-1	
7	1 Stainless steel tube 8/6 mm x 70 mm length	
8	1 Swagelok PTFE front ferrule 8 mm T-8M3-1	
9	1 Swagelok PTFE back ferrule 8 mm T-8M4-1	

9.2. Specification, Technical Data

aerosol	primarily diluted exhaust gases or air which contains nanoparticles
inlet gas flow	1.5 l/min, actively fed to the primary diluter and returning from there; accuracy: 3%
air supply flow	0...15.0 l/min; accuracy: 3% of set value + 0.1 l/min ex
dilution factor	1...11
measuring gas	1.2...16.2 l/min measuring gas, directly depending on dilution factor
excess gas	min. 0.3 l/min
power supply	90...240 VAC, 50/60 Hz, max. 600 VA with integrated testo MD19-3E
local operation	primary dilution air supply pump switch, secondary air supply pump switch, scaled 10-turn secondary dilution setting potentiometer, evaporation tube switch, evaporation tube temperature control panel, LED indicators
remote operation	• in combination with CU-2 digital control unit • controlled by digital (5 VDC) and analog (0...10 VDC) signals via 25-pole D-Sub female interface connector on rear side
Evaporation Tube temperatures	ambient...400°C / 752°F; accuracy +/- 2°C/4°F approx. heating up times: ambient to 200°C: 2 min ambient to 300°C: 4 min ambient to 400°C: 7 min

assembly	3U-19" case for rack mounting with handles left ½-19” half wired for testo MD19-3E primary diluter plug-in evaporation tube mounted on rear side of 19” case dimensions (w · h · d): 485 · 146 · 530 mm
weight	without testo MD19-3E primary diluter ca. 13.5 kg with integrated testo MD19-3E : ca. 19.1 kg complete withtesto MD19-3E and CU-2: ca. 26.7 kg
operating conditions	T_{amb}: 10 ... 40 °C 0...80% relative humidity, max. 80%@30°C, linearly degrading to 50%@40°C, non-condensing
calibration	• standard calibration with CAST soot particles, 80 nm, testo ASET15-1 operated with cold (ambient temperature) and heated evaporation tube • UN-ECE R83 calibration possible with integrated testo MD19-3E Rotating Disk diluter
conformity	testo ASET15-1 Air Supply Evaporation Tube is in conformity with the following standards or other related documents: EN 61326-1 : 2006 / B1 Electrical equipment for measurement, control and laboratory use. EMC requirements. EN 61010-1 : 2001 Safety requirements for electrical equipment for measurement, control and laboratory use. and therefore is in conformity with the following European Directives in their current versions: 2014/30/EU Electromagnetic compatibility 2006/95/EG Low voltage directive

9.3. Thermophoretic Losses

Thermophoretic particle losses occur due to the temperature gradient when a hot aerosol passes cool surfaces. This effect can be reduced by cooling down the aerosol quickly when it leaves the hot area. In the testo ASET15-1 the effect appears in the aerosol tubing downstream the evaporation tube and can be reduced significantly by setting a higher secondary dilution factor which means a large amount of cool air is added to the hot measuring gas cooling it down immediately when it comes from the evaporation tube 34) and enters the mixing chamber 37).

The diagram in Fig. A.1 shows the typical thermophoretic losses in the evaporation tube heated up to 300°C measured on testo ASET15-1 with 82 nm soot particles. Each testo ASET15-1 is calibrated individually for most accurate loss determination.

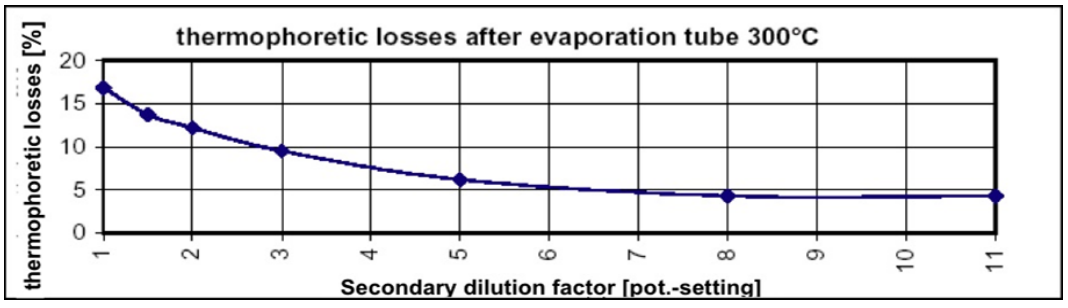

Fig.A.1: secondary dilution flows

9.4. Definitions, Units and Conversion Table

Pressure	Pascal	Bar	Pound per square inch
	(Pa)	(bar)	(psi)
1 Pa	1	$1.0 \cdot 10^{-5}$	$1.450 \cdot 10^{-4}$
1 bar	$1.0 \cdot 10^{5}$	1	14.504
1 psi	6 894.8	0.0689	1

Length	Meter	Centimeter	Millimeter	Micrometer	Nanometer	Inch
	(m)	(cm)	(mm)	(µm)	(nm)	(") = (in)
1 m	1	100	1 000	$1.0 \cdot 10^{6}$	$1.0 \cdot 10^{9}$	39.37
1 cm	0.01	1	10	$1.0 \cdot 10^{4}$	$1.0 \cdot 10^{7}$	0.3937
1 mm	0.001	0.1	1	1 000	$1.0 \cdot 10^{6}$	0.0394
1 µm	$1.0 \cdot 10^{-6}$	$1.0 \cdot 10^{-4}$	1.001	1	1 000	$3.937 \cdot 10^{-5}$
1 nm	$1.0 \cdot 10^{-9}$	$1.0 \cdot 10^{-7}$	$1.0 \cdot 10^{-6}$	0.001	1	$3.937 \cdot 10^{-8}$
1 " = 1 in	0.0254	2.54	25.4	$2.54 \cdot 10^{4}$	$2.54 \cdot 10^{7}$	1

Temperature	Celsius	Fahrenheit
	(°C)	(°F)
0 °C	0	32
100 °C	100	212
0 °F	-17.78	0
100 °F	37.78	100

T[°C] = (T[°F]-32)/1.8

T [°F] = T[°C] · 1.8 + 32

Mass	Kilogram	Gram	Pound	Ounce
	(kg)	(g)	(lb)	(oz)
1 kg	1	1 000	2.205	35.27
1 g	0.001	1	0.0022	0.0353
1 lb	0.4536	453.6	1	16
1 oz	0.0283	28.35	0.0625	1

Volumetric	Cubic Meter	Liter	Milliliter	Cubic Inch	Cubic Foot
	(m3)	(l)	(ml) = (ccm)	(cin)	(cft)
1 m^3	1	1 000	$1.0 \cdot 10^{6}$	61 024	35.315
1 l	0.001	1	1000	61.024	0.0353
1 ml = 1 ccm	$1.0 \cdot 10^{-6}$	0.001	1	0.0610	$3.531 \cdot 10^{-5}$
1 cin	$1.639 \cdot 10^{-5}$	0.0164	16.387	1	$5.787 \cdot 10^{-4}$
1 cft	0.0283	28.317	$2.832 \cdot 10^{4}$	1728	1

Volumetric flow		
	(l / min)	(m^3 / h)
1 l / min	1	0.060
1 m^3 / h	16.667	1

	1 l	=	1 standard liter at 0 °C, 1 013.25 hPa						
Units									
	Length	m	meter	cm	Centi-meter	mm	Milli-meter	nm	Nano-meter
	Mass	kg	kilogram	g	gram				
	Time	h	hour	min	minute	s	second		
	Electricity	A	ampère	V	volt	VA	voltampère	Ω	ohm

10 Designation of All testo ASET15-1 Air Supply / Evaporation Tube Elements

1 Air supply control elements: primary dilution air feed and secondary dilution)
2 Evaporation Tube control elements (conditioner parameters)
3 Remote control LED green: remote dark: local control
4 Secondary dilution air supply ON/OFF switch
5 Sec. dil. air supply LED green: OK red: flow error dark:: OFF
6 testo MD19-3E air supply ON/OFF switch
7 testo MD19-3E air supply LED green: OK red: flow error dark:: OFF
8 10 turn potentiometer for secondary dilution air supply setting
9 High excess gas flow LED yellow: excess gas flow > 1.5 l/min
10 Sufficient excess gas flow LED green: excess gas flow = 0.3...1.5 l/min
11 Low excess gas flow LED red: excess gas flow is critically low: < 0.3 l/min
12 Excess measuring gas output
13 Quick coupling for measuring gas output to sensor(s)
14 Heating current too high LED red: current too high (short circuit)
15 Heating current OK LED green: current within range
16 Heating current too low LED red: current too low (interrupt)
17 Evaporation tube heating ON/OFF swich
18 Actual evaporation tube temperature (red)
19 Evaporation tube temperature setpoint (green)
20 Temperature controller status field
21 Temperature controller control field
22 Male gas coupling for connecting a 6 mm ID tube to measuring gas port (delivered with testo MD19-3E Rotating Disk Diluter)
23 Female gas coupling for connecting a 6 mm ID tube to excess gas port
24 Safety cage fixation nuts
25 Safety cage to inhibit skin contact to the hot parts situated at the rear of the unit
26 Digital/analog interface of the integrated testo MD19-3E rotating disk diluter
27 Digital/analog interface to connect the testo ASET15-1 to the CU-2 digital control unit
28 Fuse of integrated testo MD19-3E: 5A slow
29 Fuse of testo ASET15-1: 5A slow
30 Mains switch
31 Mains connector
32 Additional ET inlet port (closed)
33 Evaporation tube inlet
34 Thermally insulated evaporation tube
35 Electrical heater cable

36 Secondary dilution air inlet
37 Secondary dilution mixing chamber
38 ET temperature sensor
39 Heat sink
40 Connection between mixing chamber and heat sink 39)
41 Fan for cooling the components integrated in the testo ASET15-1
42 Heat sink cooling fan
43 Outlet connection to front panel

Fig. : front view of testo ASET15-1 with integrated testo MD19-3E

Fig. : excess and measuring gas connectors

Fig. : rear view of testo ASET15-1 with safety cage mounted

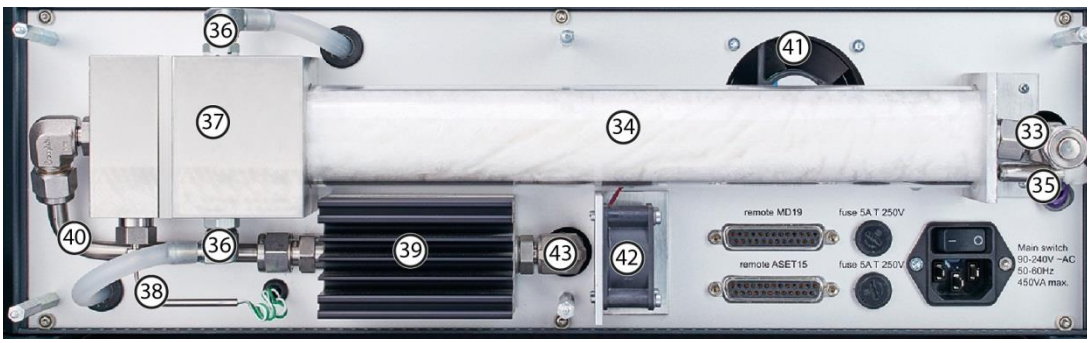

Fig. : rear view of testo ASET15-1 with safety cage removed

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