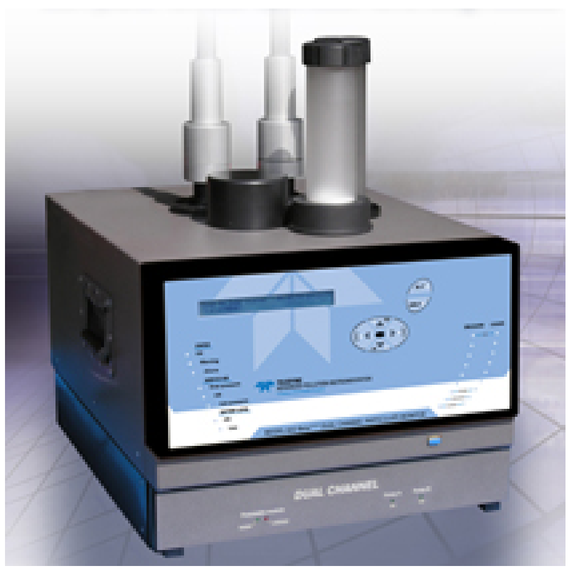
OPERATION MANUAL

MODEL 602 BETA*PLUS*
Particle Measurement System



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07318B DCN6410
16 Mar 2012

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SAFETY MESSAGES

Important safety messages are provided throughout this manual for the purpose of avoiding personal injury or instrument damage. Please read these messages carefully. Each safety message is associated with a safety alert symbol, which are placed throughout this manual and on the instrument, inside or out. It is imperative that you pay close attention to these messages, the descriptions of which are as follows:

IONIZING RADIATION: Signifies the presence of IONIZING RADIATION, exposure to which may cause health problems.

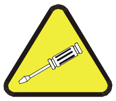
WARNING: Electrical Shock Hazard

WARNING/CAUTION: Risk of personal injury or risk of damage to or malfunction of the instrument. Read the accompanying message for specific information.

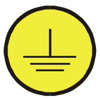
HAZARD: Strong oxidizer

CAUTION: Hot Surface Warning

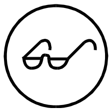
Do Not Touch: Touching some parts of the instrument without protection or proper tools could result in damage to the part(s) and/or the instrument.



Technician Symbol: All operations marked with this symbol are to be performed by qualified maintenance personnel only.



Electrical Ground: This symbol inside the instrument marks the central safety grounding point for the instrument.



READ CAREFULLY: The text marked by this symbol should be read especially carefully since it is essential for proper usage of the instrument and for the operator's safety.

CAUTION: Restricted Use

This instrument must only be used for the purpose and in the manner described in this manual. If you use this instrument in a manner other than that for which it was intended, unpredictable behavior could ensue with possible hazardous consequences.

Note

For Technical Assistance regarding the use and maintenance of this instrument or any other Teledyne API product, contact Teledyne API's Technical Support Department:

Telephone: 800-324-5190

Email: sda_techsupport @teledyne.com

or access any of the service options on our website at http://www.teledyne-api.com/

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WARRANTY

WARRANTY POLICY (02024D)

Prior to shipment, T-API equipment is thoroughly inspected and tested. Should equipment failure occur, TAPI assures its customers that prompt service and support will be available.

COVERAGE

After the warranty period and throughout the equipment lifetime, TAPI stands ready to provide on-site or in-plant service at reasonable rates similar to those of other manufacturers in the industry. All maintenance and the first level of field troubleshooting are to be performed by the customer.

NON-API MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by T-API is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturer's warranty.

GENERAL

During the warranty period, TAPI warrants each Product manufactured by TAPI to be free from defects in material and workmanship under normal use and service. Expendable parts are excluded.

If a Product fails to conform to its specifications within the warranty period, TAPI shall correct such defect by, in TAPI's discretion, repairing or replacing such defective Product or refunding the purchase price of such Product.

The warranties set forth in this section shall be of no force or effect with respect to any Product: (i) that has been altered or subjected to misuse, negligence or accident, or (ii) that has been used in any manner other than in accordance with the instruction provided by TAPI, or (iii) not properly maintained.

THE WARRANTIES SET FORTH IN THIS SECTION AND THE REMEDIES THEREFORE ARE EXCLUSIVE AND IN LIEU OF ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR PARTICULAR PURPOSE OR OTHER WARRANTY OF QUALITY, WHETHER EXPRESSED OR IMPLIED. THE REMEDIES SET FORTH IN THIS SECTION ARE THE EXCLUSIVE REMEDIES FOR BREACH OF ANY WARRANTY CONTAINED HEREIN. TAPI SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR RELATED TO THIS AGREEMENT OF T-API'S PERFORMANCE HEREUNDER, WHETHER FOR BREACH OF WARRANTY OR OTHERWISE.

Terms and Conditions

All units or components returned to Teledyne API should be properly packed for handling and returned freight prepaid to the nearest designated Service Center. After the repair, the equipment will be returned, freight prepaid.

CAUTION – Avoid Warranty Invalidation

Failure to comply with proper anti-Electro-Static Discharge (ESD) handling and packing instructions and Return Merchandise Authorization (RMA) procedures when returning parts for repair or calibration may void your warranty. For anti-ESD handling and packing instructions please refer to "Packing Components for Return to Teledyne API's Customer Service" in the *Primer on Electro-Static Discharge* section of this manual, and for RMA procedures please refer to our Website at http://www.teledyne-api.com under Customer Support > Return Authorization.

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ABOUT THIS MANUAL

The instructions for this instrument Include the following documents:.

Part No.	Rev	Name/Description
07318	B	Model 602 Beta Operation Manual
07312	(3/19/2012)	Spare Parts List (inserted as Appendix 4 of this manual)
07442	A	Model 602 Beta Quick Start Guide (separate document)

NOTE

Please read this manual in its entirety before attempting to operate the instrument.

REVISION HISTORY

Document	PN	Rev	DCN	Change Summary
16 March 2012				
M602 Manual	07318	B	6410	• Revised all pertinent sections to make them more applicable to the Hourly Mode M602 • Added installation procedures • Added calibration procedures • Added maintenance procedures • Added guidelines for cal and test procedures • Regenerated Spare Parts List
25 April 2011				
M602B Op Manual	07318	A	6070	• Initial Release

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CHAPTER 1

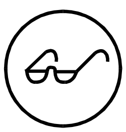
1. GENERAL INFORMATION AND SAFETY WARNINGS

1.1 GENERAL INFORMATION

The instructions in this manual describe the safety, installation, starting, and maintenance requirements of the dual-channel Model 602 Beta*PLUS* Particle Measurement System.

Periodic updates will be made to this manual and will be made available on our web site (www.teledyne-api.com).

NOTE: This manual is an integral part of the instrument and must always be available to the operator.



The operator(s) in charge of installing, running, and maintaining this instrument must read this manual carefully, paying special attention to all Safety messages throughout this manual, including the Safety Information on page iii and any labels associated with the instrument.

1.2 SAFETY WARNINGS

- **Model 602 Beta*PLUS* Particle Measurement System is a system used for sampling and mass measurement of suspended particulate matter on filter membranes. Mass measurement is carried out using an internal low-activity ß radiation source.**
- **This source does not pose a danger to the user when installed by Teledyne API.**
- **No additional ionizing radiation warnings are necessary within the United States; however, check local requirements in other locations.**
- **Only trained personnel can use the instrument.**
- **Only trained and authorized technical personnel can perform repair services inside the instrument.**

1.2.1 Specific Information about Ionizing Radiation Hazards

The Model 602 Beta*PLUS* Particle Measurement System contains a ^{14}C beta source, with 3.7 MBq (100 μCi) nominal activity.

The source is contained in an inaccessible mechanical block integrated within the instrument. Only radiation dose-rates relative to the natural background can be detected outside of the instrument. Consequently, under normal operating conditions there is no contamination risk.

The US Nuclear Regulatory Commission has registered the device under the Sealed Source Device Registry as an instrument that is exempt from licensing requirements by purchasers of the device, as it has been found to be safe when used in accordance with this operation manual.

In the event of a serious accident, such as a fire, there is a risk that radioactive material may be dispersed into the environment. However, an analytic evaluation of various improbable and worst-case scenarios (carried out in compliance with current regulations) concluded that estimated dose values for individuals and the general population are within safe limits.

The radiation source is installed and tested by Teledyne API under NRC and state of California licensing requirements. The source is not user serviceable and can only be accessed through use of a specialized tool exclusively available to Teledyne API personnel trained in its use.

No formal radioactive safety training is required for those working with the Model 602 Beta^{PLUS} instrument, provided it is done in a manner consistent with the Operating Manual and for the purposes of the instrument design – the monitoring of air quality. Under normal operating conditions, the ^{14}C radioactive source should never need to be handled throughout the instrument's useful life.

According to State of California government radioactive shipping laws, no more than 270µCi can be combined together in any single shipment. Since each source has a nominal activity level of 100µCi, no more than two Model 602 Beta^{PLUS} instruments should be shipped together.

1.3 SAFETY REGULATIONS

The Model 602 Beta^{PLUS} Particle Measurement System has been engineered to satisfy the requirements listed in the following European Directives and their subsequent revisions:

2006/95/EC	Low-Voltage Directive
2006/42/EC	Machinery Safety Directive
2004/108/EC	Electromagnetic Compatibility Directive

The equipment is in compliance with the following harmonized technical regulations:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use
Electromagnetic Compatibility (EMC):	
EN 61326-1	Emission and Immunity
EN 61000-3-2	Harmonics
EN 61000-3-3	Flicker

The US Nuclear Regulatory commission has authorized the unit for distribution as an exempt device under Sealed Source Device Registry NR-1335-D-101-E.

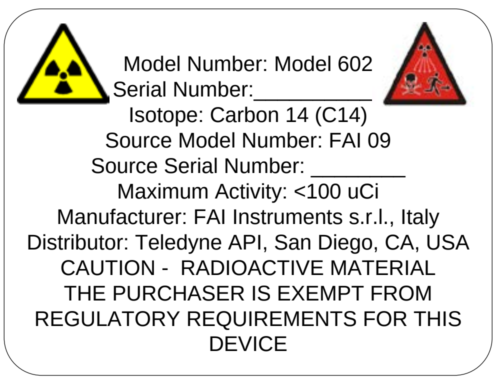
1.4 SAFETY LABELS

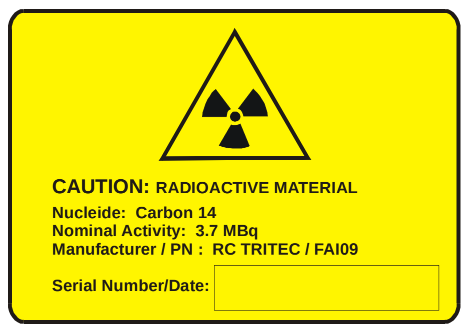
CAUTION: Follow Regulatory Requirements

Do not remove the warning labels. They must be kept in good condition, and if they are damaged or illegible, they must be immediately replaced.

The following label is located inside the instrument on the source holder.

The following warning labels are located on the back of the **Model 602 Beta*PLUS* Particle Measurement System**:





1.5 INTENDED USE OF THE INSTRUMENT

The instrument has been engineered for the following use:

- to automatically and sequentially sample the suspended particulate matter on filter membranes
- to measure the mass of the gathered particulate matter using the β attenuation method

The instrument must be used in the following ambient conditions:

- where the temperature and relative humidity are in compliance with the technical specifications
- in locations where the risks of explosions or fires are minimal.

CAUTION: Use this Instrument Only as Intended and Prescribed
The instrument must be used only for the operations and in the environmental conditions explicitly described in this manual. Any other use is considered improper and prohibited.

1.6 PRESCRIBED OPERATION

The instrument must be used as intended, under proper technical operating conditions, and by qualified personnel in compliance with the current safety and accident prevention regulations.

This “User manual” is meant for the Qualified User, who must:

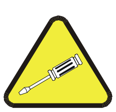
- verify that the operating room and related arrangements are suitable for installation and use of the instrument
- know in detail all necessary operations for correct use and routine maintenance, and all the general safety rules and warnings in this manual
- never perform repairs to the instrument

This "User manual" is also meant for the Qualified Technician, who will follow the detailed instructions received during training to perform:

- instrument maintenance repairs
- β source handling (installation, removal, storage, etc.)

If necessary, for maintenance or repairs call Teledyne API Technical Support for assistance with providing specialized technicians, suitable tools, and/or original spare parts.

WARNING: Risk of Regulatory Violation
The source is not user-serviceable and must only be maintained by specifically trained Teledyne API personnel.



Installation and removal of the source must be performed only by qualified and expressly authorized personnel.

1.7 NOTES ON INSTALLATION AND TRANSPORTATION

1.7.1 Removal of the Mass Measurement System Safety Lock

Before powering on the instrument it is necessary to remove the lock that protects the mechanical components of the mass measurement system. To avoid potential damage during the transportation and installation steps, the power supply connector of the measurement system is connected to the lock board (see Figure 1-2).

To remove the system lock:

1. Open the front panel of the instrument (Figure 1-1).
2. Unplug the female connector from the lock board (Figure 1-2).
3. Plug the female connector into the male connector labeled “Geiger” on the MOTEV board, (Figure 1-3).
4. Close the front panel of the instrument.

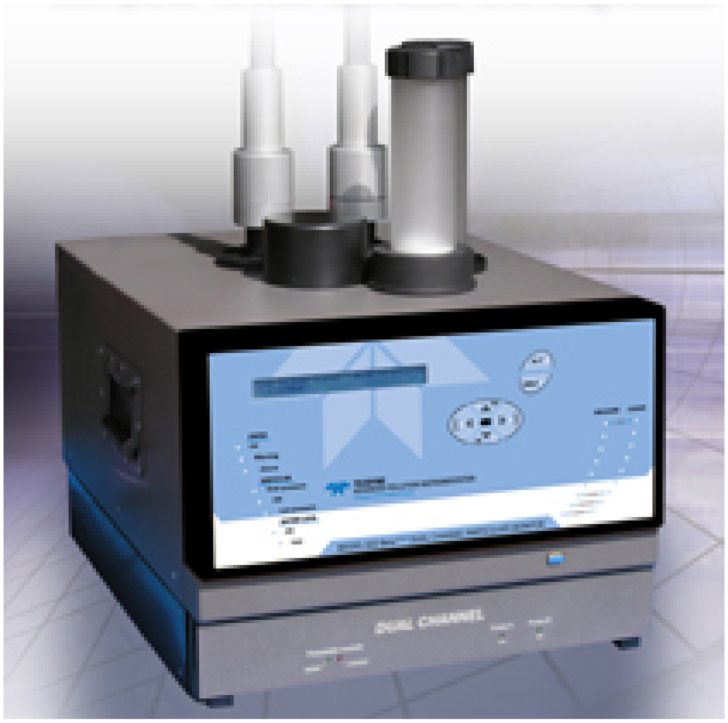


Figure 1-1. Instrument Front

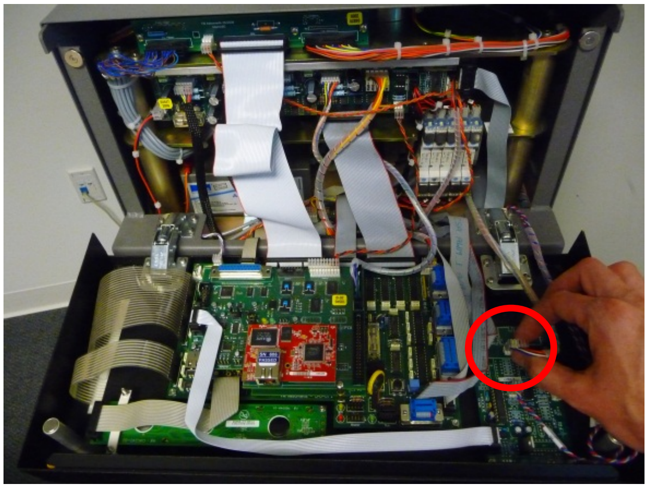


Figure 1-2. Connector on Lock Board, Unplugged

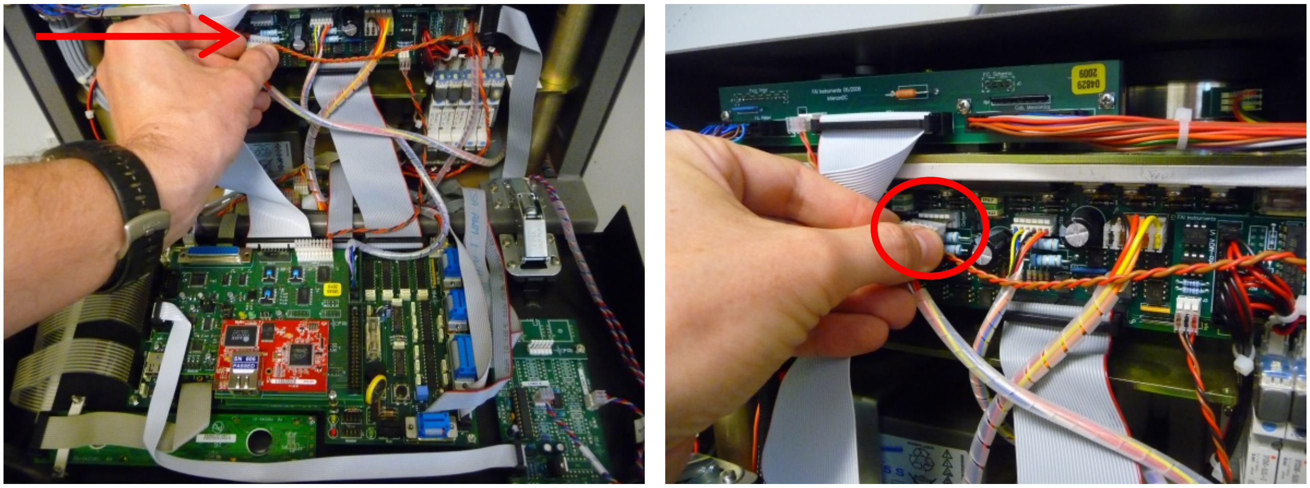


Figure 1-3. Male Connector, *Geiger*, on MOTEV Board

1.8 Model 602 Beta^{PLUS} Quick Start Guide

Teledyne API Model 602 Beta^{PLUS} Quick Start Guide

This Quick Start Guide provides a typical inventory list (varies by configuration purchased) and set-up instructions to supplement the *Model 602 Beta^{PLUS} Particle Measurement System Operation Manual*, Teledyne API Part Number 70318.

Unpacking and Verifying Contents

✓one box with Model 602 Instrument

✓one cylinder with sample tubes (1" OD anodized aluminum), and • (2) offsets to mount inlets at appropriate height differences: 2.1 m, 1.7 m (indoors) or 1.4 m, 1 m (outdoors option). • Additional sampling line lengths as specified at time of order, based on distance between instrument top and inside roofline. *Sample tube extension kits are available with (2) tube/coupler sets per kit.*

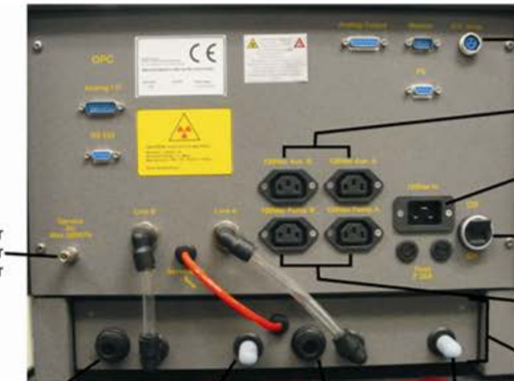
✓one box with accessories, typically as follows:

Accessories box:
- (2) HEPA Filters
- (2) Sample Line Heaters w/tubing couplers
- (2) Exhaust Mufflers
- Loader and Unloader Magazines
- Power Cord
- Ambient Temperature Sensor Cable (5m)
- PM10 pre-impactor (16.7 lpm)
- PM2.5 VSCC (16.7 lpm)
- (2) Condensation Collectors w/tubing couplers
- (2) Vacuum Pumps
- Service Air Compressor
- Operating Manual
- Tubing for Vacuum Pumps
- Ambient Temperature Sensor Radiation Shield
- PM10 inlet (16.7 lpm)
- Small Accessories Bag as follows:

Small Accessories Bag:
- Tweezers for Filter Handling
- Filter Cartridge Separator Tool
- Filter Cartridge Stacker Pedestal
- Flow Check Adapter (at instrument)
- Flow Check Adapter (at inlet)
- Spy Filter and Reference Filter Loading Tool
- Leak Check Cassette
- (3) Spy Filter Assemblies
- Leak Check Adapter (at instrument)
- Spy Filter Cutter Tool
- (2) Reference Filters (R1, R2)
- Spy Filter Cassette Key

Hardware Setup

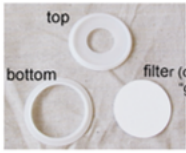
⚠ **CAUTION: Use only power supply outlets with correct electrical specifications.**



1. Adjust regulator to 30 psi.
2. Connect Service Air Compressor power cord to power supply outlet. (Compressor powers on, and automatically turns off/on to maintain psi level).
3. Connect power cord from instrument to power supply outlet. (2-second delay prior to initializing: activates relays, valves, mechanical reset for ~ 1 minute, then the front panel screen displays "READY" status).
4. Create Spy Filters from supplied filters per instructions in Section 5 of the Operating Manual, using tools supplied in small accessories bag. (Follow filter selection guidelines provided in the manual, Section 4.3; *for Hourly Mode use glass fiber filters only*).
5. Load Reference (R1, R2) and (3) Spy Filters into instrument.
   a. Press and hold ESC button ~5 seconds. (Display changes from READY to Menu code: 000).
   b. Press arrow keys to change Menu code: 000 to 920 and press Enter.
   c. Press arrow keys to scroll through loading positions to S12; press Enter. (Plate moves to the S12 loading position).
6. Use tool to place first Spy filter into frontmost port in instrument top.

7. Repeat Step 5 to load remaining filters into loading positions S34, S56, R1, and R2.
8. Assemble filter cartridges per instructions in Section 4.7 of the Operating Manual. (US EPA Class III FEM configuration requires glass fiber filters, which are also recommended for Hourly Mode).



properly assembled filter

(color and white cartridge bottoms can be used interchangeably, but also can be used to differentiate between the two channels when running chemical speciation analysis).

9. Place hollow end of filter plunger into loader magazine (see picture in Step 11).
10. Stack a manageable number, i.e., 20, of assembled cartridges on top of filter loading pedestal (see picture in Step 11).
11. Align loader magazine over stacked cartridges and press down for insertion.


Filter plunger into loader magazine.

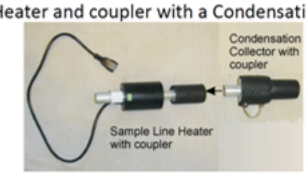

Cartridges on pedestal.


Inserting cartridges into loader.

12. Repeat Steps 10 and 11 until all cartridges are inserted into loader magazine.

13. On top of instrument lock Loader and Unloader magazines into respective ports using ¼ turn clockwise. (Loader port identified by yellow dot to one side).
14. On rear panel connect two fritter filters (blue, see rear panel illustration at start of this Hardware Setup section). Pneumatic tray may move; slide it back.
15. Connect power cord from each vacuum pump to corresponding rear panel vacuum pump power connector (Pump A and Pump B).
16. Connect a vacuum pump suction line from each vacuum pump to its corresponding vacuum pump suction line connector on the pneumatic tray. (See rear panel illustration at start of this Hardware Setup section: Pump A to connector for Suction Line A in center of tray, Pump B to connector for Suction Line B in left side of tray).
17. Connect an exhaust tube with carbon dust filter to each pump. An extension tube can be connected to the exhaust end of carbon dust filter to redirect hot air out of area.

18. Assemble a Sample Line Heater and coupler with a Condensation Collector and coupler.

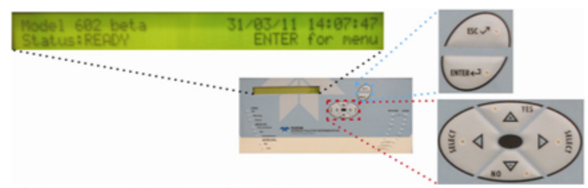


Note: if disassembled, the coupler that is smooth inside with o-ring on each end *must* be connected to the condensation collector.

19. Insert each heater/collector assembly into a sample port on instrument top and connect sampling line into the top of each.

20. Connect each heater cable to ***its respective*** (see Note) AUX power connector (A or B) on the rear panel. NOTE: Facing the instrument front, the left sample port is "A"; right is "B".
21. Connect the ambient temperature sensor cable to the rear panel Ext Temp connector.

SOFTWARE SETUP AND PROGRAMMING



Set the date and time: press ENTER; at the START menu press > arrow to Instrument Settings; press ENTER then > arrow to Date&Time; press ENTER and use arrow buttons to update (DD/MM/YY format); press ENTER to accept changes and ENTER again to reset instrument.

Default operation is Hourly Mode (US EPA Class III FEM configuration). Settings can be modified locally at the front panel or remotely (remote control requires software); refer to the Operating Manual for either method. Default settings are as follows:

Line Settings
- Sampling Flow Rate: 1.00 m3/hr
- Min Flow Rate: 90%
- Min/Max Filter Pressure Drop: 00 kPa
- Equivalent Beta Spot Area: 0.95cm2
- Duty Cycle: Off
- Filter Requirements Hourly Mode:
  - - Filter Accumulation Step: 8, Pressure Drop Control: 40 kPa
- Heater: On

Normalization Settings
- Temperature: 298.1K
- Pressure: 101.3 kPa

SAMPLING

In the START submenu press ENTER; at Line A&B press ENTER; at TIMING press v arrow to scroll to Hourly and press ENTER. At START TIME the display shows the earliest possible start time to begin sampling (instrument requires 1.5 hrs to perform self-diagnostics including leak, flow and mass calibration checks). Use arrow buttons to change to later time if/as desired (for testing for FEM, START TIME must begin at same time as FRM sampler); press ENTER to set.

CHAPTER 2

2. DESCRIPTION OF INSTRUMENT & ACCESSORIES

The Model 602 Beta^{PLUS} Particle Measurement System is an advanced-design, automatic, dual-channel, ambient particulate matter (PM) analyzer/sampler utilizing a (primary) measurement principle based on attenuation of beta radiation by PM collected on pairs of matched sample filters. The two channels have separate and independent sample inlets, filter holders, and flow control, but share a single beta attenuation mass measurement system. Each channel can be separately configured to measure various particle size ranges by use of the appropriate inlet and particle size separator (if required), and a wide range of sample flow rates and collection periods can be programmed. The sampled PM is collected on standard 47 mm (nominal) filters, which are moved, in pairs and in sequence, by a carousel from a supply magazine to the sample positions, to the measurement positions, back to the sample positions for additional sampling (if appropriate), and eventually to a storage magazine for retrieval. This design allows for advanced beta attenuation measurement of the collected PM, with extensive compensation for filter density, beta intensity variation, various blank measurements, and other measurement variables to provide exceptionally high measurement reproducibility. Retrieved filters are suitable for further gravimetric and/or chemical analysis, and the instrument can also operate as a conventional sequential filter sampler (with or without the beta attenuation analysis). In addition, an optical particle counter is optionally available to provide simultaneous, real-time OPC measurements without interference with either the beta attenuation measurement or collection of filter samples

The engineering and manufacturing characteristics of the instrument provide the ability to perform metrological evaluations of particulate matter sampling and mass measurement systems; such as, evaluation of the loss of volatile compounds during the enrichment phase, evaluation of the equivalence of two different sampling inlets, evaluation of biases associated with particle size cut variations with the fractionation device, evaluation of mass measurement reproducibility, etc.

2.1 TECHNICAL SPECIFICATIONS

Table 2-1. Specifications

Parameter	Description
Operative interval of the mass thickness measurement	Total mass thickness (filtering medium + particulate matter film) up to 10 mg/cm²
Resolution	0.1 µg/m³
Detection limit 1 h	2 µg/m³
Detection limit 24 h	0.3 µg/m³
Range	0-2000 µg/m³
β source	^{14}C with 3.7MBeq (100µCi) nominal activity
Operating flow rate	Programmable range 1 - 2.5 m³/h
Flow rate accuracy	±1%
Flow rate control	Automatic, with regulation valve moved by a step motor. Flow rate control stability better than 1% of the required nominal value
Max. allowed pressure drop	50 kPa For pressure drop values higher than 50 kPa, a 1 m³/h nominal flow rate is not guaranteed
Filter Loader/Unloader capacity	96 filter cartridges
Filter cartridges	Standard ∅ 47 mm filter membranes
Interfaces	User interface: Menu-driven interface, LCD display and dynamic keypad Analog output: four 0-5 V DC outputs Serial interfaces: RS-232 serial port for PC and RS-232 serial port for modem communication
Service compressed air	Operating pressure 200-300 kPa (supplied by an auxiliary air compressor provided with the instrument)
Power supply	100-230 VAC, 50/60 Hz factory configured
Power consumption	Maximum 1.1 kW 10 A (115 V) with pumps, air compressor and smart heater running
Power supply continuity in direct current	Two 12 V 3.5 Ah floating batteries - Autonomy to complete mass measurements and filter movements
Air compressor unit	12 L/min at 300 kPa
Operating conditions inside the installation cabinet	Relative Humidity lower than 85% (with no condensate)
Storage conditions	Temperature between -10°C and +55°C Relative Humidity lower than 85% (with no condensate)
Dimensions (W x D x H)	14in x 17in x 21in (36cm x 43cm x 54 cm)
Weight (Monitor) Weight (Pump) Weight (Service air compressor)	79 lbs (36 kg) 15 lbs (7 kg) 17 lbs (8 kg)

2.2 INSTRUMENT COMPONENTS

The instrument is comprised of multiple components: the Sampling unit, sampling inlets, sampling lines, vacuum pumps, and a compressor for service air.

2.2.1 Sampling Unit

This unit contains all of the servomechanisms, sampling and mass measurement devices. The control panel is located in the front; pneumatic, electrical connections, and communication interfaces are located in the back. On the top surface of the instrument are Loader and Unloader housings for the filters and the sampling line connections.

Figures 2-1 and Figure 2-2 show the front and the back view of the unit.

Figure 2-1. Sampling Unit Front

Figure 2-2. Sampling Unit Rear

2.2.2 Sampling Inlets

Figure 2-3. Sampling Inlets

The instrument samples the airborne particulate matter using sampling inlets (Figure 2-3) with a particle size fractionation device.

The instrument can work simultaneously with two different sampling inlets (TSP, PM_{10}, $PM_{2.5}$, PM_1, etc.), as long as they have nominal flow-rate values within the range 1-2.5 m^3/h. The choice of the operating flow rate value depends on the characteristics of the sampling inlet used and the desired particle d_{50} cut point.

Note:

For US EPA Federal Equivalent Method (FEM) PM10 NAAQS compliance use, it is not allowable to remove the PM2.5 Very Sharp Cut Cyclone (VSCC™) from the PM10/PM2.5 combination inlet to obtain a valid PM10 measurement. A valid PM10 FEM measurement for the Model 602 Beta^{PLUS} instrument requires the use of the standard US EPA louvered PM10 inlet.

2.2.3 Sampling Lines

Particle laden air is drawn into each of the sample tubes simultaneously following the particle fractionation device, and through the sample filter, where the particles are deposited.

The instrument measures and stores the relevant values during sampling which are needed to describe the sampling phase, i.e. ambient and filter temperatures, filter % relative humidity, barometric and filter pressures, and volumetric flow rate.

In its basic configuration, the instrument is equipped with the two insulated sampling lines (labeled Line A and Line B in Figure 2-4) inside the installation cabinet. Both lines are provided with a condensed water collector and a relative humidity controlled sample line heater.

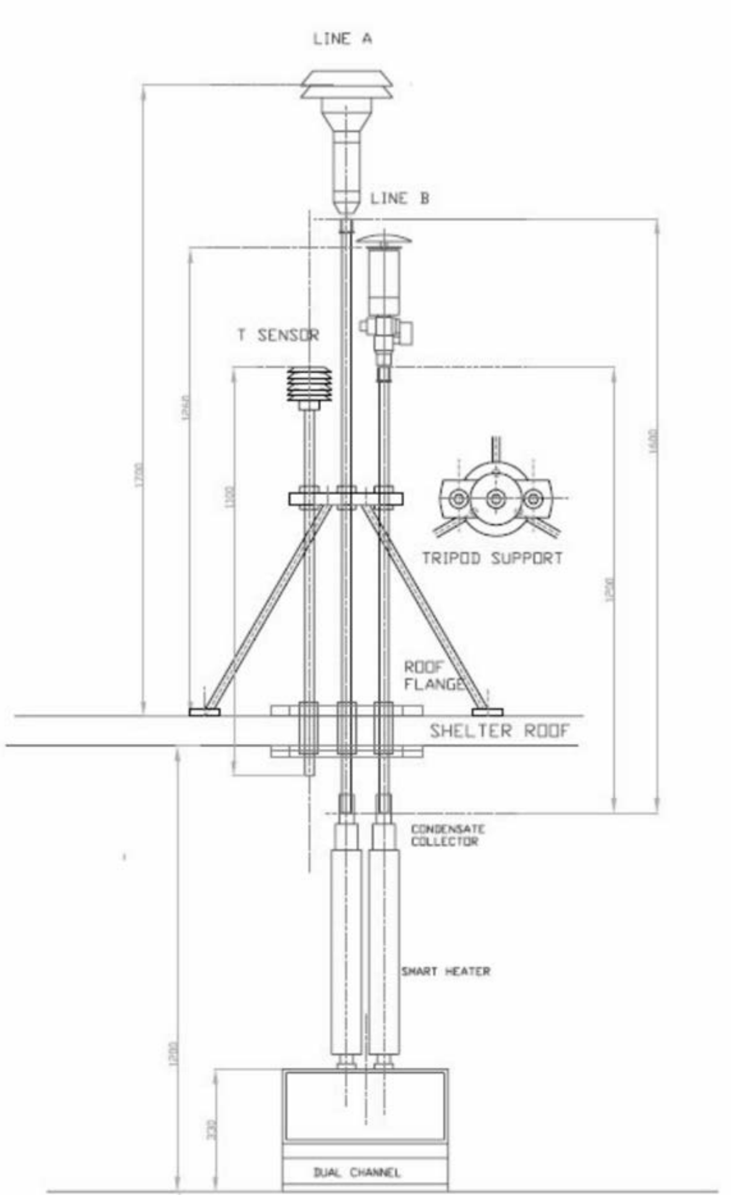


Figure 2-4. Sampling Lines

2.2.3.1 Humidity / Condensation

The instrument sample tubes should always be kept insulated and away from the direct exhaust of HVAC (blowing hot or cold air) in order to avoid possible damage to the equipment

Sample Line Heater Control

The instrument contains a sample line heater on each flow channel. The sample line heater is used to maintain the desired % relative humidity of the sample air stream. A % relative humidity sensor is located in the air stream of each channel, and this measurement is used to control the frequency and amount of heating applied to the sample. The instrument is a US EPA candidate method for PM_{10}, $PM_{2.5}$, and $PM_{10\text{-}2.5}$. For the purposes of using this system as a Candidate FEM method, the sample line heater should be set to activate at 40% relative humidity and deactivate at 30% relative humidity.

Condensation Water Trap

There is a condensation water trap located just above the sample line heater. This is designed to capture water droplets that form on the inside of the sample tube as the result of water condensing out of the sample stream. In some cases of very high ambient dew points, it may be necessary to install self-draining condensation water traps. These are available as options from Teledyne API.

Spy Filter

Beta attenuation based mass measurements are especially sensitive to interferences due to moisture. To counteract these effects, the instrument contains a special 'Spy' filter which is a representative sample of the collection media. This special filter is installed in specific locations within the instrument and is referenced by the beta attenuation mass sensor intermittently throughout the sample analysis process to account for humidity effects on the sample filter matrix. The Spy filters are installed during initial setup and should be replaced if the instrument is relocated, and/or turned off for an extended period.

2.2.3.2 Sample Filter Exposure Conditions

The Model 602 Beta*PLUS* instrument method is similar to the Federal Reference Method, by design, and has shown to produce FRM-like results independent of location and environmental conditions, without the need for any adjustment factors. Maintaining the Model 602 Beta*PLUS* filter exposure conditions to those which are similar to the FRM will produce extremely accurate results.

Filter Temperature

During sampling, the filter temperature, pressure, and relative humidity will be measured and recorded. Maintain sample filter temperature to as close to ambient temperature as possible.

Shelter or Enclosure Temperature

During sample analysis, both the % relative humidity and temperature of the filter analysis region are measured and recorded. For best performance, maintain the enclosure temperature below 30°C at all times.

2.2.4 Vacuum Pump Units

The two vacuum pump units (Figure 2-5) located below the sampling unit draw ambient air through the sampling inlets, sampling lines and two filter membranes.

Both pumps are carbon vane with silencers on the exhaust outlet to reduce noise.

The flow rate through the two sampling lines is regulated automatically and independently.

NOTE:

The sampler can be also used with other types of vacuum pumps provided the pump(s) can sustain a constant flow rate greater than 1m^3/h.

Figure 2-5. Vacuum Pumps

2.2.5 Service Air Compressor Unit

The instrument is equipped with a compressor (Figure 2-6) that supplies service air (200–300 kPa) for moving the servomechanisms. The typical line pressure to the Model 602 instrument should be 150 – 200 kPa.

Note:

If the installation room is already equipped with a system able to supply compressed air (filtered and dehumidified), the air compressor is not necessary.

Figure 2-6. Service Air Compressor

2.3 THE PNEUMATIC CIRCUIT

The sampling module uses two vacuum pumps which can provide a programmable operating flow rate in the range of 1-2.5 m^3/h. Real-time flow rate regulation is performed by a step motor that moves the regulation valve.

Two electronic solenoid valves (EV1 and EV2) placed on each sampling line allow for switching the pneumatic circuit from the sampling configuration to the Span test configuration (automatic check of the flow rate measurement system calibration, see Section 7.1.2) and to the Leak test configuration (automatic check of the pneumatic circuit seal, see Section 7.1.1).

The three possible pneumatic configurations are:

- **Sampling**: EV1 open EV2 closed
- **Leak test**: EV1 closed EV2 closed
- **Span test**: EV1 closed EV2 open

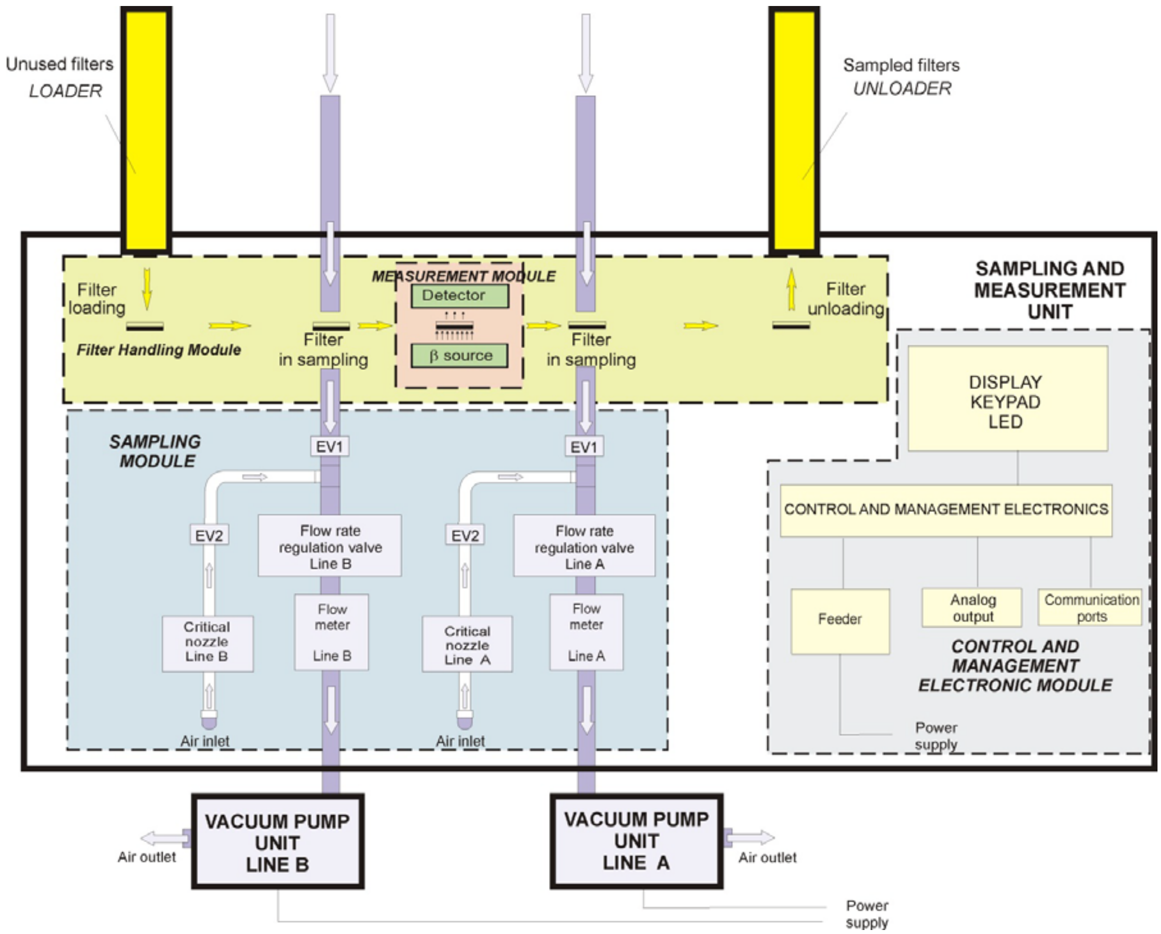


Figure 2-7. Pneumatic Flow

The sampling flow rate measurement is based on the physical laws controlling the air mass transfer through a nozzle that, in the Particle Measurement System, is placed downstream from the regulation valve.

By measuring the pressure value *“P_f”* downstream from the nozzle along with the nozzle pressure drop “ΔP” and the air temperature value *“T_a”* in the measurement area, it is possible to calculate the standard flow rate value “*Qs*” using the equation:

$$Qs = f(z)$$

where:

Pf: pressure downstream of the filter

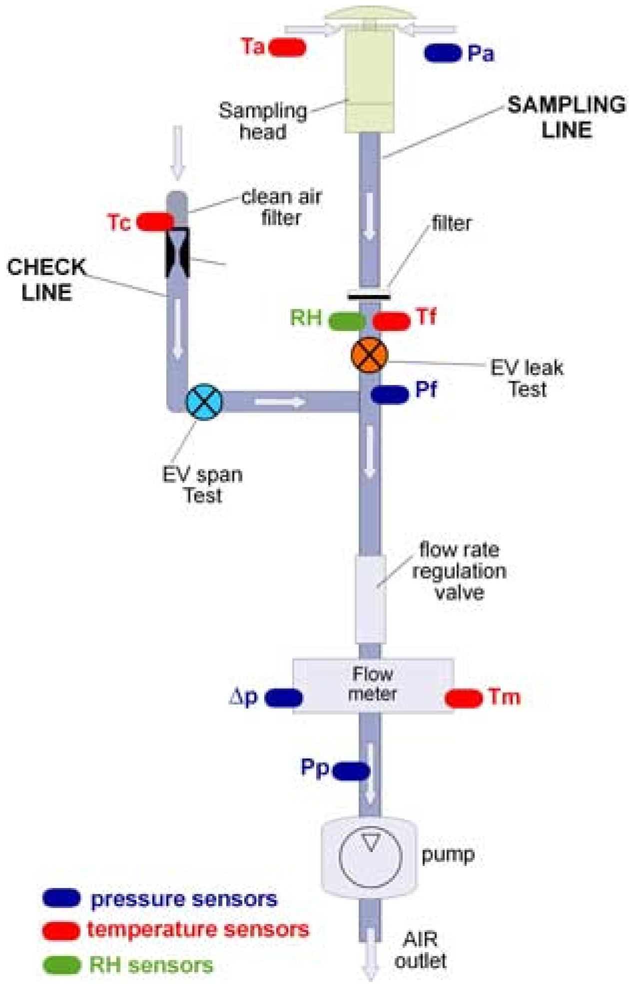
ΔP: pressure drop at the measurement system nozzle

Ta: air temperature in the measurement area

$$z = \sqrt{\frac{\Delta P(2P_f - \Delta P)}{T_a}}$$

In the Model 602 Beta***PLUS*** Particle Measurement System, the form of the function “*f(z)*” is approximated to a second-order polynomial in “*z*” whose coefficients are determined using a multipoint calibration procedure (see Section 2.4 “*Calibration of the flow rate regulation and measurement system*”).

The figure below shows a schematic of the pneumatic circuit for a single pneumatic line.



Sampling line:

Pa: atmospheric pressure
Ta: air temperature
Tf: temperature in the accumulation area
Pf: pressure downstream the filter
ΔP: pressure drop at the measurement system nozzle
Pp: vacuum pump pressure
RH: RH in the accumulation area
Tm: flow meter temperature
Test Line:
Tc: air temperature at nozzle inlet level

Figure 2-8. Single Pneumatic Line Flow

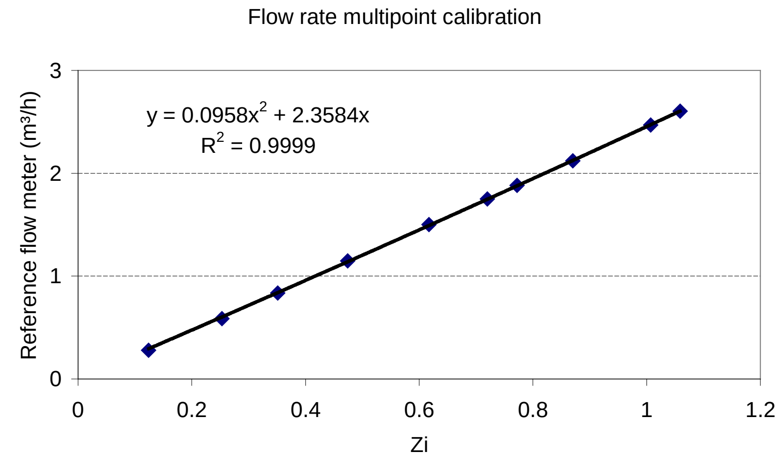
2.4 MULTIPOINT CALIBRATION OF THE FLOW RATE REGULATION AND MEASUREMENT SYSTEM AND QUALITY CONTROLS

Calibration of the pneumatic system is carried out during general testing and inspection, using instruments for measuring

- flow rate
- volume
- temperature
- pressure

These instruments are provided with traceability certificates. In particular, the calibration procedure is based on a "multipoint" calibration approach within the operating flow rate range 1-2.5 Nm^3/h (Temperature=298.1 K; Pressure=101.3 kPa).

For each "zi" value supplied by the instrument at a defined operating flow rate, there is a corresponding value of the reference standard flow rate. Thus it is possible to calculate the coefficients a, b, c of a second-order relation in "z" y=az2+bz+c that best describes the relation between “z” and the reference flow rate.



The following quality control (QC) measures are implemented before and during each measurement cycle:

- **QC Pneumatic Circuit Seal (Leak test):** At the beginning of every sampling cycle, the instrument can perform a procedure that, using the equation describing the equilibrium state of a perfect gas in a system at known volume, allows for checking the pneumatic circuit seal downstream from the filter membrane (see Section 7.1.1 “*Leak Test*”). The leak test results are stored in the *Buffer* data (see paragraphs 6.2.1 “*Access to the Buffer Data from display*” and 6.3 “*Connection to an external PC and Buffer data download*”) and if the specific leak exceeds the defined threshold, a warning message is displayed and an alarm is sounded.

- **QC Flow Rate Measurement System (Span test):** At the beginning of every sampling cycle, the instrument can perform a procedure to draw an ambient air flow that can be used as a transferring standard, since it is generated using a convergent-divergent nozzle operating in critical pressure conditions (ISO 9300:2005). The mass flow rate value “Q_m” of this ambient air flow comes from the equation

$$Q_m = \frac{C_d P_0 A C^*}{\sqrt{R_{gas} T_0}}$$

Where:

Q_m: mass flow rate
C_d: discharge coefficient
P: atmospheric pressure downstream from the nozzle
A: nozzle area
C*: flow critical factor
R: gas constant
T: temperature downstream from the nozzle

By measuring the atmospheric pressure and the temperature downstream from the nozzle and knowing the characterizing parameters, it is possible to determine the value of the mass flow through the nozzle with a relative uncertainty of about 1%. The expected mass flow through the nozzle is compared with the value measured by the instrument. The instrument supplies the percentage deviation between the two values and stores this value in the Buffer Data. If the calculated percentage deviation value exceeds the programmed threshold value, a warning message is displayed and an alarm is sounded (see Section 7.1.2 "*Span Test*").

- **QC Inlet Flow Rate Stability:** the instrument automatically checks the inlet flow rate, regulating it to keep it to within 1% of the nominal value. A quantitative estimation of the effectiveness of this control is obtained by calculating the Relative Standard Deviation (*RSD*) variable expressed as per cent (%). The value of this variable is calculated using the following expression:

$$RSD\% = \left(\sqrt{\frac{\sum (Q_i - Q)^2}{N - 1}} \right) \cdot \frac{1}{Q} \cdot 100$$

Where:

Q_i: measured flow rate
Q: programmed flow rate
N: nominal flow rate
The *RSD* value is available both during the sampling phase and in the relative buffer data.

- **QC Filter Pressure Drop:** the instrument automatically measures the filter pressure drop. The control of this parameter is essential for assuring that sampling takes place under optimal conditions. The filter pressure drop value provides, for example, information about potential filter damage, improperly installed filters (i.e. 2 stacked together in one filter cartridge), potential condensation, or whether the maximum load capacity of the filter membrane has been reached.

- **QC Sensors:** the instrument performs some automatic quality controls aimed at checking whether all the sensors are functioning correctly. In particular it checks the pressure and temperature sensors to verify that under operating conditions, the following relation is always respected: $P_{atmosphere} > P_{filter} > P_{pump}$ (see figure 2.8) (Warning 9, See Appendix 3). It also checks that the temperature sensors are functioning correctly (Warning 24, see Appendix 3).

2.5 MASS MEASUREMENT SYSTEM

PMx mass measurement with the Model 602 Beta*PLUS* Particle Measurement System is based on the β attenuation technique. This technique has been implemented on the basis of an in-depth theoretical analysis of the interaction between β rays and matter that led to the formulation of a generalized parametric equation. This equation describes the relationship between the attenuation of the β-particle flux passing through the thin film and the mass thickness of this matter film.

Use of this methodological approach allows the β measurement technique implemented in the instrument to be refined so as to make it metrologically traceable.

2.6 MASS MEASUREMENT SYSTEM CALIBRATION

Periodic calibration of the mass measurement system is not required, but instrument failure or measurement errors may indicate that one or more components (the Geiger-Müller detector and/or associated electronics) need to be replaced. The following quality control measures are implemented during the mass measurement phase:

- **QC background noise**: Background radioactivity counts are checked at the beginning of each measurement cycle, and if they are outside the predefined range, the instrument sounds an alarm, displays an error message, and stores the message in the buffer data.
- **QC short-term Geiger counter stability**: During the measurement of the β radiation flux passing through the filter, the instrument continuously monitors whether the counts ratio obeys Poisson statistics (radioactive decay). If the result of this comparison is negative, the instrument sounds an alarm, displays an error message and stores it in the buffer data.
- **QC long-term Geiger counter stability**: In order to monitor drifting of the instrument's detector (which may occur, but does not affect mass measurement quality) the "Air counts" of two consecutive measurement cycles are compared. If the percentage difference between the measured "Air counts" value and the reference value is higher than the defined threshold, the displays an error message and stores it in the buffer area.
- **QC Geiger counter high voltage**: The Geiger detector's response quality depends strongly on the stability of its high voltage supply, which provides a stable voltage that varies by less than 1‰. If the voltage deviates by greater than 2‰, the instrument flags and displays an alarm, and stores it in the buffer area.
- **QC mass measurement system calibration**: At the beginning of every operating cycle, an automatic calibration can be performed using beta particle flux measurements in air (Φ_0) and two reference aluminum foils (R_1, R_2) with known mass thickness. After calculating the mean values $\overline{\Phi}_0, \overline{\Phi}_{R1}, \overline{\Phi}_{R2}$, the

instrument determines the mass-thickness values "x_{mis}" of R_1 and R_2, using the calibration function:

$$x_{mis}(R1) = a\,z^3(R1) + b\,z^2(R1) + cz(R1)$$
$$x_{mis}(R2) = a\,z^3(R2) + b\,z^2(R2) + cz(R2)$$

Where $z = \ln\left(\dfrac{\Phi_0}{\Phi(x_i)}\right)$, x_i = nominal value of the i[th] mass thickness

By comparing the mass thickness values so determined with the corresponding nominal values, the instrument calculates the relative percentage deviations:

$$\frac{x_{mis}(R1) - x_{R1}}{x_{R1}}\%$$

$$\frac{x_{mis}(R2) - x_{R2}}{x_{R2}}\%$$

Because the time required to measure beta fluxes through R1 and R2 for the calibration check is about 25 minutes in Multi-Time Mode and 10 minutes in Hourly Mode, the value of the associated uncertainties will be higher than the values obtained in the last acceptance test. (In other words, shorter measurement times will result in higher uncertainty).

2.7 QC AND INSTRUMENTAL FUNCTIONALITY

2.7.1 Warning Messages

The Model 602 Beta*PLUS* Particle Measurement System performs internal automated diagnostic tests before and during operation. These quality control tests include both the pneumatic and mass measurement systems.

The Warnings are signalled by a yellow LED on the control panel and are displayed in the Instrument Info menu and stored in the Buffer Data. Some of them also function to inform the user and/or the maintenance engineer about what caused the Warning.

2.7.2 Alarm Messages

The Model 602 Beta*PLUS* Particle Measurement System will automatically halt in case of a severe instrument problem, signal the user by a red LED on the control panel and display, and provide Alarm messages (see Appendix 2) indicating the cause. These Alarm messages are stored in the instrument and available both locally and by remote. If you are unable to resolve the alarm after referring to the table of alarm codes in Appendix 2, please contact Teledyne API Technical Support for technical assistance:

800-324-5190 (phone) or sda_techsupport@teledyne.com (email).

2.8 CONTROL ELECTRONICS, MANAGEMENT SOFTWARE AND INTERFACES

The sampler's electronics have been engineered with two CPUs configured in a master-slave architecture, that are responsible for different tasks. The slave CPU oversees mechanical processes and the acquisition of digital and analog signals. The master CPU manages I/O, communications, operation timing, flow rate measurement and control, sample mass measurement, and data storage tasks.

All information related to sampling and mass measurement processes, test logs, alarm/warning logs and mechanical movement logs is stored in the master CPU structure. This characteristic allows the mechanical operating conditions to be continually (and remotely) monitored in order to determine possible failure causes. Local I/O is managed by the LCD display, membrane keypad and status indicators (LED).

The management software is structured in tree menus and allows:

- access to the sampling and measurement data from the processed filters
- access to the data from the sampling and measurement in progress
- setting of the sampling and measurement parameters
- use of the tools for testing and calibrating the instrument

The Model 602 Beta*PLUS* Particle Measurement System is equipped with the following interfaces:

- "Display" interface: the display on the front control panel shows all of the instrument's information and Alarm and Warning messages
- RS-232 serial interface PC: allows data interchange with a PC
- RS-232 serial interface Modem: allows for connection with a modem to control the instrument remotely
- Analog data output

2.9 REMOTE CONTROL OF THE INSTRUMENT "GSM modem"

The instrument can be equipped with a GSM/GPRS modem (Figure 2-9) for complete remote control (see Section 6.3). In particular it allows:

- setting of the operating parameters
- continuous access to the sampling and measurement data (see Section 6.3)
- checking the mechanical functionality
- reading of the system "trace files" (storage of all servomechanism movements, tests, all Alarm and Warning messages, etc.)
- reception of diagnostic SMSs automatically sent by the instrument (see Section 6.5)

Figure 2-9. GSM Modem

2.10 ANALOG DATA OUTPUT

An analog data output port is located on the back panel of the instrument, allowing for connection with an analog *data logger* using a cable with a 15-pin connector (see Figure 2.10). The signal distribution on the connector pins is presented in Table 2-2.

Table 2-2. Analog Output Connector Pin Assignments

Pin	Description
5	Ground
8	Analog signal proportional to the ***concentration value measured on Sampling Line A*** varying between 0V and 5V (the 5V value corresponds by default to 200 µg/m^3. This value can be modified if desired) or *a negative concentration value*[1]
15	Analog signal proportional to the ***concentration value measured on Sampling Line B*** varying between 0V and 5V (the 5V value corresponds to 200 µg/m^3. This value can be modified if desired) or *a negative concentration value.*[1]
14	Analog signal proportional to the ***Service air pressure value*** varying between 0V and 5V (the 5V value corresponds to 500 kPa)
1-9	***ALARM*** signal (NO† contact)
2-10	***WARNING*** signal (NO contact) (see Appendix 3 "*Warnings*")
3-11	***Data validation*** signal (NO contact)
4-12	***Available measure*** signal (NO contact)

† Normally Open

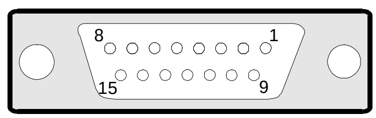


Figure 2-10. Analog Output Connector

[1] Starting with firmware revision 04080166, negative mass concentration values are represented in the instrument's buffer data preceded by the minus sign, but they are associated, independently from their absolute value, with the emission of a fixed value of 5V from the corresponding analog output.

2.11 SEQUENTIAL SAMPLING MECHANICS

The Model 602 Beta^{PLUS} Particle Measurement System has been designed to achieve highly reliable mechanical performance.

The main mechanical actions (filter loading/unloading, filter placement in the accumulation area, etc.) are carried out by electro-pneumatic servomechanisms with a single degree of freedom, guaranteeing very high repeatability. In addition, a set of quality controls on mechanical movement times allows for objective monitoring and characterization of the system's mechanical status, which provides for effective preventive diagnosis.

Finally, the use of electro-pneumatic actuators allows for considerable movement autonomy even in power-down conditions.

2.12 INSTRUMENT MANAGEMENT DURING POWER FAILURE AND AUTO-SWITCH-OFF PROCEDURE

The Model 602 Beta^{PLUS} Particle Measurement System can handle all possible fluctuations or interruptions of the power supply. The instrument is equipped with two rechargeable batteries and has a mechanical movement architecture (electro-pneumatic) which lets it achieve any mechanical configuration even during power failures.

During power failure:

- the sampling processes in progress will stop (vacuum pump power failure)
- the instrument estimates the battery charge status and the remaining battery operation time
- if the remaining battery operation time is long enough, the instrument completes the mass measurement cycles in progress
- by analyzing the operating and programming status, the Model 602 Beta^{PLUS} Particle Measurement System selects the best mechanical configuration to correctly restart the operating cycle when power is restored
- once it is in the correct mechanical configuration, the instrument starts an automatic switch-off procedure deactivating the control panel until power is restored
- After power is restored the instrument unloads the filters and loads 6 new unused filters that will be used to go ahead with the programmed sampling and measurement cycles.

"Power failure" events are displayed with a *Warning* message and stored in the *Buffer Data* (Warning 28, see Appendix 3).

CHAPTER 3

3. INSTRUMENT INSTALLATION

There are two primary installation options for the Model 602 Beta^{PLUS}; indoor (existing building, shelter, trailer, etc.) OR instrument cabinet (outdoor install). The indoor installation involves the installation of the instrument into an existing building or structure, and will require drilling holes into the roof for the sample inlet tubes. The instrument cabinet installation option is available from Teledyne API and is used when there is no space available in the existing building or shelter.

3.1 LIST OF TYPICAL INSTRUMENT COMPONENTS AND ACCESSORIEs

- Model 602 (not shown)
- 2.1m, 1.7m tubes (not shown)
- (2) Multi-time Inlet Nozzles (not shown)
- HEPA Filters
- (2) Condensation Water Trap Collectors
- (2) Sample Line Heaters
- (2) Vacuum Pumps
- Small Accessories Bag
- Service Air Compressor
- Loader and Unloader Magazines
- 100 cassettes: 50 black-white & 50 white-white
- Pack of 200 GF10 filters
- Operating Manual
- Quick Start Guide
- Power Cord
- Tubing for Vacuum Pumps
- (2) Exhaust Mufflers
- Ambient Temperature Sensor Radiation Shield
- Ambient Temperature Sensor Cable (5m)
- PM_{10} inlet (16.7 lpm)
- PM_{10} pre-inlet (16.7 lpm)
- $PM_{2.5}$ VSCC (16.7 lpm)

Figure 3-1. Model 602 Components and Accessories

Depending on configuration and options, the accessories may be different than what is displayed here in Figure 3-1.

3.2 LIST OF TOOLS

A. Cabinet Installation

- Level
- Screwdriver (flat head)
- Waterproof sealant or Roof caulk
- 1” diameter sample tubing insulation (1m)
- Duct tape
- Zip ties

B. Indoor/Shelter Installation

- Roof Flange Kit (3 piece, optional from TAPI)
- Support Quadrapod (optional from TAPI)
- Drill (drill and driver)
- Adjustable Wrench
- 1” core drill bit / hole saw
- Phillips / Flat head driver bits
- Thirteen (13) 2” deck screws
- 1” diameter sample tubing insulation (enough to completely cover both sampling lines)
- Duct tape
- Zip ties
- Waterproof sealant or Roof caulk

3.3 SITING

The Model 602 Beta*PLUS* instrument is designed to operate in an environmentally controlled, weather proof location. The operating range of the instrument is -10 to 55°C, with relative humidity below 85% (non-condensing). The ambient sampling environmental range is virtually unlimited.

General environmental siting requirements can be found in US EPA 40 CFR Part 58.

A. Cabinet Installation

The Outdoor cabinet provided by Teledyne API dimensions are: 48 ¾"W (including side mounted AC unit) x 65"H (including 4" feet) x 32"D; weight is 320lbs (without instrument)

The cabinet must be installed in an unobstructed area and placed on level ground. The cabinet contains its own series of circuit breakers and requires a dedicated 20AMP circuit. The power cable coming from the cabinet is a NEMA 15/20R.

The cabinet consists of two main spaces, the upper space where the instrument is placed and the lower space where the two vacuum pumps and compressor are placed. There are pre-drilled holes with cable management for the vacuum supply and compressor lines.

Figure 3-2. Instrument Installed in Outdoor cabinet, Door Open (a) and Door Closed (b)

B. Indoor Installation

Review the instrument dimensions, physical and electrical requirements prior to siting. In addition, there are other general considerations which might be helpful:

Physical

a) Instrument Weight – the main instrument box is approximately 79lb (36kg)

b) Distance from the Model 602 instrument to Ceiling – the sample line heater / condensation water trap assembly extends above the top of the instrument by 10" (254mm)

NOTE: A sample line extension kit must be used to connect between the Model 602 instrument and the external Sample Inlet Lines. The length of these sample tube extensions will be site dependent. The user must measure the distance between the ceiling / bottom of roof deck and the Model 602 instrument (including the sample line heater / condensation water trap assembly) to determine the correct sample line

extension kit to use. The Model 602 instrument is 14.2" (360mm) high and the sample line heater / condensation water trap assembly is 10" (254mm) high; total height 24.2" (615mm).

Sample tube extension kits are provided in 0.5 (DU0000051), 0.75m (DU0000052), and 1m (DU0000053) lengths.

- The external Sample Inlet Lines (2.1m + 1.7m) are provided by Teledyne API as part of the instrument package to ensure proper inlet height and spacing.

c) Additional Installation Hardware Options:

- Angle Support Brackets (HW000712) are optional components for rack mount installations.
- A three piece Roof flange kit (DU0000009) and Support quadrapod (DU0000010) are supplied as installation options to ensure a proper seal for the roof and support for the inlet tubes and inlets.
- If these are not acquired from Teledyne API, they will need to be supplied locally.

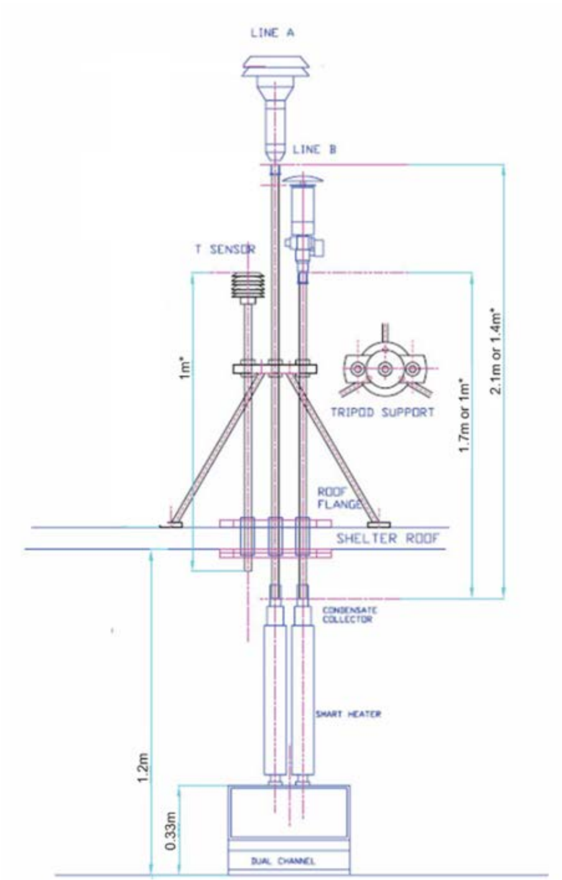


Figure 3-3. Typical Indoor/Shelter Installation with Roof Penetrations

Electrical

a) Main instrument box requires one AC power connection

- The two vacuum pumps and sample line heaters plug directly into the rear panel of the instrument.

b) The Service Air Compressor requires one AC power connection

c) Total power consumption: 1200W (worst case)

3.4 PREPARING FOR THE INSTALLATION

A. Cabinet Preparation

1) Locate the enclosure in an area free of obstructions in all directions, and follow siting criteria described in the US EPA 40 CFR Part 58.

2) Be sure the enclosure is on flat ground (front to back, and side to side) and provide shims if necessary to ensure it is level.

3) Locate the sample tube inlet support bracket arm and place it on the enclosure roof.

4) Loosen the cover from the rear panel electrical conduit port. This is where the ambient temperature sensor cable will be run.

5) Connect the power cable to an appropriate AC power source and Turn the circuit breakers into the ON position.

6) Using a flat head screwdriver, remove the side panel of the Air Conditioning / Heating unit to expose the thermostat controller. Set to an appropriate temperature given the environmental conditions of the area.
NOTE: In order to avoid overworking the AC / Heater unit, identify a reasonable temperature given the ambient conditions; a set point range of 65°F (18°C) to 84°F (30°C) is acceptable.

7) Close the door, and fasten the screws tightly using a screw driver.
NOTE: You should revisit the thermostat once the instrument has been running inside the cabinet for several days. Observe the internal digital thermostat and reset the controller to obtain the desired level.

B. Building / Shelter Preparation

Interior

The Model 602 Beta*PLUS* instrument can be installed into a rack or on a table top. Normal safety precautions should be considered when installing the instrument including the stability, integrity, and weight capacity of the structure where the instrument will be placed.

The instrument has sample inlet downtubes which connect directly to the top of the instrument which will prevent from installing any other instruments above it in the rack or on the table.

The sampling tubes should not be exposed to the direct exhaust of a Heating / Air Conditioning unit in order to avoid condensation inside the sampling line and possible damage to the equipment.

Be sure to have adequate space on the table or in the rack to locate the instrument with rear panel access (for connecting power, sample tubes, etc), directly below the area selected for the Inlet locations on the roof.

The instrument should be located in proximity to an AC power source.

Remove any drop ceiling panels to expose the bottom of the roof deck where the holes will be drilled. Place a drop cloth below the location of the holes to catch debris during drilling.

Exterior – Installing the Roof Flange Kit

The process of drilling the sample tube holes will vary based on the type of roof, roof materials and construction, and location. Normal safety procedures should be followed, and the procedure may need to be accomplished by a roofing professional to ensure the roof penetrations are made properly and the roof is completed sealed following the installation of the roof flange and inlet tubes. It is important to understand and follow the proper procedures to ensure the roof integrity remains intact, and that none of these actions will void the manufacturer's warranty of the existing roof.

The optional hardware installation accessories provided by Teledyne API (i.e. Roof Flange Kit and Quadrapod) are designed for a flat roof. In the case of a slanted or corrugated roof installation, special accessories will be required. Teledyne API can provide specific guidance if necessary in these cases.

For a flat roof, locate the exact location where the inlet holes will be drilled and clear any debris. Mark the center spot of the holes to be drilled and double-check that they are in the correct position prior to drilling. Using the 1" Core Drill Bit / Hole Saw, drill three (3) holes spaced 4" apart on center. Be sure to drill completely through the roof – depending on the type of roof, this could consist of up to several inches of Built-up Roofing (some crushed stone and layers of tar paper and taring, and either wood or metal). Remove any tar paper or built up roofing extending an additional 1 ½" outside of the 1" diameter hole to allow for the installation of the flange and fastening of the flange to the solid roof deck material (wood or metal). Two adjacent holes will be used for the sample tubes, and the third hole will be used for the ambient temperature sensor cable.

The Roof Flange Kit consists of three individual flanges, designed specifically for the 1" sample inlet tube. Locate the flange over the hole to be sure it is properly aligned and that there is adequate clearance for the sample line tube to run directly through the flange and the roof. When you are comfortable with the drilled holes and you are ready to permanently install the flanges, locate the roof sealant material, deck screws, and power drill. Apply a bead of roof sealant into the recessed ring on the bottom side of each roof flange and place it directly over each hole. *NOTE: Do not overfill the recess as the roof sealant will seep into the hole when the flange is pressed and fastened into place.* Using the power drill and 2" deck screws, fasten the roof flanges directly to the roof deck (wood or metal). Finish by applying a modest amount of roof sealant around the perimeter of the roof flange, and over the tops of the screw heads. Allow the roof sealant to dry and set for a few hours.

3.5 INSTALLING THE SAMPLE TUBES, INLETS, AND SUPPORT HARDWARE

A. Assembling the Quadrapod

The quadrapod provided by Teledyne API is specifically designed to accommodate the two sample inlet tubes as well as the ambient temperature sensor mount. Assemble the four legs to the cross bar using a screwdriver and adjustable wrench. Locate the quadrapod directly above the three roof flanges, and be sure the cross bar sits directly above the sample inlet tube holes. Note the bracket hardware which will be used to fasten the tubes to the cross bar of the quadrapod.

B. Installing the Sample Inlet Tubes

Locate the two sample inlet tubes (2.1m and 1.7m). One at a time, insert them into adjacent roof flanges (one Sample Inlet Tube must be installed into the center hole). The 2.1m sample tube should be just less than 2m (~1.8m) above the roof. The top of the 1.7m sample tube should be positioned 400mm (~17") lower than the 2.1m tube. The opposite end of the tubes should penetrate the roof flange and be visible and accessible from inside the shelter. When properly installed, the tubes should reach the same height inside the trailer or shelter. A sample tube extension kit will be connected to the bottom of the sample tubes from inside the trailer, to reach the top of the sample line heater / condensation water trap assembly.

An additional 1m tube is provided to act as conduit for the ambient temperature sensor cable, as well as a mount for the ambient temperature sensor radiation shield. This tube can be placed through the third roof flange.

Once the tubes have been placed into the flange cord grips and set to the proper height, tighten firmly onto each of the cord grips by hand. An adjustable wrench can also be used in order to be sure there is a good seal around the sample tube. Once the cord grip has been completely tightened, some roof sealant can be placed around the sample tube to be sure there is a waterproof seal.

C. Installing the Quadrapod

Locate the quadrapod directly above the sample tube holes, and up against the sample tubes. Attach the three tubes to the cross bar of the Quadrapod using the supplied hardware. Be sure the Sample Inlet Tubes are directly upright. Secure the quadrapod to the roof using a combination of 2" deck screws and roof sealant. Be sure to completely cover the screws with roof sealant. Allow the roof sealant to dry for several hours (follow the roof sealant instructions).

D. Installing the Sample Inlets and Ambient Temperature Sensor

Locate the three size selective inlets: US EPA PM_{10} inlet, PM_{10} pre-impactor, and $PM_{2.5}$ Very Sharp Cut Cyclone (NOTE: if using an alternate size selective inlet configuration, the actual inlets may be different). Inspect the inlets and be sure they are properly assembled and connections are tight. Further instructions on inlet assembly, cleaning, etc., can be found in Section 8.1 of this Manual. Check that the o-rings are installed in the end that will be placed onto the Sample Tube. The o-rings should be properly greased prior to installation onto the Sample Tube.

Place the US EPA PM_{10} size selective inlet onto the taller sample tube (2.1m length). The top of the PM_{10} inlet should sit approximately 2m above the roof. Next, place the $PM_{2.5}$ Very Sharp Cut cyclone on the shorter sample tube (1.7m length), and then place the PM_{10} pre-impactor onto the $PM_{2.5}$ cyclone inlet.

Next, obtain the ambient temperature sensor cable and radiation shield. From the roof level, lower the ambient temperature sensor cable down through the center of the 1m tube using the end that will connect to the rear panel of the instrument. The opposite end containing the ambient temperature sensor contains a 'stopper' which will hold the sensor in the appropriate position in the tube. Place the radiation shield onto the end of the tube and tighten the cord grip by hand.

Figure 3-4. Typical Configuration of Sample Inlet Tubes and Support Hardware

3.6 INSTALLING THE MODEL 602 BETA*PLUS* INSTRUMENT

A. Physical Inspection

Upon receipt of the Model 602 instrument, be sure to check for any potential shipping damages, or impacts to the box. If any damage is suspected, please make notes and take photographs to document it. Notify Teledyne API immediately.

B. Preparing the Instrument

Place the instrument onto a sturdy surface or into the rack. Lower the instrument front panel to remove instrument safety lock (See Section 1.7.1 in Operating Manual for details).

C. Setting up the Service Air Compressor

Set up the Service Air Compressor near the instrument and connect the (red) supply air tube to the rear of the instrument. The service air connection is located on the rear right hand side of the instrument if viewing from the front. Simply press the connector into place and it will automatically latch.

Connect the Service Air Compressor power cord into a suitable power supply outlet. Once connected to AC power, the compressor will activate and increase the pressure to the level set at the regulator. Adjust the regulator to 30 psi. The compressor will turn off once this level is achieved. Adjust the regulator until the instrument reading of the service pressure is between 150 – 200 kPa. The compressor will turn on occasionally during instrument operation in order to maintain the pre-set pressure level.

D. Assembling and Loading Filter Cassettes

Glass fiber filters are recommended in hourly mode and are required in the US EPA Class III FEM configuration. Also, the same filter media must be used in both channels. The loader magazine can accept up to 96 filter cartridges for an autonomy period of 15 days in hourly mode. The instrument will consume six (6) filters per day in hourly mode.

If multi-time mode is used, filter consumption is greatly reduced and a variety of filter media can be used (Teflon, Quartz, etc.). Multi-time mode requires the use of the alternate inlet nozzles (which are also supplied with the instrument).

See Sections 3.7 & 5.5 of this Manual for more details on the Multi-time Mode configuration.

Details for assembling and loading the filter cartridge magazines are located in the Section 4 of this manual.

E. Connections and Hardware

After filling the Loader Magazine with filter cassettes, connect both the Loader and Unloader magazines to the appropriate ports on the top of the instrument. The loader port is located on the farthest right side and is identified by a small yellow dot on the side. The magazine connections are unique and keyed to fit only into the appropriate port. A quarter turn clockwise will lock magazines into position.

Moving to the rear of the instrument, connect the two blue fritter filters into the threaded connections on the back of the instrument pneumatic tray. If you press hard on the rear of the pneumatic tray, it will slide forward, as it is connected by magnet on the front of the instrument chassis. If this happens, gently slide the tray back into position under the instrument.

It is recommended to position the vacuum pumps in an isolated area to reduce the heat accumulation. Connect the vacuum pumps power cord to the rear of the instrument, then connect the vacuum pump suction lines to the rear of the pneumatic tray. The connections are labeled and be sure to use Pump A with Line A and Pump B with Line B.

Connect the exhaust tube with filters to each of the two pumps. The pump exhaust is hot and should be vented away from the instrument, and preferably outside using an extension tube.

Assemble the two sample line heater / condensation water traps together for each line and place them into the inlet ports in the top of the instrument. Be sure the coupling that connects to the top of the condensation collector will be smooth on the inside and contain two O-rings for sealing, one on either end.

Locate the sample tube extension kit. These are the sample tubes that will connect between the sample line heater / condensation water trap assembly to the sample inlet tubes. The kit consists of a sample tube (lengths are 0.5, 0.75, or 1m) and a coupler for connecting to the sample inlet tube. Connect the sample tube to the top of the condensation water trap. If measured properly, the sample tube extension should meet very closely to the previously installed sample inlet line. The sample inlet tube height may be adjusted slightly to help accommodate the connection to the sample tube extension. Repeat this with the second sampling line. Be sure couplers are in place and have a good seal. A leak check can be performed once the instrument is set up to confirm the integrity of the sample tube connections.

Once the sample line installation is complete, tubing insulation should be applied to all exposed metal pipes and couplers.

Plug each sample line heater into the power connection on the rear of the instrument labeled Aux. It is important to align them with the proper label (Line A vs Line B).

Connect the ambient temperature sensor cable to the rear of the instrument. The connector on the rear of the instrument is labeled Ext Temp.

F. Initializing the Instrument

Connect power cable to rear of the instrument and suitable outlet. Turn on the instrument using the switch on the rear left hand side. There will be an approximate 2 second delay following activation of the switch. The instrument will immediately initialize by activating a series of relays, valves, and perform a mechanical reset. The initialization will take approximately 1 minute. When finished, the instrument main screen will show a 'READY' status.

G. Loading the Reference and Spy Filters

Load Reference (R1, R2) and (3) Spy Filters into instrument. The Spy filters will need to be created using filters from the box supplied with the instrument. Tools for spy filter creation are supplied in the small accessories bag and instructions can be found in the Operating Manual, Section 5.

Once the three (3) Spy Filters are created (See Section 5.7 of this Manual for making Spy Filters), you can load them into the instrument along with the Reference Filters (R1, R2). Unlike the Reference Filters (R1, R2), the Spy Filters can be placed into any of the three Spy Filter positions inside the instrument. The Spy Filters should all consist of the same type of media that is being used for the sampling and should come from the same filter manufacturer. In hourly mode, the instrument must use Glass Fiber filters only.

To load the Reference and Spy Filters (See Sections 5.7 & 5.8 of this Manual), Press and Hold the ESC button for approximately 5 seconds. A Menu button will appear with the code 000. Replace 000 with 920 using the arrow keys, press ENTER. This will bring you to the Reference Filter loading screen. Using the up and down arrow keys, select S12 (this refers to the Spy Filter located between Filters 1 & 2). Press ENTER. The instrument will move the plate to the S12 loading position.

Once in the loading position, look into the Filter Unloading port which is the front most port in top of the instrument. Place the first Spy Filter into the holder position located in the plate using the supplied tool.

Repeat this process for S34, S56, R1, and R2. Once all of these filters have been installed, press ESC. The instrument will reset the plate and bring the instrument back to the Main Screen

3.7. OPERATING MODES

The instrument has two operating modes that can be selected by the operator, *Dual Channel Mode (which is the standard operating mode of the instrument)* and *Single Channel Mode*. In *Dual Channel Mode,* Hourly (1-hr sampling time) and Multi-Time (8, 12, 24, 48, 72, 96, 120, 144, or 168-hr sampling times) Sampling Modes can be used. In *Single Channel Mode*, only the Multi-Time Modes (sampling time ≥ 8 h) can be used.

3.7.1 Dual Channel (Line A & B) Mode

Dual Channel (Line A&B) Mode permits particulate matter sampling and mass measurement on two independent lines. Operating in this mode allows two PM_x samples (replicated or representative of two different particle size fractions) to be drawn simultaneously and the relative mass concentration value to be measured using the instrument as two "*co-located samplers*". This makes it is possible, for example, to determine simultaneously the PM_{10} and $PM_{2.5}$ ($PM_{2.5}$ and PM_1, etc.) mass concentrations. Moreover, this configuration allows the user to perform particularly interesting metrological evaluations, for example:

- evaluation of volatile material losses using the capability of the system to heat or cool the two sampling lines (note: the accessory heating or cooling systems for the lines are not supplied as standard with the system, and must be ordered separately)
- evaluation of the performance of two different sampling inlets

In addition, the instrument allows the use of only a single line (A or B) for sampling particulate matter. To start the instrument in *Dual Channel Mode*, see section 5.9.1 "*Sampling start in Dual Channel (*"Line A & B) Mode")

NOTE: In *Dual Channel Mode* we recommend using the same type of filtering medium on both lines.

3.7.2 Single Channel (Line A) Mode

Single Channel (Line A) Mode permits particulate matter sampling and mass measurement on just one line of the instrument. Operating in this mode allows for either PM10, PM2.5, or PM1 (depending on the inlet being used) to be sampled on the single channel.

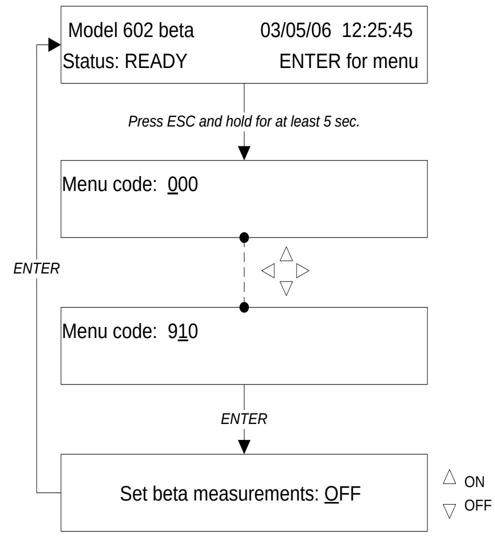
This operating mode has been made avaialbe for sites that may only need to sample one size regime and do not need to run collocated samplers (which is what the Model 602 is when both channels use the same size cut inlets). This mode may also be useful when (for whatever reason) inlet maintenance would cause one channel to be down for an extended time.

NOTE: When operating in Hourly Mode, *Monitor Mode* using a single line is not available.

3.7.3 "Sampler" Mode with Mass Measurement Disabled

Model 602 Beta*PLUS* Particle Measurement System may also be used as a simple sampler by disabling mass measurement (option not available in Hourly Mode). To do this, follow the procedure below:

- With the instrument status set to READY, press and hold the ESC key for at least 5 seconds to access the *Menu code* (access to support *tools*).
- Enter the *code 910* using the Arrow keys and press ENTER to access the function that activates or deactivates mass measurement.
- Using the YES/NO keys, select "ON" to activate the measurement or "OFF" to deactivate it and press ENTER to confirm your choice.



CHAPTER 4

4. FILTER MEMBRANE MANAGEMENT

The Model 602 Beta^{PLUS} Particle Measurement System can automatically and continuously manage the unused filter-loading steps and the steps for sampling, mass measurement and unloading of the sampled filters. At the end of every sampling cycle, the sampled filters are immediately moved to the Unloader where they are available for the operator. The maximum capacity of the instrument (without adding new unused filters) is 96 filters if the instrument is equipped with the standard Loader and Unloader.

It is possible to add new unused filters and to remove the sampled ones at any moment without interfering with the instrument’s operating cycle (see section 5.10.2 “Automatic interruption of the sampling cycles due to lack of filters - ENDING”).

The constituent elements of the filter membrane management module are:

- filter cartridges
- new filter Loader
- sampled filter Unloader

4.1 FILTER HANDLING MODULE

The module consists of:

- **rotating plate:** where the 6 filter membranes “F”, the 3 spy filters “S”, and the 2 reference aluminum foils “R” (see figure 4.2) are placed. On the plate there is also a hole “A” for measuring the air ß flux. The plate is moved by a step-motor controlled by electronics.
- **unused filter reserve**: an area inside the instrument, located between the plate and the Loader bottom, that can hold up to 6 filter membranes.
- **electro-pneumatic pistons** for loading and unloading filters and for the moving the Beta source.
- **electro-pneumatic filter-presser pistons** for operative positioning of the filters on the sampling line.
- **sensors for plate positioning**
- **sensors for detecting filter presence** (i.e. for checking that the filter has been loaded)
- **sensors for mass measuring system positioning**

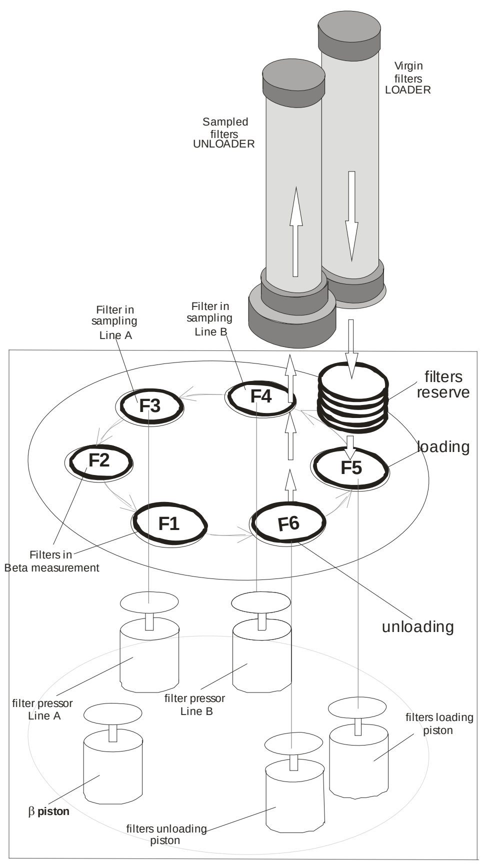


Figure 4-1. Filter Handling Module Diagram

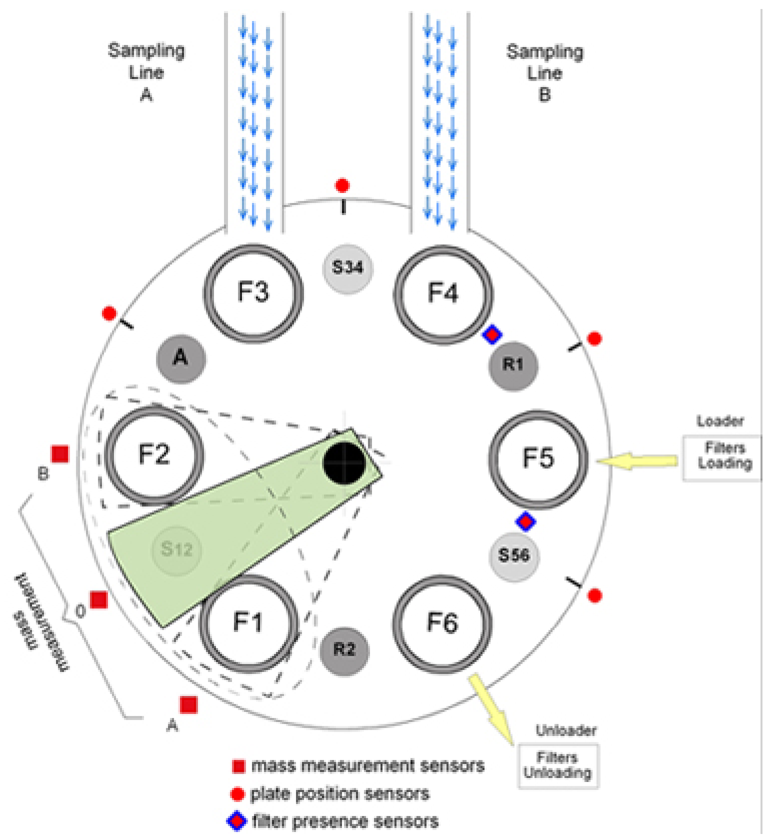


Figure 4-2. Rotating Plate Diagram

Figure 4-3 summarizes the filtering handling steps.

The movement operations during start-up are preceded by an initialization phase that consists of:

- insertion of the filter membranes in the Loader (at least 10 filters, see section 4.8)
- insertion and locking of the Loader in the instrument
- automatic filling of the unused filter reserve; when the Loader is connected to the instrument, the contained filters move down, so that the first 6 filters fill the reserve (see Figure 4.3).

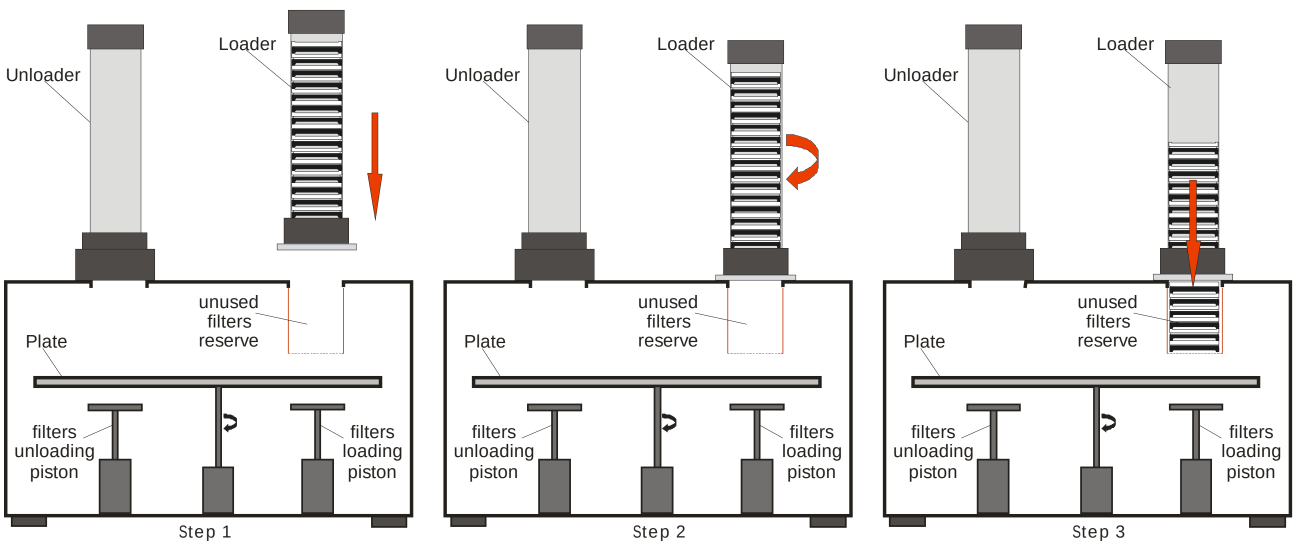


Figure 4-3. Filter-handling Steps

- After this step, it is now possible to program the sampling cycles (see section 5.9).
- After the programming step, the instrument moves six filter membranes from the reserve to the plate in sequence. While each membrane is moved to the plate, the pile of filters above moves down. In this step six filters are on the plate and the other filters (at least 4) are in the reserve.
- After loading the filters, the instrument performs the Blank measurements on the membranes that will be used in the first 2 sampling cycles. At the programmed date and time, the instrument starts the sampling process and performs the Blank measurement on those membranes that will be used in the third cycle.
- When sampling is completed, the instrument will collect measurements on those membranes used in the first cycle and simultaneously starts the sampling process on the next membranes.
- After collecting measurements in Multi-time Mode, the sampled filters will be moved to the Unloader and the same number of filters will be moved from the reserve to the plate to replace the previous ones. After collecting measurements in Hourly Mode, the pair of filters is available for new sampling; this operation goes on until reaching the programmed accumulation step

number or “Max Filter Pressure Drop” (see section 5.5 “Instrument Setting” (Filter requirements Hourly Mode).

- The instrument repeats the whole set of operations of unloading sampled filters, loading unused filters, making Blank measurements, sampling, and making measurements while unused filters are present in the reserve. If no unused filters are in the reserve, the instrument does not perform the loading procedure, the plate positions corresponding to the last unloaded filters are left empty. In this state the instrument starts a procedure (see section 5.10.2 “Automatic interruption of the sampling cycles due to lack of filters - ENDING”) allowing it to continue with the sampling cycles using just the filters on the plate.

- At the end of this procedure, the instrument goes back to Ready Status (see par. 5.3) and is ready for a new programming procedure.

NOTE: To keep the instrument running continuously, it is necessary to avoid letting the Loader run empty. If the Loader (and reserve) are empty when it comes time for the next set of new filters to be loaded, the instrument will detect that there are no filters and initiate the “Ending Procedure”. Once the Ending procedure has been triggered, the instrument will automatically stop sampling and will have to be restarted by the operator.

4.2 “COMPLETE FILTER” COMPOSITION

A complete filter is made up of a filter membrane placed in a filter cartridge made up of two circular discs that apply pressure to hold the filter membrane in place.

Figure 4.4 shows the composition of a complete filter.

Figure 4-4. Complete Filter Diagram

4.3 FILTERING MEDIUM SELECTION

Selection of the filtering medium (glass fiber, Teflon, quartz fiber, etc.) to be used in the Model 602 Beta^{PLUS} Particle Measurement System is based on optimization of the β mass measurement performance, the choice of the sampling operating conditions and the potential need for sample chemical speciation. The mass thickness of the filtering medium used must be in the range of 0-9 mg/cm².

With regard to optimization of the mass measurement, the primary consideration when selecting the filtering medium is its structural homogeneity (the mass thickness value must be consistent across the section of the filtering medium that the beta radiation passes through). Moreover, the filtering medium homogeneity is essential to guarantee uniform deposition of the particulate matter film.

The other factors determining filter selection are: sampling operating conditions, expected PMx average concentrations, fluid-dynamic impedance of the filtering medium, and its chemico-physical characteristics.

NOTE: ***The Model 602 Beta^{PLUS} currently only carries US EPA FEM designation when using glass fiber filters.***

Filter Selection Guidelines

a. *The EPA approved Model 602 Beta^{PLUS} Particle Measurement System is used for hourly mass concentration measurement (monitoring networks, etc.) at 1 m³/h operating flow rate only.*

   In this condition, to maintain US EPA approved FEM status, the use of glass fiber filters is required. For example, "Whatman Schleicher & Schuell GF10 Ø 47mm" or other glass fiber filters with equivalent homogeneity characteristics. We recommend the use of these filters, since they have:

   - suitable separation efficiency
   - low load drop under normal operating conditions
   - high load capacity
   - low hygroscopicity
   - suitable structural homogeneity
   - good mechanical resistance
   - low cost

b. For research purposes, the Model 602 Beta^{PLUS} Particle Measurement System can be used both for mass concentration measurement and for drawing samples to be used for particulate matter chemical speciation. This post-analysis can be performed on glass fiber filters (with some limitations); however, PTFE and Quartz Fiber filters are the more proper mediums to choose.

   In this case, the filtering medium choice must be the best compromise among:

   - analytical needs
   - mass measurement quality
   - sampling operating conditions
   - cost

PTFE Filters

If the type of analysis (e.g. ionic characterization, trace metal detection, etc.) requires the use of PTFE filters, we recommend “PALL Life Sciences Teflon™ Ø 47mm 1µm” or filters with equivalent characteristics. This type of filter has high structural homogeneity. We advise against the use of PTFE filters with porosity higher than 1 µm due to the lack of sufficient homogeneity. The use of this kind of filter requires a careful choice of the operating fluid dynamic conditions, since they have some limitations due to:

- high load drop on the filtering medium in standard operating conditions
- low load capacity for collection of particulate matter under optimal operating conditions
- potential for obstruction of the filter’s pores in high relative humidity conditions due to the hydrophobic properties of the medium

Therefore, the accumulation flow rates on each single line must be kept quite low (for example 1 m^3/h) and the length of the sampling cycles must be chosen depending on both the expected particulate matter concentration values during the sampling period and the climatic conditions at the site.

Under these operating conditions, the attainable quality level in PMx mass concentration measurement is equivalent or higher than the one attainable using glass fiber filters at a 2.3 m^3/h operating flow rate.

Quartz Fiber Filters

If quartz fiber filters are needed for analytical needs (organic and inorganic carbon, etc), please bear in mind that they have some structural limits. In particular, they have lower homogeneity in comparison to the glass fiber filters and PTFE filters. They also have low mechanical resistance and high hygroscopicity, which, under particular RH conditions (values near to saturation or extremely low values), could add some positive or negative bias in the determination of the particulate matter mass concentration values.
By using the “spy filters” technique, the Model 602 Beta^{PLUS} Particle Measurement System, allows one to collect good quality mass concentration data, provided that filters with a high structural homogeneity are chosen (e.g. “Whatman Schleicher & Schuell QF20 Ø 47mm” filters). In particular, higher quality mass concentration data can be collected due to the presence of the field blank (dynamic spy filter).

Given that the filter type is an important factor in the quality of the instrument’s performance, Teledyne API cannot recommend using any other filters than described here.

4.4 FILTER CARTRIDGE SELECTION (β equivalent spot area)

Mass measurement performed using the ß attenuation method is based on determination of the mass surface density. For the same quantity of sampled particulate matter, the mass surface density is inversely related to the usable enrichment surface. For the purposes of operating as a US EPA approved FEM, only cartridges for hourly mode are to be used.

HOURLY MODE

In Hourly Mode, only the filter cartridges with part numbers DU0000042 and DU0000043 (not interchangeable with the filter cartridges used in Multi-Time Mode) can be used. In Hourly Mode, the β equivalent spot area is fixed (0.95 cm^2) and is not determined by the filter cartridge but by the specific "inlet tool" for this operating mode (see section 5.6 "Changing the sampling line inlet tool").

MULTI-TIME MODE

For research and non-EPA FEM method purposes, the Model 602 Beta*PLUS* Particle Measurement System can use filter cartridges with a *β equivalent spot area* ranging from 11.95 cm^2 to 5.20 cm^2 with a 2.3 m^3/h operating flow rate and from 11.95 cm^2 to 2.54 cm^2 with a 1 m^3/h operating flow rate. By choosing different *ß equivalent spot areas*, the signal-to-noise ratio can be optimized, depending on the expected concentration levels at the sampling site, environmental conditions, and the impedance and load capacity of the filtering medium used.

Since glass and quartz filters have a low fluid-dynamic impedance and a high loading capacity, reduced *β equivalent spot areas* (see Table 4-1) are recommended when possible.

If, for analytical needs, the use of Teflon filters with 1µm porosity is desired, filter cartridges with an 11.95 cm^2 *β equivalent spot area* must be used.

NOTE: **During instrument start-up, the usable sampling and measurement surface (β *equivalent spot area*) of the filter cartridge type used must be set (see section 5.5).**

Table 4-1. Filter Criteria

Filter	Sampling flow rate [m^3]	Expected maximum concentration [µg/Nm^3]	*ß equivalent spot area* [cm^2]
Glass fiber	1	< 80	2.54
	2.3	< 80	5.20
	2.3	80 - 150	7.07
	2.3	> 150	11.95
Quartz fiber	1	< 80	2.54
	2.3	< 80	5.20
	2.3	80 - 150	7.07
	2.3	> 150	11.95
Teflon	1	--	11.95

NOTE: The data shown in Table 4-1 refer to 24-hour long sampling cycles.

4.5 FILTER LOADER AND UNLOADER

<u>Unused filters Loader</u>

The *Loader* consists of a white semi-transparent cylindrical body, a white plastic plunger placed inside the Loader, and a black plug marked with a yellow circle corresponding to the yellow circle on the *Loader* body.

NOTE:
The plunger must be placed inside the Loader with the hollow surface turned upward. It contains a magnet that starts a reed-relay to signal that the Loader is out of unused filters.

<u>Sampled Filter Unloader</u>

The Unloader is made up of a white semi-transparent cylindrical body, a white plastic plunger and a black cap.

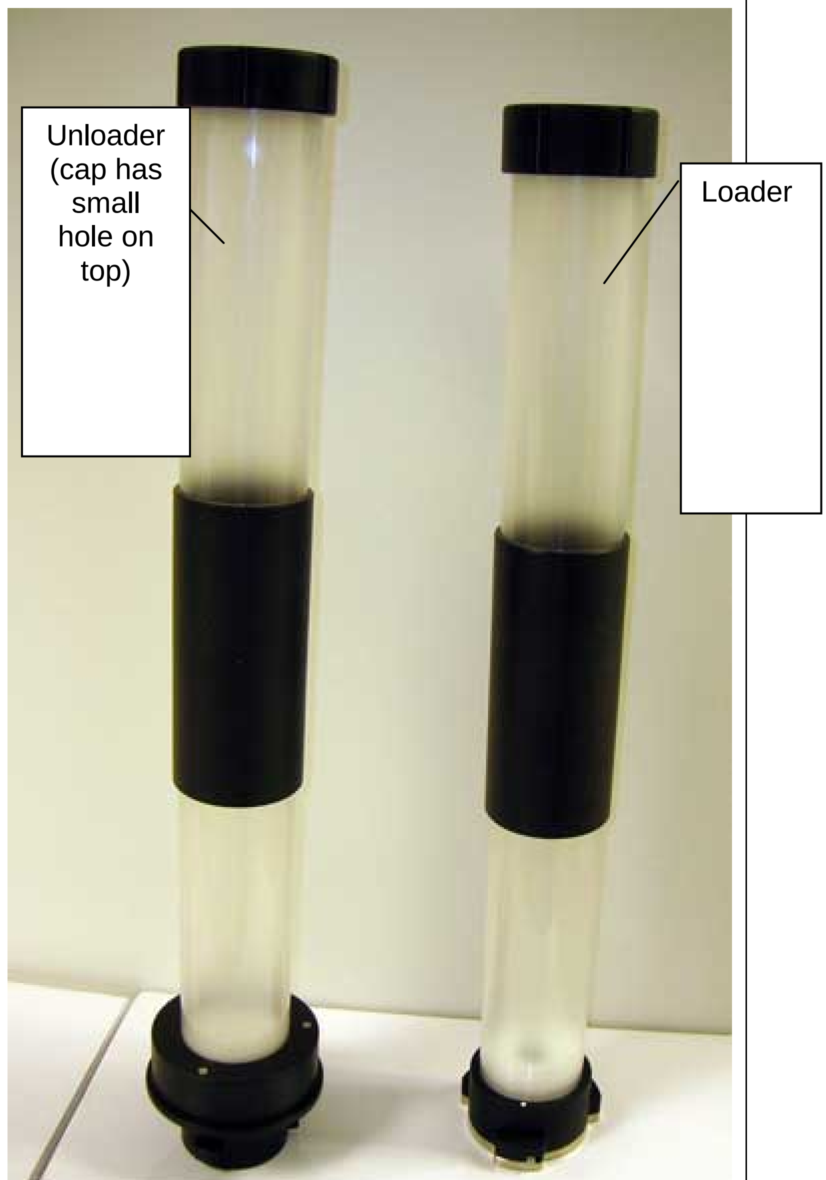


Figure 4-5. Filter Loader and Unloader Componenets Description

⚠	*<u>Do not switch the Loader and Unloader caps (Unloader cap has a small hole on top</u>*

4.6 REMARKS ON THE INSTRUMENT AUTONOMY

In determining the length of instrument autonomy, it is necessary to consider:

- the rotating plate inside the instrument (see par. 4.1) has 6 housings
- the internal reserve of the instrument (see par. 4.1) contains 6 filters
- at start-up, the instrument draws 10 filters from the Loader, loading 6 of them onto the rotating plate and 4 of them into the internal reserve
- adding new unused filters without stopping the sampling and measurement cycles is possible until the instrument enters Ending Status (see par. 5.10.2 “Automatic interruption of the sampling cycles due to lack of filters - ENDING”)
- the maximum Loader and Unloader capacity is 96 filters for the standard Loader/Unloader supply

To determine the instrument’s autonomy in the Hourly Mode, it is necessary to consider the following:

- o The number of hourly samplings performed on each filter is equal to the number of programmed “Accumulation steps” (see section 5.5 “Sampling and measurement parameters setting – Instrument Setting”).

  i.e. Accumulation steps = 8
  Number of filters used = 6 filters every 24 hours
  Number of days before having to reload new filters = 16

- The duration of autonomous operation of the instrument may be reduced if the control “Max Filter Pressure Drop” is active (see Note 1 below and section 5.5 “Sampling and measurement parameters setting – Instrument Setting”).

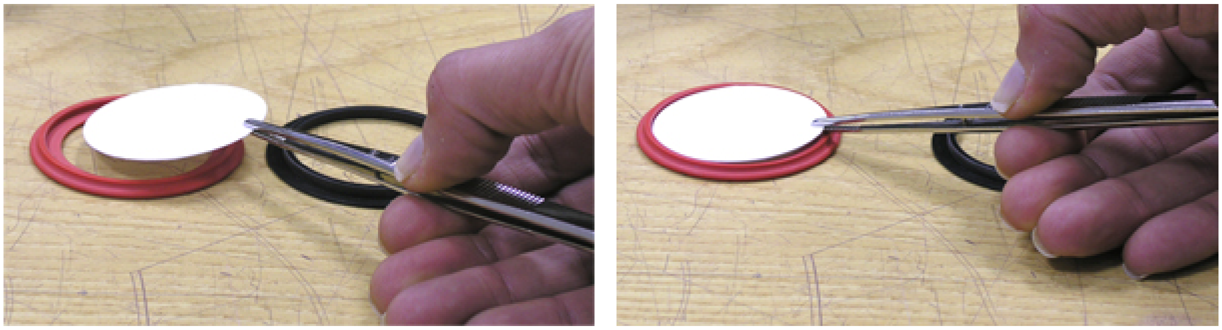
NOTE 1 When the “Max Filter Pressure Drop” control is active, if the pressure drop across one of the two filters of the pair in use during sampling reaches the maximum allowed value, both filters will be unloaded and replaced by two new unused filters even if the programmed number of “Accumulation Steps” has not been reached.

NOTE 2 For maximum autonomy, we suggest programming a high number of “Accumulation Steps” and activating the control on the “Max Filter Pressure Drop” (see section 5.5 “Setting Sampling and Measurement Parameters (Instrument Settings)”).

To prevent the overfilling of the Unloader, remove the unloaded filters before adding new unused filters and add the appropriate number of filters where the total number of filters (loader, reserve, plate) does not exceed the maximum capacity of the used filter Unloader.

4.7 INSERTIING FILTER MEMBRANES INTO THE FILTER CARTIDGES

The filter membrane must be inserted in the appropriate housing in the upper disc.



While the picture above shows the filter being inserted with tweezers, if the filters are not going to be used for post sampling analysis (i.e. chemical speciation) it is then okay to use your clean (or latex gloved) hands to insert the filters as long as they are handled from the edges where they are not sampled or analysed by the Model 602.

Once the filter membrane has been inserted, place the lower disc of the filter cartridge onto the upper one as shown in Figure 4-6. Then manually apply pressure around the edges of the discs until they are completely coupled together.

Figure 4-6. Assembling the Disks of the Filter Cartridge

Note that the lower part of the assembled filter is hollow (Figure 4-7). When inserting filters into the Loader, make sure that the hollow part of each filter cartridge faces downwards (see section 4.8 “Inserting filter membranes into the Loader”).

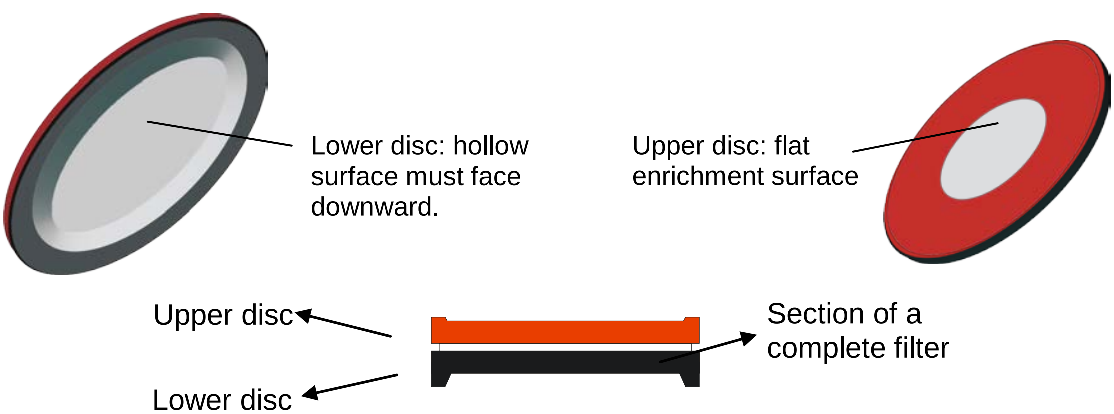


Figure 4-7. Assembled Filter Orientation

CAUTION: Position the filter correctly.

The color of the filter cartridge discs is not relevant to their correct positioning inside the Loader. The filter cartridges can have different color couplings (white-black, white-white, etc). Also, the filter cartridges shown in the photos are used for Multi-time mode. Hourly mode filter cassettes will have a smaller hole in the center of the front cassette half.

The key factor for correct positioning of the filter cartridges is the surface shape. The complete filter must be inserted into the Loader with the hollow part turned downward, because the hollow shape of the lower disc corresponds to the upper surface of the loading and unloading pistons and the filter plungers (see sections 4.1 and 4.8).

4.8 INSERTING FILTER MEMBRANES INTO THE "LOADER"

To insert unused filters into the Loader (not interchangeable with the sampled filters *Unloader*), disconnect the Loader by turning it counter-clockwise and make sure that each filter cartridge is placed in the lower part of the *Loader* with the hollow part facing downward. It is important to pay attention to the filter insertion direction, because they will be loaded based on their starting position inside the Loader. In all operating modes – except for Monitor Mode Line A and Monitor Mode Line B - the filter insertion sequence shown in Figure 4-8 (filter A – filter B) must be followed.

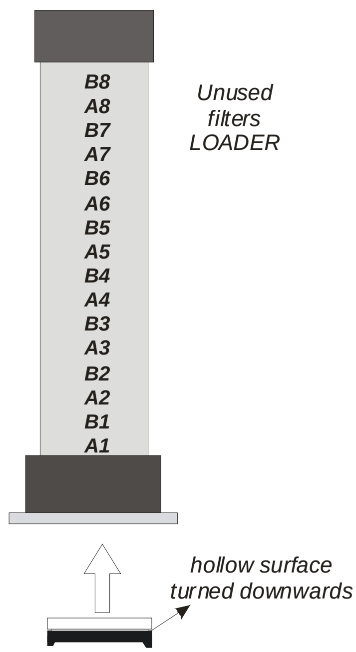


Figure 4-8. Filter Insertions into Loader

Use the appropriate accessory supplied with the instrument (Figure 4-9, left) to insert filters into the *Loader*. Place the filter cartridges onto it with the hollow part turned downward and then place the Loader onto it as shown in Figure 4-9, middle & right.

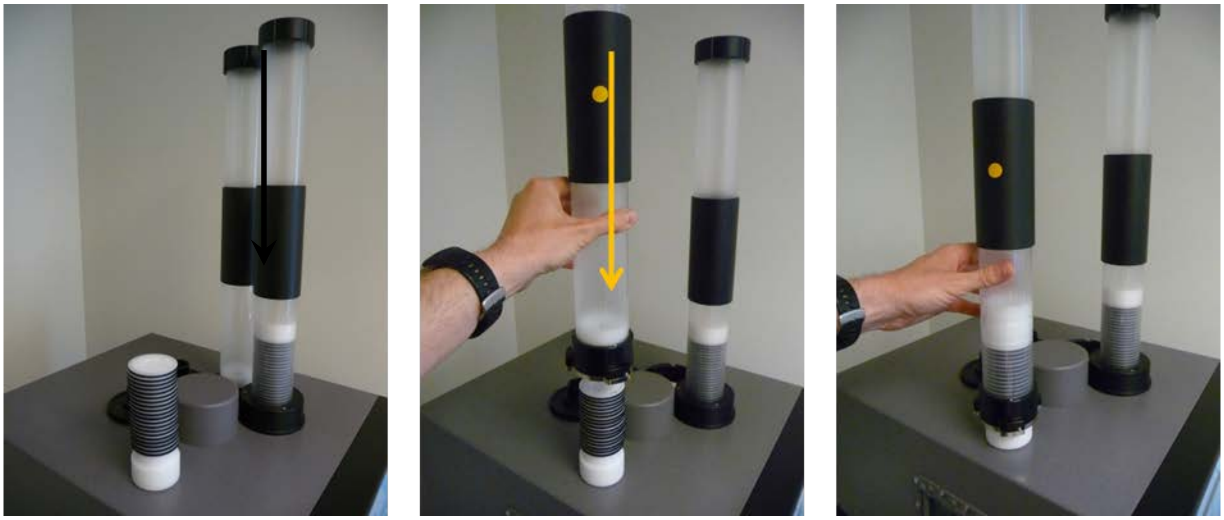


Figure 4-9. Filter Loading Accessory and Use

If the *Loader* is not empty and it is necessary to add new unused filters while respecting the order of the filters already inside the Loader, we suggest using the appropriate accessory (Figure 4-10, not included as standard with the instrument) and follow this procedure:

1- Assemble the accessory used for unlocking the filters by placing the ring (b) on the accessory used for inserting filters (a)
2- Place the *Loader* over the top of the filter unlocking accessory.
3- Rotate the *Loader* clockwise, to lock into place (b)
4- Lift the *Loader* while maintaining the filters in a stack
5- Remove the plunger (c) and add the new unused filters to the stack
6- Before loading the filters into the Loader, put the plunger back in with the hollow part turned upward

If accessory shown below is not available, it is possible to unload the filters from the Loader by placing it on the filter loading pedestal, pressing the three release buttons on the bottom sides of the Loader mechanism, and then lifting the Loader straight up while still holding those buttons down. One just needs to be careful not to knock over the filter stack while performing this method.

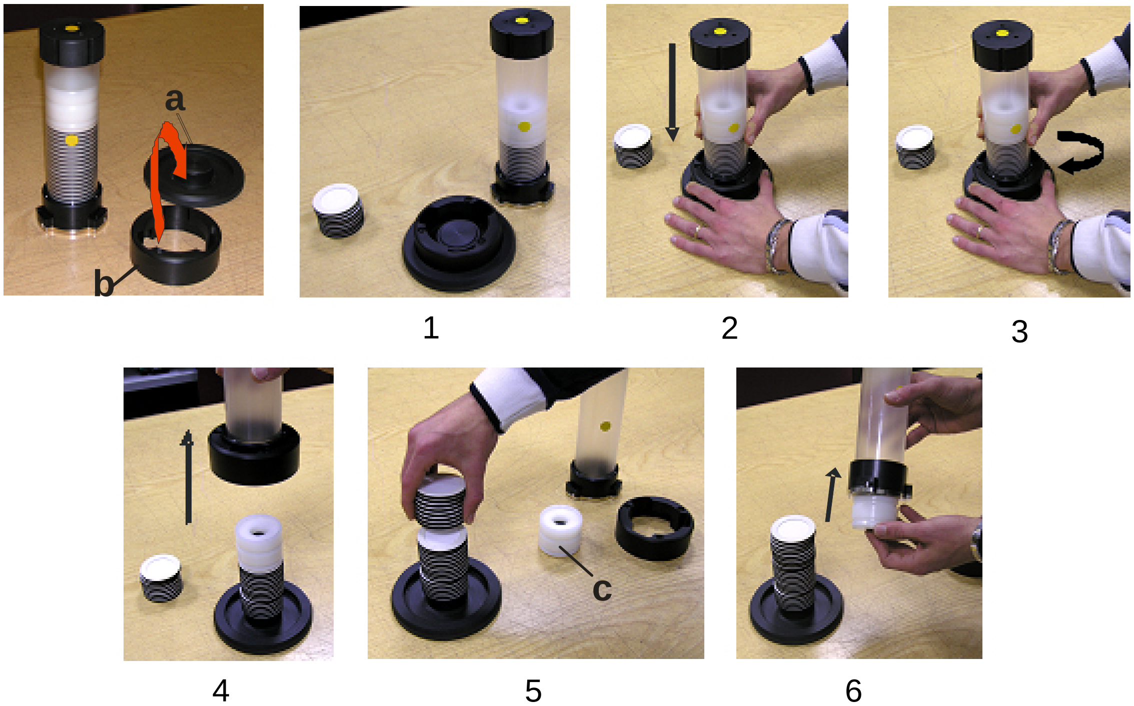


Figure 4-10. Steps to Add New Unused Filters

It is possible to add new unused filters to the *Loader*, even during sampling, without stopping the cycle.

To start the sampling and measurement cycles, insert at least 8 unused filters into the Loader.

After loading the unused filters, to insert the Loader into its slot (which is to the right when facing the instrument) firmly rotate it clockwise until it clicks into place in the mechanical block.
This operation unlocks the Loader's filters lock system, causing the filters to move down into the sampling unit.
On the LOADER control panel, the green "locked" LED lights up and simultaneously the red "unlocked" LED turns off. Additionally, the "EMPTY" LED turns off and the green "filters present" LED flashes to indicate that the filters have been loaded.

Figure 4-11. Front Panel LEDs

The yellow LED on the Loader control panel signals that the filters are running out. When the Loader is empty, the red "EMPTY" LED lights up.

4.9 REMOVING FILTER CARTRIDGES FROM THE UNLOADER

At the end of each sampling and measurement cycle, the instrument will immediately move the processed filters to the Unloader. To remove the used filters from the Unloader follow the steps below:

1. Disconnect the Unloader by turning it counterclockwise
2. Quickly turn over the Unloader as shown in Figure 4.12 left
3. Keep the Unloader in a vertical & upside-down position and place it on a flat surface as shown in Figure 4.12 center and right.
4. Carefully remove the tube from the plug and lift it straight up to ensure that the filters remain stacked.

Figure 4-12. Removing Used Filters

Before inserting the *Unloader* back into its slot, make sure that the plunger has been correctly inserted (see Figures 4-5 and Figure 4-10.

To insert the *Unloader* into its slot (which is to the left when facing the instrument), turn it clockwise until it clicks into place in the mechanical block.
On the UNLOADER control panel, the green “locked” LED will light up and simultaneously the red “unlocked” LED will turn off. The UNLOADER control panel progressively shows the Unloader filling until it reaches maximum capacity, and then the red “FULL” LED will turn on.

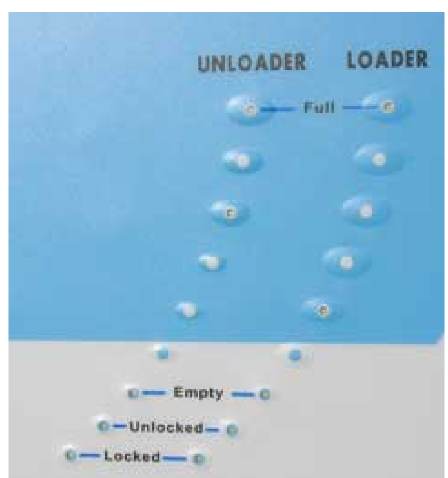


Figure 4-13. Front Panel LEDs

If the Unloader is out of its slot for more than 10 seconds, the sampler assumes that all of the filters have been removed from the Unloader.

4.9.1 Removing Membranes from the Filter Cartridge

To quickly and easily open the filter cartridges, we recommend using a custom tool provided with the instrument (Figure 4-14).

Figure 4-14. Filter Disassembly Tool

By putting a complete filter into the slot in the tool (Figure 4-15) and squeezing the levers (Figure 4-16), the two discs of the filter cartridge can be separated.

To remove the filter membrane from the filter cartridge:

Insert the filter cartridge into the slot within the tool with the sampled surface of the filter turned downward.

Figure 4-15. Filter Disassembly Step 1

Press the levers firmly so that the two discs uncouple.

Figure 4-16. Filter Disassembly Step 2

Remove the upper disc.

Figure 4-17. Filter Disassembly Step 3

Using tweezers, lift the filter membrane out of the filter cartridge, as shown in Figures 4-18 and 4-19.

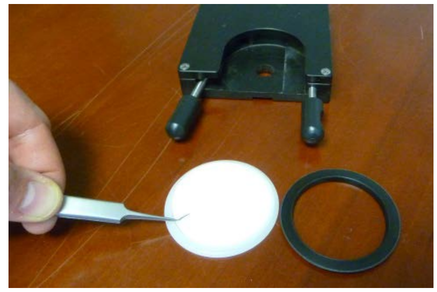


Figure 4-18. Filter Disassembly Step 4

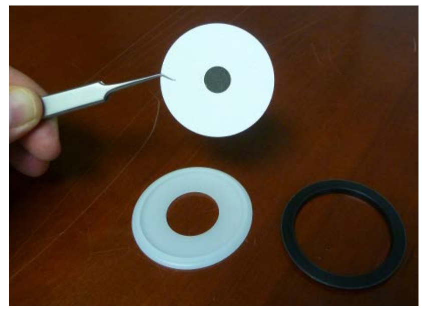


Figure 4-19. Filter Disassembly Step 5

NOTE:

The sample image on the filter must be homogeneous and the outline of the sampling surface must be well-defined (see Figure 4-20, left, example of a 0.95 cm² β spot area). If the sample image has irregularities, for example, due to the presence of condensation (see Figure 4-20, center), check the condensate collection devices.

If the outlines of the sampling surface are not well-defined (see Figure 4-20, right), there could be problems with the sealing of the filter cartridge-filter plunger system. In this case, please contact Teledyne API Technical Support.

In both cases (Figure 4-20 center and right), *the mass concentration data corresponding to the filter must be considered invalid.*

homogeneous image, well-defined outline | irregular image | irregular outline

Figure 4-20. Sampling Image and Surface Conditions for Valid and Invalid Data

NOTE: The filters shown in Figure 4-20 are multi-time mode. Hourly mode filters will have a smaller sample spot.

4.10 AUTOMATIC QUALITY CONTROL OF FILTER MEMBRANE LOADING

If a filter cartridge has been accidently inserted into the Loader upside-down or without a filter membrane, the instrument operates as follows, depending on the current operating mode (see Chapter 3.7):

- In Dual Channel Mode, where both Line A and Line B are active, the pair of filters containing the upside-down (or without membrane) filter cartridge will be replaced. The unloaded pair will be replaced by the following pair in the reserve.
- In Single Channel Mode (Line A), the cartridge will be unloaded and will be replaced by a new unused cartridge (the following one in the reserve).

In both cases, this event will be stored in the Buffer Data and will be signalled by a Warning message (Warning 10, see Appendix 3). This warning will not halt the instrument, nor will it affect the sampling, but will show as a flag in the data for quality monitoring purposes.

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CHAPTER 5

5. SAMPLING

IMPORTANT: **During use as a US EPA FEM monitor, the Model 602 must meet the following requirements:**

- Instrument must be installed with firmware version 05-02.07.63-30.03.00-U or newer for US, or 05-02.07.23-30.03.00 or newer for International
- Start Time must either match the FRM Start time or default to midnight.
- Sample only in Hourly Mode.
- Use only glass fiber filters.
- Have spot area set to 0.95cm2.
- Use a flow rate of 1.00m3/hr and US EPA approved PM10 inlet (for the PM10 channel) as well as US EPA approved PM2.5 cyclone (for the PM2.5 channel). The PM10 pre-impactor supplied with the Model 602 is to be used as the pre-impactor above the PM2.5 cyclone and not as a standalone PM10 inlet.
- Have sample line heaters ON, and set to activate at 40%RH and deactivate at 30%RH.

5.1 INSTRUMENT- OPERATOR INTERFACE

Figure 5-1. Instrument Front Panel Operating Interface

5.2 CONTROLS AND INDICATORS

Table 5-1. Front Panel Controls

ENTER	*Press to access main menu and then to enter data and/or to start a function*
ESC	*Press to go back to the previous menu(s), or to cancel numeric input*
YES / NO	*Press to accept the proposed options, or to select values*
SELECT	*Press to scroll the menus*
ESC + NO	*Pressing the two keys at the same time RESETS the instrument*

Table 5-2. Front Panel Indicators

STATUS	*Green LED (OK) - no anomalies* *Yellow LED (Warning) - alert/warning* *Red LED (Alarm) - instrument malfunction*
SERVICE AIR	*Yellow LED (Over pressure) – service - compressed air pressure too high* *Green LED (OK)* - optimum service compressed air pressure *Red LED (Low pressure) - service - compressed air pressure too low*
BATTERY LEVEL	*Green LED (OK) - battery adequately charged* *Red LED (Low) - battery low*
LOADER	*Yellow LED - Loader almost empty* *Flashing Green LED - indicates that unused filters have been loaded* *Green LED - Loader full* *Green LED (locked) - Loader correctly inserted and locked* *Red LED (unlocked) - Loader incorrectly inserted and/or not locked* *Red LED (FULL) - Unloader full*
UNLOADER	*Yellow LED - Unloader almost full* *Green LED - Unloader has room for used filters* *Green LED (locked) - Unloader correctly inserted* *Red LED (unlocked) - Unloader incorrectly inserted*
PNEUMATIC MODULE	*Green LED - Pneumatic module correctly connected* *Red LED - Pneumatic module not connected correctly*
PUMP A	*Green LED - Line A vacuum pump on*
PUMP B	*Green LED - Line B vacuum pump on*

5.3 OPERATING STATUS

Table 5-3. Status Descriptions

STATUS: READY	*The instrument is ready to start a sampling and measurement cycle.* *It is possible to read data, set instrument and sampling parameters, and perform tests and checks.*
STATUS: DELAY	*The instrument has been programmed (start) and will start the sampling and measurement process at the programmed date and time. It is possible to read data and modify some instrument parameters. If needed, the starting procedure can be stopped.*
STATUS: SAMPLING	*The instrument is sampling and measuring. It is possible to read data and information regarding the sampling and mass measurement processes. If needed, the sampling sequence can be stopped.*
STATUS: ENDING	*The filters in the Loader and in the reserve have been used up. The sampling and the measurement processes continue until the last filter on the plate is used.*
STATUS: ALARM	*The instrument's functionality has been compromised by an anomaly that caused the interruption of the sampling and measurement cycles. After fixing the cause of the anomaly, reset the instrument by simultaneously pressing the two keys ESC + NO [▾] so that the instrument can go back to Ready status.*
STATUS: TEST	*The instrument is performing automatic functionality tests on the servomechanisms/ sensors/pneumatic circuit/ mass measurement system.*

5.3.1 Instrument in Sampling Status

In Hourly Mode the cycle duration depends on the maximum number of Accumulation Steps for the three pairs of filters used in the cycle. Particulate matter is collected onto the filters during each cycle with a mass measurement performed immediately following sampling. As the mass measurement is being performed, the subsequent sampling event proceeds immediately on the next set of filters. This process is repeated using the same set of 3 filter pairs (6 total filters) until the programmed threshold is reached. The threshold can be determined based on number of Accumulation Steps or Maximum Filter Pressure Drop, or both.

The default setting for the EPA certified FEM Hourly Mode is 8 Accumulation Steps which results in the use of six total filters per day. The instrument will automatically exchange a sample filter if the pressure drop reaches 50 kPa.

In no way does this interrupt the continuity of the sampling; however, it will result in a new pair of filters replacing the one(s) that exceeded the 50 kPa limit. Since it is important that the Model 602 instrument maintains synchronicity with the local FRM instruments, it will always cycle in new filters at the standard daily start time (this can be set by the user, but for EPA purposes will be midnight).

If the control on the Max Filter Pressure Drop is inactive, all filter pairs will be used for sampling for the same number of Accumulation Steps. If the control is active, each filter pair may be sampled for a different number of Accumulation Steps (see example below).

i.e. Set Accumulation Steps = 8

Max Filter Pressure Drop = 50 kPa

Step	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	…
Filters	1-2	3-4	5-6	1-2	3-4	5-6	1-2	3-4	5-6	1-2	3-4	5-6	1-2	3-4	5-6	1-2	3-4	5-6	…
Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	…
Step	7	7	7	8	8	8	1	1	1	2	2	2	3	3	3	1	4	4	…
Filters	1-2	3-4	5-6	1-2	3-4	5-6	7-8	9-10	11-12	7-8	9-10	11-12	7-8	9-10	11-12	13-14	9-10	11-12	…
Hours	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	…
Step	2	5	5	3	6	6	4	7	7	5	8	8	1	1	1	2	2	2	…
Filters	13-14	9-10	11-12	13-14	9-10	11-12	13-14	9-10	11-12	13-14	9-10	11-12	15-16	17-18	19-20	15-16	17-18	19-20	…
Hours	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	…

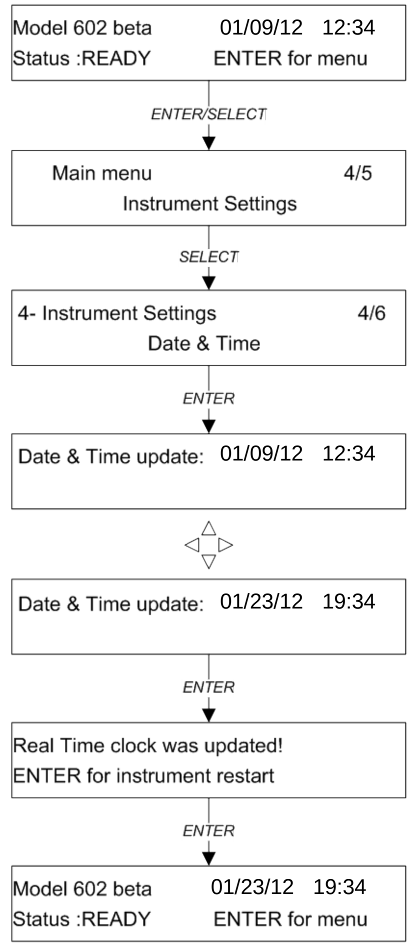
In the example above, pair 7-8 achieved the Max ΔP after the 3^{rd} step, resulting in a new filter pair (13-14) being inserted for what would have been the 4^{th} accumulation step for the 3-4 pair. Since 13-14 is a new filter pair, the accumulation step starts over at 1; however, notice that the 13-14 pair is switched out to match with the first accumulation step (and normal starting time) with the other filters.

In Multi-Time Mode the instrument operates in consecutive **cycles**. The duration of one cycle corresponds to the duration of the sampling process carried out on each filter membrane (*timing*: 8-12-24-48-72-96-120-144-168 hours).

5.4 DATE AND TIME SETTING

Before starting the sampling and measurement cycles, it may be necessary to update the date and time setting. Follow the procedure below to set the date and time:

1. With the instrument in READY Status, press ENTER to access the main menu.
2. Using the Select key, select the "Instrument Settings" menu and press ENTER.
3. Using the Select key, select the "Date & Time" menu and press ENTER (NOTE: date format is dd/mm/yy).
4. Using the Select keys, move the cursor to the number to be modified (to modify one number of the date use the YES/NO keys).
5. Once the correct date and time have been programmed, press ENTER.
6. Press ENTER again to confirm the date and time update and wait until the display goes back to the main menu.
7. The instrument will have to restart in order for the new Date/Time to take hold. A confirmation for the system to reboot will come up once the Date/Time change has been confirmed by the user.



Note: the date and time can only be updated when the instrument is in READY Status.

5.5 SETTING SAMPLING AND MEASUREMENT PARAMETERS (Instrument Setting)

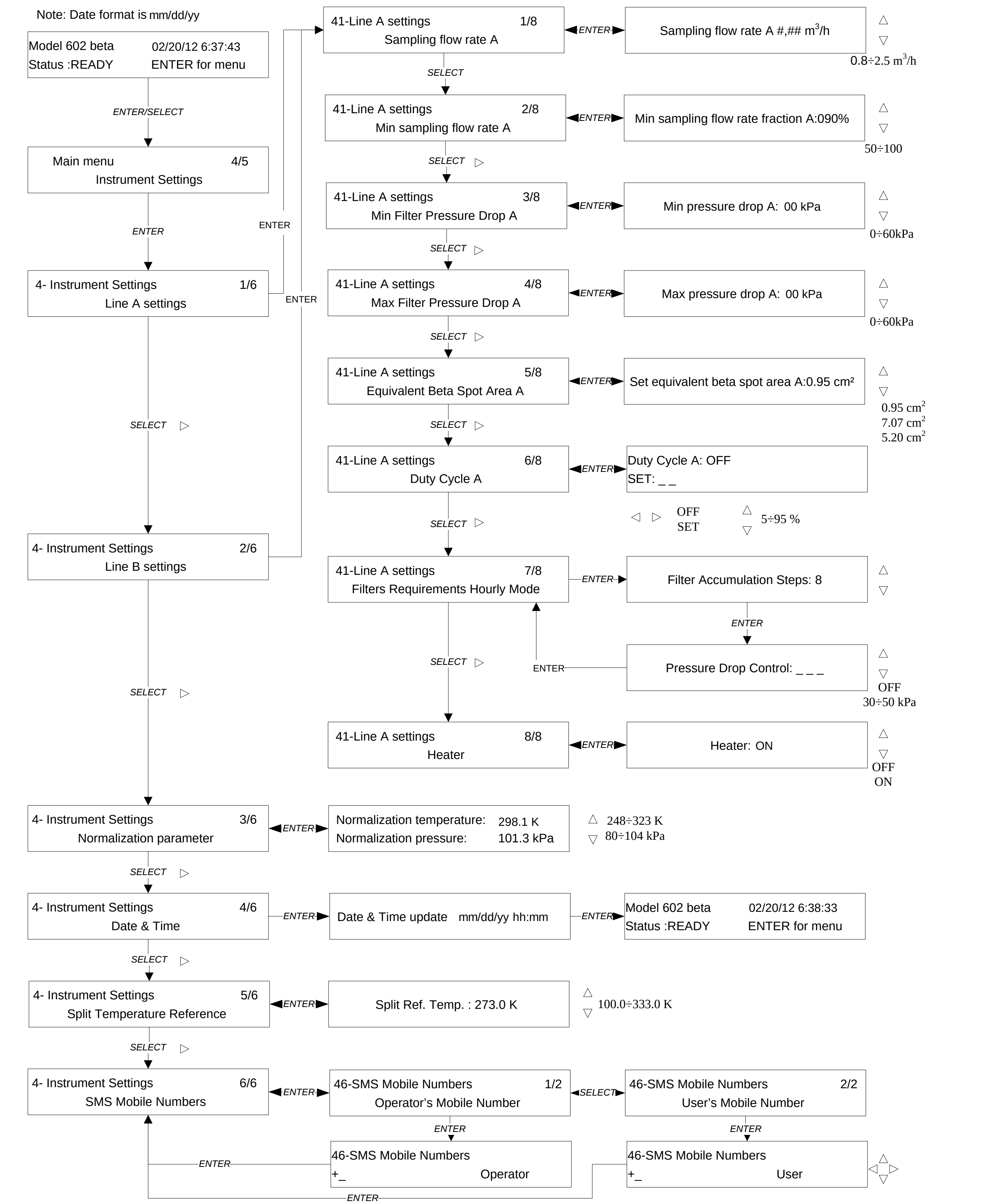
By default, the instrument is setup with all parameters configured to run as approved with EPA FEM designation. Any changes made to these parameters by the user may equate in the instrument no longer meeting EPA FEM designation.

The programmable parameters accessible from the *Instrument Setting* menu are:

- Sampling parameters for the single sampling line(s) A and/or B
- Sampling operating flow rate in m^3/h (range 1 to 2.5 m^3/h).
- Minimum value of the percentage ratio "$Q_{operative}/Q_{nominal}$ %" of the operating flow rate to the nominal flow rate.
- For example, setting this value to 90 with a sampling nominal flow rate equal to 1.0 m^3/h and an operating flow rate lower than 0.9 m^3/h, will cause the display and the Buffer Data to show a Warning message (Warning 6, see Appendix 3).
- Minimum and maximum filter pressure drop in kPa (range 0 to 60 kPa). If the load drop reaches the lower or upper limits during the sampling process, the event is displayed and stored in the *Buffer Data* along with Warning messages (Warnings 4, 5, 7, 8 - see Appendix 3). In order to preserve the integrity of the fritted filter (located in the filter presser), the instrument automatically stops the vacuum pumps if the filter pressure drop is lower than 4 kPa. The correct limit values to be programmed must be based on analysis of previous field data. To program the maximum pressure drop value, it is necessary to keep in mind that its value depends on the concentration levels, the meteorological conditions during sampling, the filtering medium type and the *ß equivalent spot area* used.
- In addition to programing the effective sample spot size, the appropriate filter cartridge must be used which is compatible with the nozzle (see Section 4.4). (In Hourly Mode it is necessary to set the β equivalent spot area to 0.95 cm^2).
- If the Duty Cycle setting is active, it sets the percentage time for which the instrument samples (i.e. Duty Cycle 90% implies that sampling goes on for 90% of the programmed Timing).
- Filter Accumulation Steps: number of samplings performed on every single filter membrane (parameter active only in Hourly Mode and must be set to 8 if running as an EPA FEM).
- Pressure Drop Control: Maximum allowed Filter Pressure Drop value (parameter active only in Hourly Mode – set to 50 kPa in high PM areas).
- Heater: activation and deactivation of the sample line heaters.

Instrument parameters common to the two sampling lines:

- Temperature value used for the standard volume calculation (range: 248.0 to 323.0 K, default value: 298.1 K).
- Pressure value used for the standard volume calculation (range: 80.0 to 104.0 kPa, default value: 101.3 kPa).
- Temperature value used for the impactor dimensions required to get the desired nominal particle size cut diameter "*Split temperature reference*" (range: 100.0 to 333.0 K). The exact setting of this value is critical when using the Model 602 Beta*PLUS* Dual-Channel Monitor in "Reference mode Split Constant Stokes Number" mode. When using standard sampling inlets supplied by Teledyne API, the "Split Temperature Reference" must be set to 273 K. If using different sampling inlets, please contact the manufacturer to determine the correct value.


Note: Date format is mm/dd/yy
Model 602 beta 02/20/12 6:37:43
Status :READY ENTER for menu
ENTER/SELECT
Main menu 4/5
Instrument Settings
ENTER
4- Instrument Settings 1/6
Line A settings
SELECT
4- Instrument Settings 2/6
Line B settings
SELECT
4- Instrument Settings 3/6
Normalization parameter
SELECT
4- Instrument Settings 4/6
Date & Time
SELECT
4- Instrument Settings 5/6
Split Temperature Reference
SELECT
4- Instrument Settings 6/6
SMS Mobile Numbers
ENTER
41-Line A settings 1/8
Sampling flow rate A
Sampling flow rate A #,## m³/h
0.8÷2.5 m³/h
SELECT
41-Line A settings 2/8
Min sampling flow rate A
Min sampling flow rate fraction A:090%
50÷100
41-Line A settings 3/8
Min Filter Pressure Drop A
Min pressure drop A: 00 kPa
0÷60kPa
41-Line A settings 4/8
Max Filter Pressure Drop A
Max pressure drop A: 00 kPa
0÷60kPa
41-Line A settings 5/8
Equivalent Beta Spot Area A
Set equivalent beta spot area A:0.95 cm²
0.95 cm²
7.07 cm²
5.20 cm²
41-Line A settings 6/8
Duty Cycle A
Duty Cycle A: OFF
SET: _ _
OFF
SET
5÷95 %
41-Line A settings 7/8
Filters Requirements Hourly Mode
Filter Accumulation Steps: 8
Pressure Drop Control: _ _ _
OFF
30÷50 kPa
41-Line A settings 8/8
Heater
Heater: ON
OFF
ON
Normalization temperature: 298.1 K
Normalization pressure: 101.3 kPa
248÷323 K
80÷104 kPa
Date & Time update mm/dd/yy hh:mm
Model 602 beta 02/20/12 6:38:33
Status :READY ENTER for menu
Split Ref. Temp. : 273.0 K
100.0÷333.0 K
46-SMS Mobile Numbers 1/2
Operator's Mobile Number
46-SMS Mobile Numbers 2/2
User's Mobile Number
46-SMS Mobile Numbers
+_ Operator
46-SMS Mobile Numbers
+_ User

If a temperature measurement sensor is disconnected or malfunctioning, the instrument will use 298 K as the default value (Warning 24, see Appendix 3).

If you need to modify this temperature value, please contact Teledyne API.

To enable the SMS messaging service (see par. 6.5), set the "User" and "Operator" telephone numbers before starting the sampling and measurement cycles.

5.6 CHANGING THE SAMPLING LINE INLET NOZZLES

The instrument is supplied with two different sampling line inlet nozzles (see Figures 5-2a and 5-2b). The tools differ only in the shape and dimensions of the lower part. In Hourly Mode, use tool model DU0000044 (shown in Figure 5-2a) **(installed by default in the instrument)**. In Multi-Time Mode, tool model DU0000045 must be used (shown in Figure 5-2b).

If running the instrument for monitoring purposes as an EPA approved FEM the procedure below may be ignored as the correct (hourly mode) nozzle comes installed in the instrument.

5-2a

TAPI p/n DU0000044

5-2b

TAPI p/n DU0000045

Figure 5-2. Sampling Line Inlet Nozzles

Follow this procedure to change the inlet tool:

1. Unlock the Loader and the Unloader

2. Remove the black discs from the line's inlet

3. Remove the plastic ring positioned on the Loader seat

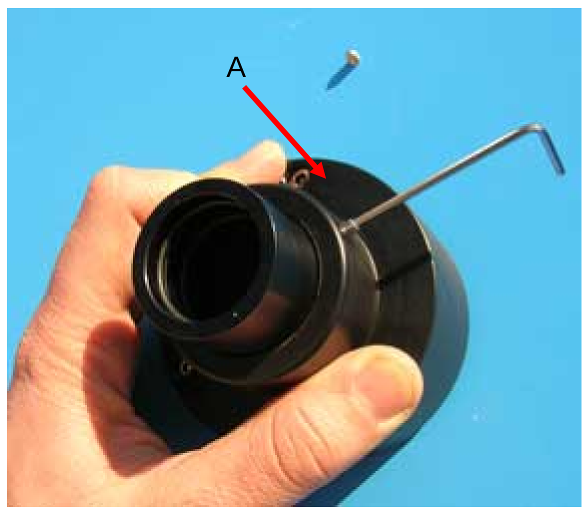
4. Remove the 6 screws locking the upper cover of the instrument (3 for each side)

5. Remove the upper cover

6. Remove the rubber gasket/moisture barrier

7. Unscrew the three check pins

8. Place component A on a flat surface and unscrew the three security dowels from the plastic flanges



9. Separate the nozzle from the black flange and remove the spring and the white cylindrical shim

10. Place the white shim and the spring back onto the new nozzle

11. Replace the black flange and while pressing it down on the flat surface (compressed spring), screw in the three security dowels

12. Make sure that the o-ring on the bottom is inserted and positioned correctly
13. Position the component back on the instrument and screw in the three check pins
14. Replace the rubber gasket which acts as a moisture barrier
15. Replace the instrument’s upper cover and fasten the 6 screws
16. Replace the black protection discs
17. Reload the Loader and Unloader and lock them

    See Section 5.5 for Setting up the System Sampling and Measurement Parameters

WARNING: the lower part of the Hourly nozzle must be handled very carefully to avoid impacts that could damage it. Damage to the nozzle could affect the pneumatic seal of the inlet system.

5.7 ASSEMBLING AND INSERTING THE SPY FILTERS

Before starting the sampling and measurement cycles, it is necessary to make sure that the three spy filters (S12, S34, and S56, used by the instrument during the mass measurement procedure) are inside the instrument. These filters must be of the same type as the filters used for the sampling. To assemble and insert the spy filters, follow the procedure below:

Spy Filter Assembly

To assemble the spy filters, use the accessory kit provided (Figure 5.3) and follow this procedure:

Step 1: place a filter membrane on the rest and press it using the provided spy filter punch.

Step 2: extract the obtained membrane with reduced diameter and insert it into the aluminum filter cartridge

Step 3: close the filter cartridge using the clamping key

Step 4: using the tweezers, grab the spy filter and insert it into the instrument

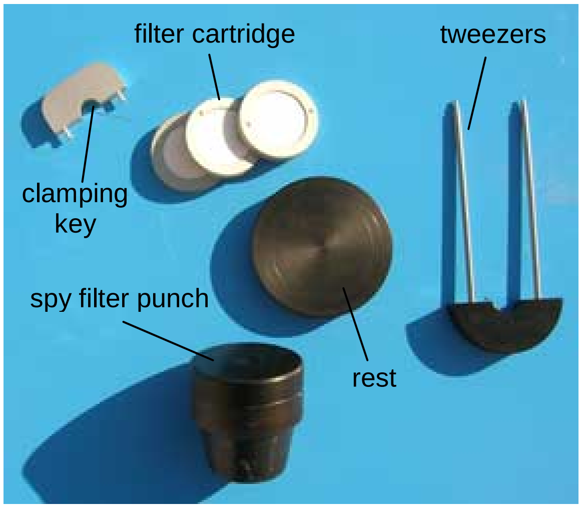
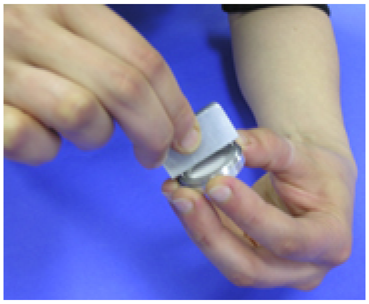


Figure 5-3. Spy Filter Components

Step 1

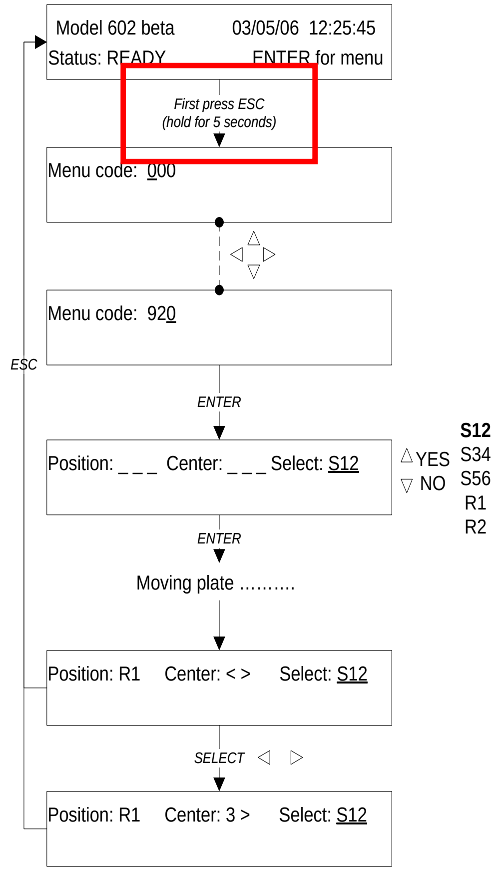
Step 2



Step 3

Step 4

Spy Filter Insertion and Removal



1. With the instrument in READY Status, press and hold the ESC key for at least 5 seconds to access the *Menu code* (access to support tools).
2. Using the SELECT keys, select the code *920* and press ENTER to access the tool for inserting or removing the S12, S34, and S56 membranes.
3. Remove the Unloader to obtain access to the spy filter housings on the plate.
4. Using the YES/NO keys, select the code for the spy filter that you want to insert or remove (S12/S34/S56) and press ENTER. The plate will automatically rotate so that the housing corresponding to the selected filter cartridge lies below the Unloader insertion slot. If the housing does not align correctly with this slot, it is possible to adjust the position of the former by using the SELECT keys which rotate the plate clockwise or anticlockwise in small increments (the *Center* indicator can have values between “<5” and “5>”).
5. Insert or remove the filter cartridge containing the spy filter, using the suitable tweezers (see Figure 5.4).
6. Repeat steps 4 and 5 of the procedure to insert or remove the other two filters.
7. Press ESC to go back to the main menu.

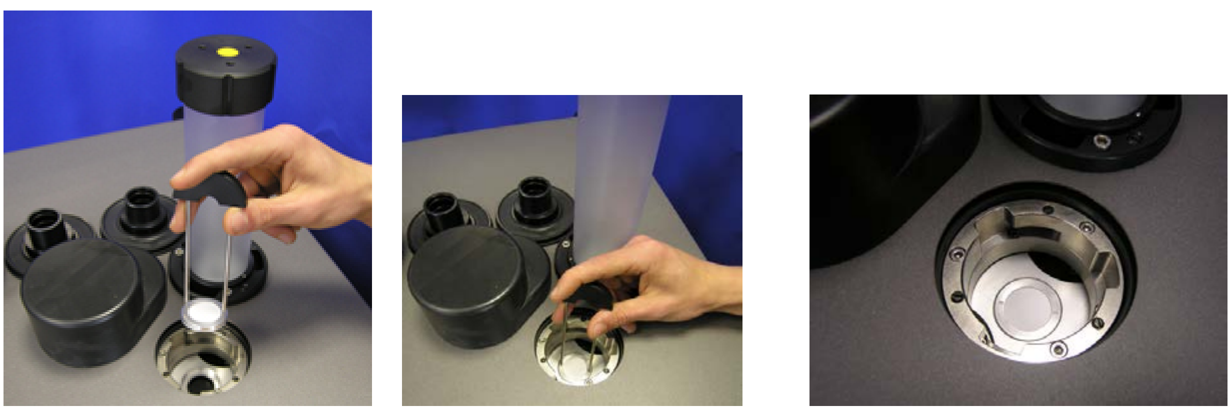


Figure 5-4. Filter Insertion/Removal

5.8 INSERTING OR REPLACING THE REFERENCE ALUMINUM FOILS

Before starting the sampling and measurement cycles, it is necessary to make sure that the two aluminum reference membranes R1 and R2 with known surface mass density are inside the instrument. If R1 and R2 are not inside the instrument or if you need to replace them, follow the procedure below:

1. With the instrument in READY Status, press and hold the ESC key for at least 5 seconds to access the *Menu code* (access to support tools)
2. Using the SELECT keys, select the code *920* and press ENTER to access the tool for inserting or removing the R1 and R2 membranes.
3. Remove the Unloader to obtain access the reference membrane's housings on the plate.
4. Using the YES/NO keys, select the code of the reference membrane that you want to insert or remove (R1 or R2) and press ENTER. The plate will automatically rotate so that the housing corresponding to the selected filter cartridge lies below the Unloader insertion slot. If the housing does not align correctly with this slot, it is possible to adjust the position of the former by using the SELECT keys which rotate the plate clockwise or anticlockwise in small increments (the *Center* indicator can have values between "<5" and "5>").
5. Insert or remove the filter cartridge containing the reference membrane, using the suitable accessory
6. Repeat steps 4 and 5 of the procedure for inserting or removing the second membrane.
7. Press ESC to go back to the main menu screen.

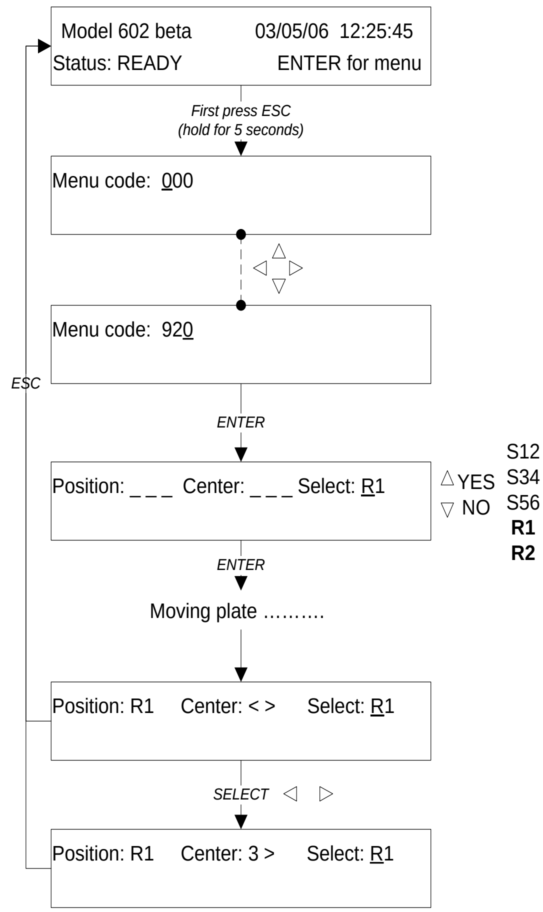


Figure 5-5. Aluminum Reference Membranes

5.9 BEGINNING THE SAMPLING PROCESS

Before starting the sampling process it is necessary to:

- Make sure that all connections to the instrument have been made correctly
- Insert the Unloader into the correct housing and make sure that it is properly locked
- Switch on the instrument by moving the main power switch to the ON position
- Check that the green status LEDs on the front panel are on (STATUS, SERVICE AIR, BATTERY LEVEL)
- Check that no filters are inside the Unloader; if filters are present, remove them and lock the Unloader back into its housing
- Make sure that the reference aluminum foils and the spy filters have been inserted into the instrument (see sections 5.8 "*Inserting or replacing* the *reference aluminum foils*" and 5.7 "*Assembling and inserting the spy filters*")
- Check that the filters have been inserted into the Loader correctly (see section 4.8)
- Insert the Loader into the suitable housing and ensure that it is correctly locked (see section 4.8 "*Insertion of the filter membranes in the Loader*")
- Set the sampling and measurement parameters (see section 5.5 "Setting *sampling and measurement parameters – Instrument Setting*")
- Make sure that the proper sampling line inlet nozzle is installed.

NOTE: If the programmed *β equivalent spot area* is different from the actual one that is used, the Model 602 Beta*PLUS* will still perform the programmed sampling and measurement cycles, but the final mass calculations will be incorrect because the instrument will use an incorrect sampling area value. In that case, the data stored in the buffer can still be used to re-calculate the correct mass concentration value.

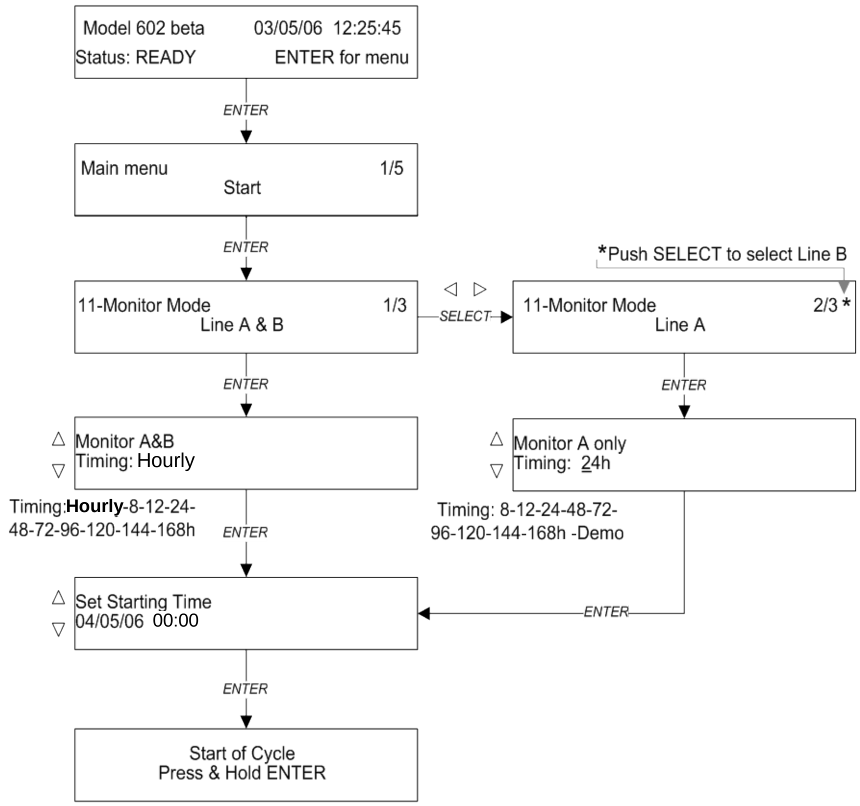
For EPA FEM purposes, make sure that the spot area is set to 0.95 cm^2.

The next section describes the programming procedures to be used for starting the sampling process, depending on whether *Dual Channel (Line A & B) or Single Channel (Line A) is selected*.

5.9.1 Sampling Start in Dual Channel (Line A & B) or Single Channel (Line A) Mode

To start the instrument:

1. From the main screen, with the instrument in READY Status, press ENTER to access the *Start* menu.
2. Using the SELECT keys, select option *Line A & B* if both lines are to be used, or select option *Line A* if samples will be collected on a single filter membrane and press ENTER to confirm.
3. Using the Up/Down arrow (or "YES/NO") keys, select the sampling *Timing* and press ENTER.



4. Set the sampling start date and time using the SELECT keys (the display will show the first possible sampling start time) and press ENTER to confirm.
5. Press and hold the ENTER key for a few seconds to complete the setup.

NOTE: Hourly Mode is available only by choosing the option "Line A&B"

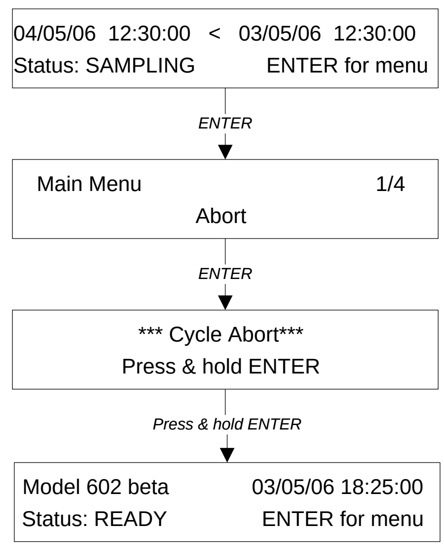
5.10 SAMPLING STOP

5.10.1 Manual Interruption using the Abort Procedure

To stop the sampling and measurement cycles, select *Abort* from the main menu and press and hold the ENTER key for a few seconds.
The instrument stops the sampling in process and unloads the filters from the plate. If the filters in the reserve and the Loader also need to be removed, follow the *Unloading* procedure (see section 5.11 "*Filter removal – Unloading procedure*").

Note:
A Warning message is displayed (Warning 21, see Appendix 3) in the Buffer record regarding the interrupted sampling and measurement cycle.

Note: Date format is dd/mm/yy

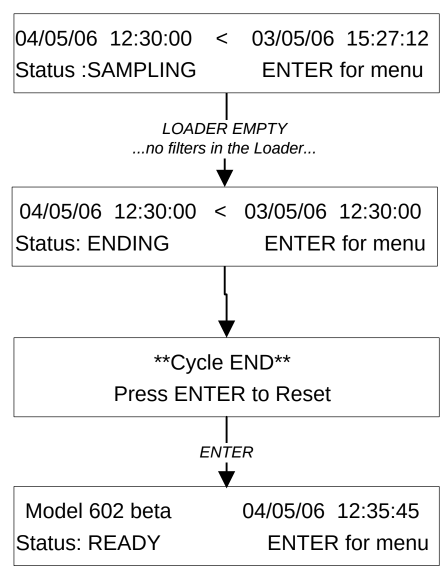


5.10.2 Automatic Interruption of the Sampling Cycles Due to Lack of Filters "ENDING"

If the instrument runs out of filters (Loader EMPTY) during the sampling and measurement cycles, it will automatically change its status to ENDING.
The sampling and measurement processes will continue for all the filters remaining on the plate. After the last filter has been used, the instrument will stop.
At this point it will be necessary to insert new unused filters into the Loader and restart the sampling procedure.

Note:
After switching to Ending Status the instrument stops loading new unused filters onto the plate.

Note: Date format is dd/mm/yy



5.11 FILTER REMOVAL “Unloading” Procedure

To remove all the filters inside the instrument (i.e. from the rotating plate, from the reserve and from the Loader), use the “***Filters unloading***” procedure available in the *“Instrument tools / Mechanics Direct Control*” menu.

In this case, the order of the unloaded filters will not correspond to the Loader filling order.

Model 602 beta 03/05/06 12:25:45 Status: READY ENTER for menu
↓ *ENTER / SELECT* ◁ ▷
Main Menu 5/5 Instrument Tools
↓ *ENTER / SELECT* ◁ ▷
5-Instrument Tools 2/4 Mechanics Direct Control
↓ *ENTER / SELECT* ◁ ▷
52-Mechanics Direct Control 1/9 Filters unloading
↓ *ENTER*
Press ENTER to Start
↓ *ENTER*
Unloading …..

5.12 “RESET” PROCEDURE

If the instrument needs to be reset, simultaneously press and hold the ESC and NO keys on the front control panel for at least three seconds. At the end of the reset procedure the instrument enters “Ready” status.

Figure 5-6. ESC+NO Keys for Reset

CHAPTER 6

6. SAMPLING AND MEASUREMENT DATA

6.1 INFORMATION AVAILABLE DURING THE SAMPLING PROCESS (“*Instrument Info*”)

During the sampling and measurement cycles, the following information is available from the *Instrument Info* menu:

- *Sampling Info* - Information pertaining to the sampling cycle in process
- *Beta Info* - Information pertaining to the mass measurement
- *Test Info* - Information pertaining to pneumatic tests, mass measurement system and power supply system
- *Program Info* - Information pertaining to the programmed sampling and measurement cycles
- *System Info* - Information pertaining to the instrument and the general working condition
- *Warnings Info* - Information pertaining to possible Warning messages
- *About* - Information pertaining to the instrumental management software
- *GSM signal* - Information pertaining to the GSM modem

The diagrams on the following pages show the structure of the submenus in the *Instrument Info* menu.

6.1.1 Sampling Info

```
Model 602 beta          2/02/06 12:37:43
Status :READY           ENTER for menu
```

ENTER/SELECT ◁ ▷ ↓

```
Main menu                          3/5
          Instrument Info
```

ENTER ↓

```
3-Instrument info                  1/8
          Sampling Info
```

ENTER ↓

```
31-Sampling Info                   1/2
          Sampling Info A
```

ENTER ↓

```
Sampling – Sample Info – Line A    1/9
Cycle:001   Filter:002   Acc. Step : ___
```

ENTER ↓

```
Sampling – Sample Info – Line A    2/9
Pump: ON    Duty Cycle: OFF
```

ENTER ↓

```
Sampling – Timing – Line A         3/9
Frrom:                  To:
```

ENTER ↓

```
Sampling – Timing – Line A         4/9
Elapsed:             Remaining:
```

ENTER ↓

```
Sampling flow rate – Line A        5/9
Inlet: 1.00 m³/h  Standard: 0.99 Nm³/h
```

ENTER ↓

```
Sampling – Total Volume – Line A   6/9
Inlet: 12.374 m³  Standard: 12.250 Nm³
```

ENTER ↓

```
Sampling – Pressure – Line A       7/9
Absolute: 101.3kPa  Drop: 16.1kPa
```

ENTER ↓

```
Sampling – Flow rate – Line A      8/9
RSD: 1.1%      Valve opening: 64%
```

ENTER ↓

```
Sampling – Temperature – Line A    9/9
External: 281 K   Filter: 293 K
```

Available information pertaining to the sampling in progress:

Sample Info

- Cycle: number of the cycle in progress
- Filter: number of the filter currently being used for sampling
- Acc. Step: accumulation step number
- Pump: vacuum pump status (On/Off)
- Duty Cycle: duty cycle setting

Timing

- From: sampling start date and time
- To: sampling end date and time
- Elapsed: elapsed time
- Remaining: remaining time

Sampling flow rate

- Inlet: inlet operating flow rate
- Standard: operating flow rate adjusted to the programmed standard conditions (default value: 298.1 K and 101.3 kPa)

Total Volume

- Inlet: total sampled volume
- Standard: total sampled volume adjusted to the programmed standard conditions (default value: 298.1 K and 101.3 kPa)

Pressure

- Absolute: atmospheric pressure value
- Drop: filter pressure drop

Sampling flow rate

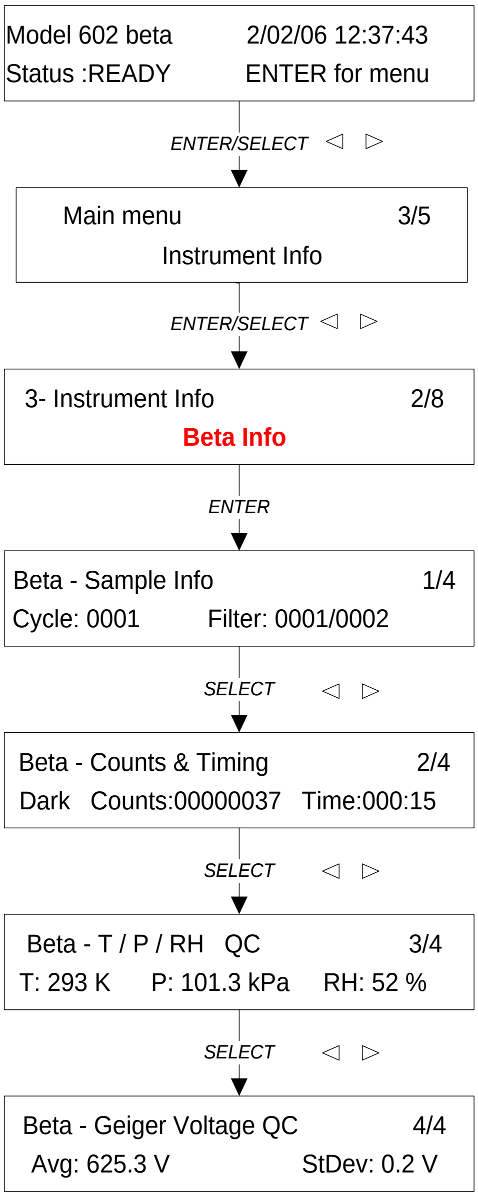
- RSD: variable describing the inlet flow rate stability
- Valve opening: extent to which the regulation valve is open (percentage)

Temperature

- External: external temperature
- Filter: temperature in the accumulation area

NOTE: if the instrument loses power or is turned off while a blank measurement is being taken and sampling does not stop at the programmed date and time, the message "*over time*" is displayed instead of the remaining time.

6.1.2 Beta Info



Available information relevant to the mass measurement in progress. If the instrument is not performing a measurement, some information will not be available.

Sample Info

- Cycle: number of the cycle in progress
- Filter: identification number of the filters currently being used
  (for example 0001/0002 = filters 1 and 2)

Counts & Timing

- Counts: instantaneous value of the counts per minute
- Time: remaining measurement time

  None= no measurement in process
  Dark= background noise measurement
  Air= “air” counts measurement
  CountA= measurement of filter in position A
  Ref= spy filter measurement
  CountB= measurement of filter in position B

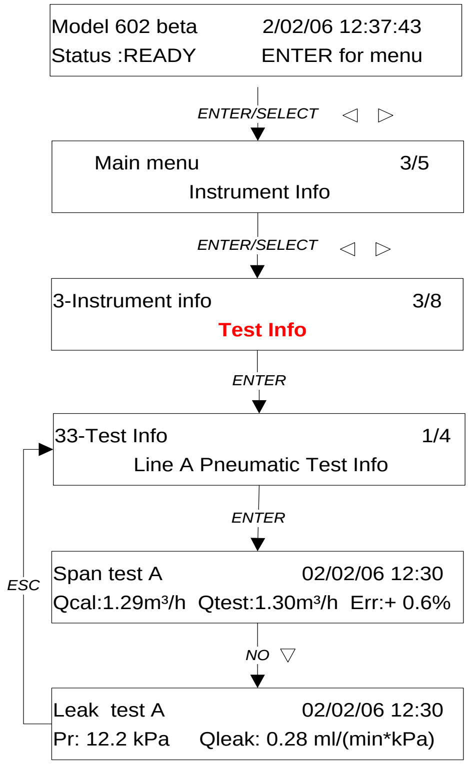
Beta - T/P/RH QC

- T: temperature at the measurement location
- P: pressure at the measurement location
- RH: relative humidity inside the instrument

Beta - Geiger Voltage QC

- Avg: average value of the Geiger detector voltage
- StDev: associated standard deviation of the power supply voltage measurements

6.1.3 Test Info



Information available in SAMPLING Status pertaining to automatic tests performed by the instrument

Line A/B pneumatic test Info: indicates which sampling line the tests refer to (see sections 7.1.1 and 7.1.2)

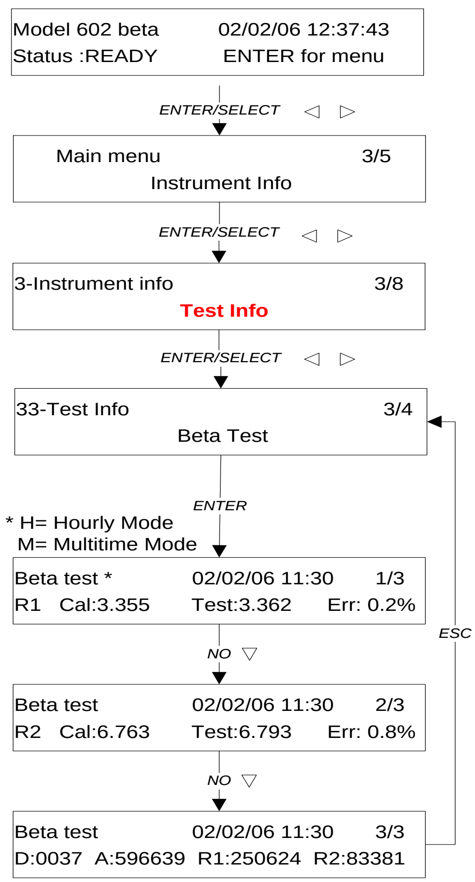
Span test A/B:

- Test date and time
- Qcal: reference flow rate value
- Qtest: measured flow rate value
- Err: percentage deviation

Leak test A/B:

- Test date and time
- Pr: residual pressure
- Qleak: specific leak

6.1.4 Program Info

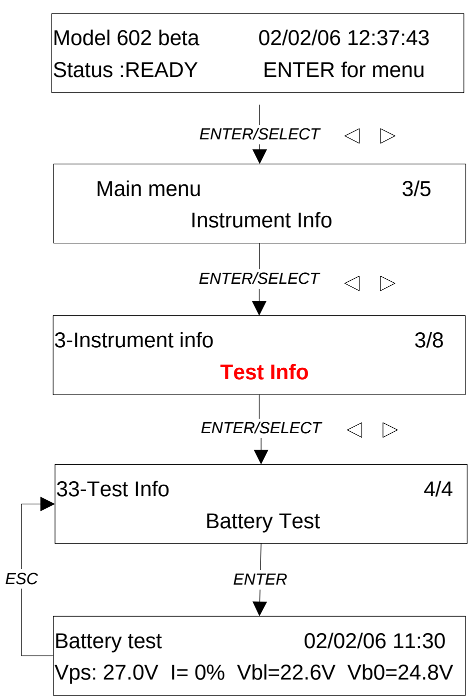


Information available in SAMPLING Status pertaining to automatic tests performed by the instrument

Beta test: contains information relevant to the automatic mass measurement system calibration check (see section 7.4.1)

Beta test:

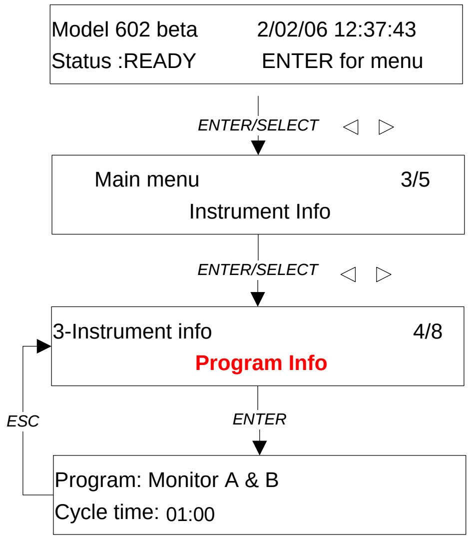
- Test date and time
- R1: the reference aluminium foil that the data refer to
  - Cal: nominal value of the mass surface density
  - Test: mass surface density value measured during the test
  - Err: percentage deviation between the two values
- R2: the reference aluminium foil that the data refer to
  - Cal: nominal value of the mass surface density
  - Test: mass surface density value measured during the test
  - Err: percentage deviation between the two values
- D: background radioactivity counts
- A: “air” counts
- R1: membrane R1 counts
- R2: membrane R2 counts



Information available in SAMPLING Status pertaining to automatic tests performed by the instrument

Battery test: contains information concerning the automatic battery status check (see section 7.6)

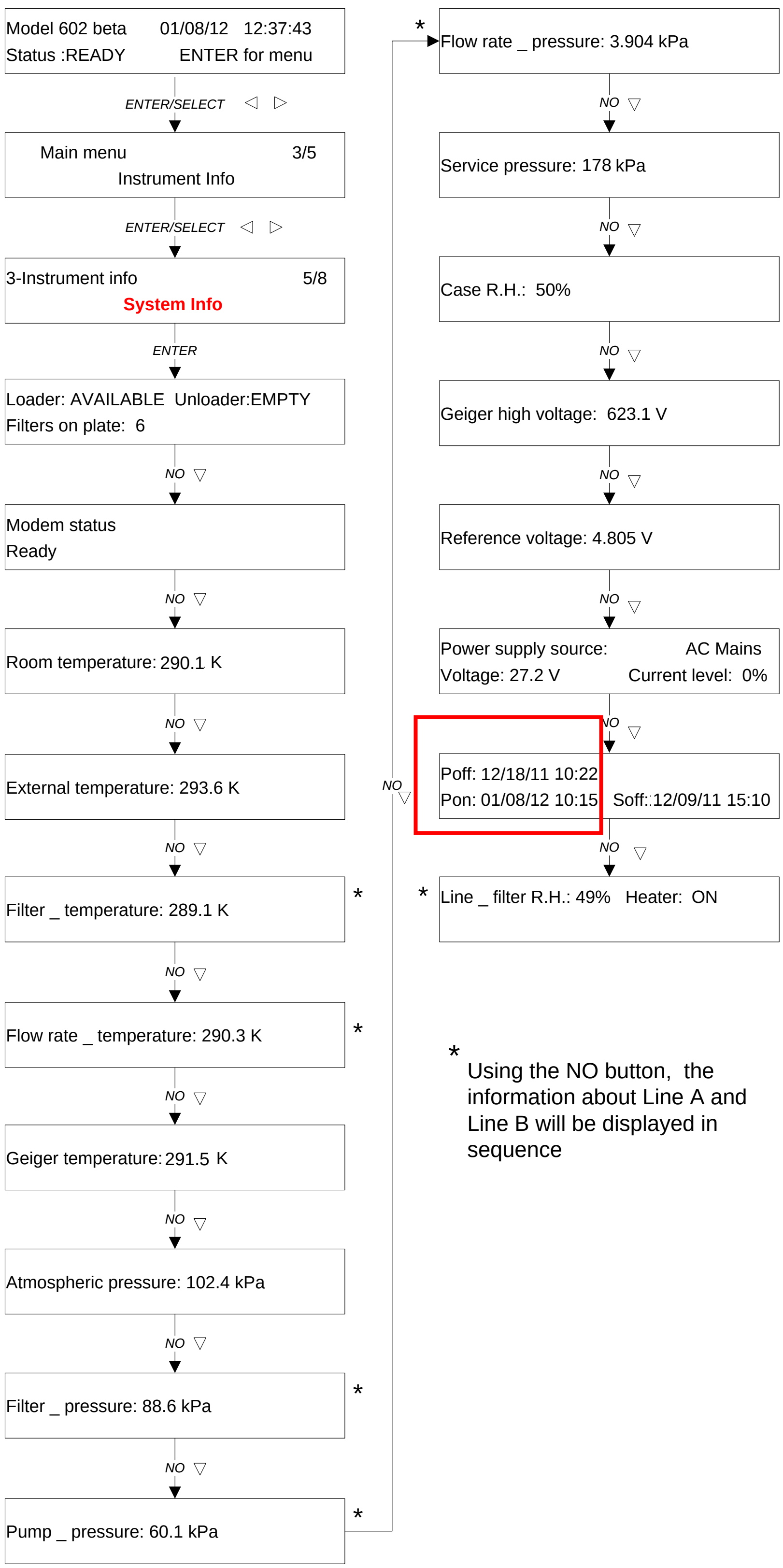
- Test date and time
- Vps: internal voltage level
- I: battery charging rate
- Vbl: battery voltage with load
- VbO: battery voltage with no-load



Information available in SAMPLING Status pertaining to the programmed sampling and measurement cycles

- Program: programmed operating mode
- Cycle time: sampling and measurement cycle duration

6.1.5 System Info



Available information in *SAMPLING Status*

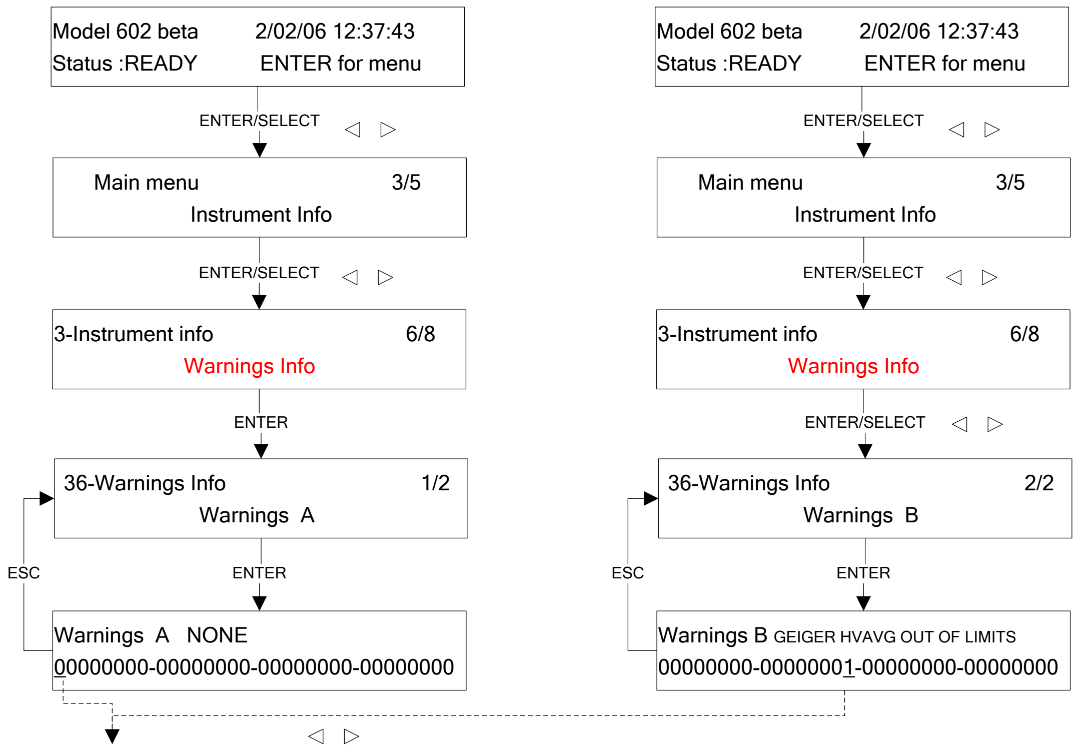
While most parameters are self-explanatory, the following are described here:

- Poff: date and time the instrument lost power
- Pon: date and time the power was restored
- Soff: auto-switch-off due to exhausted batteries
- Son: switch-on after an auto-switch-off

NOTE: date and time are in mm/dd/yy format.

6.1.6 Warnings Info

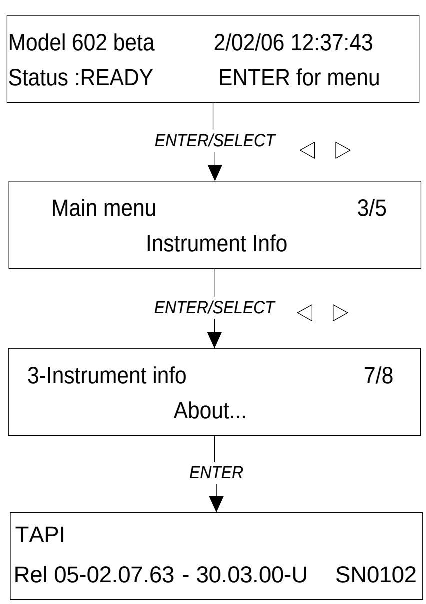
Information available in *SAMPLING* Status concerning Warnings associated with the two sampling lines (for more information about the Warning messages, see Appendix 3):



Using the SELECT buttons it's possible to move the cursor along the Warnings string. By positioning the cursor on an active bit of the string the NONE message is replaced by the Warning corresponding to the selected bit.

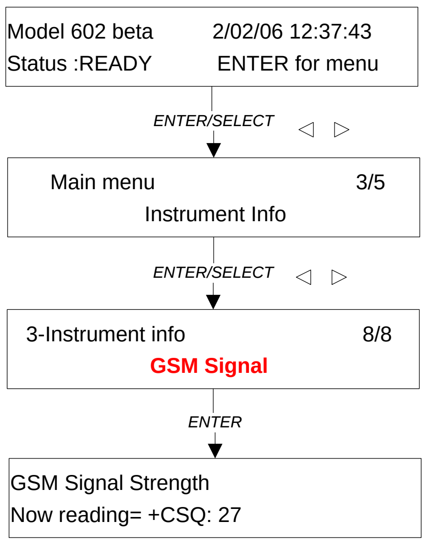
6.1.7 About

Information regarding the software version of the instrument and serial number



6.1.8 GSM Signal

GSM signal intensity if the modem is connected. When the modem is disconnected, the message "*Modem not Ready*" is displayed (see section 7.7).



6.2 INFORMATION STORED IN THE DATA BUFFER

At the end of each sampling and measurement cycle, all the information that will be needed later for characterization is stored in the instrument's Data Buffer. The Buffer's structure consists of records identified by a progressive number beginning with 0, holding up to approximately 1.5 years' worth of data records when captured in Hourly Mode.. Each record contains the sampling and measurement data pertaining to one sampling line.

Note: The *Buffer* has a cyclical structure. Therefore, once the maximum capacity of 20,000 is reached, the records are overwritten starting from 0.

Below is a partial list of the information contained in each record stored in the Buffer (for the complete list of the fields, their descriptions and format, see Appendix 1):

General Iinformation

- Identification number of the record
- Date and time that the sampling cycle started and ended
- Sampling cycle identification number
- Filter number: number of the filter that the record refers to
- Accumulation Step: number of samplings performed on the filter
- Sampling line that the information contained in the record refers to

Pneumatic and Instrument Information Pertaining to a Single Sampling and Measurement Cycle

- "Power Loss" duration (length of time the instrument operated in battery mode)

  If power is lost, the instrument activates a Warning message (Warning 29). The suction pumps will not work when the instrument is operating on batteries. As a result, the actual sampling duration will be less than the programmed one.

- Result of the last automatic test of the pneumatic circuit seal ("Automatic Leak Test")

  If the test results are outside of the programmed limit [5 mL/(min*kPa)], a Warning message will be displayed (Warning 12, Appendix 3)

- Result of the last automatic test of the operating flow rate measurement system calibration ("Automatic Span Test", see section 7.1.2)

  If the test results are outside of the programmed limit [± 4%], a Warning message will be displayed (Warning 13, Appendix 3)

- Value of the total sampled volume and of the total normalized volume under the standard programmed conditions (default: 298.1 K and 101.3 kPa)

  The temperature and pressure values used by the instrument to define the standard conditions that can be programmed by the operator before starting the sampling and measurement cycles (see section 5.5)

- Ratio of the actual sampling time to the programmed one

  The ratio of effective sampling time gives a quick indicator of the percentage of sampling time for a given sampling cycle. If this duration is less than the programmed one, a Warning message will be displayed (Warning 23, Appendix 3).

- External temperature values during the sampling process (minimum, average and maximum)
- Temperature values near the accumulation area (minimum, average and maximum)
- Average Relative Humidity in the sample accumulation area
- Maximum difference between the external temperature and the temperature inside the sample accumulation area
- Date and time of the maximum detected temperature difference
- Duration of the period for which the temperature difference exceeded the 5 K (Kelvin)
- Average value of the difference between the external temperature and the temperature inside the accumulation area
    - Measurements of the environmental conditions in the accumulation area are helpful for evaluating the conditions at the filter when it is not being sampled. These conditions represent the filter holding (between sampling cycles) and analysis periods.
- Atmospheric pressure values (minimum, average and maximum)
- Value of the "RDS" variable which describes the stability of the flow rate value at the sampling head inlet (see section 2.4)
- Initial, final and maximum values of the filter medium load drop (see sections 2.4 and 5.5)

Mass Measurement Information Pertaining to a Single Sampling and Measurement Cycle

- Value of the background noise "Dark"

  If the ß electron flux measured by the Geiger Müller detector with shielded source is not within the range of 1 to 250 counts per minute (see section 2.6.1), a Warning message will be displayed (Warning 19, Appendix 3)
- "Air counts" value (Blank session)

  The measurement of the ß-particle flux without a filtering medium placed between source and detector gives information that is useful for determining possible drifting of the Geiger Müller response
- Value of the ß-particle flux through the spy filter, measured during the *Blank* session, and associated standard deviation
- Value of the ß-particle flux through the unused filter during the *Blank* session and associated Standard Deviation

  This value must be between 20000 cpm and the value of the "air counts" (Warning 17, Appendix 3)
- Temperature, pressure and relative humidity inside the measurement area during the *Blank* session
- Geiger Müller high voltage value (see section 2.6)

  To ensure correct functionality of the detector, this value must lie between 585 V and 615 V, and the associated standard deviation must be lower than 1 V (Warnings 15 and 16, Appendix 3)

- “Air counts” valve (Collect session)
- Value of the ß-particle flux associated with the presence of natural radionuclides in the particulate matter sample accumulated on the filter
- Value of the ß-particle flux through the spy filter, measured during the *Collect* session, and associated standard deviation
- Value of the ß-particle flux measured through the sampled filter during the *Collect* session and associated Standard Deviation
- Temperature, pressure and relative humidity inside the measurement area during the *Collect* session
- Geiger Müller high voltage value (see section 2.6)
- PBL mixing status counts
- Value of the sample mass and associated uncertainty
- Value of the concentration in standard and current conditions

Information Pertaining to the Quality Controls

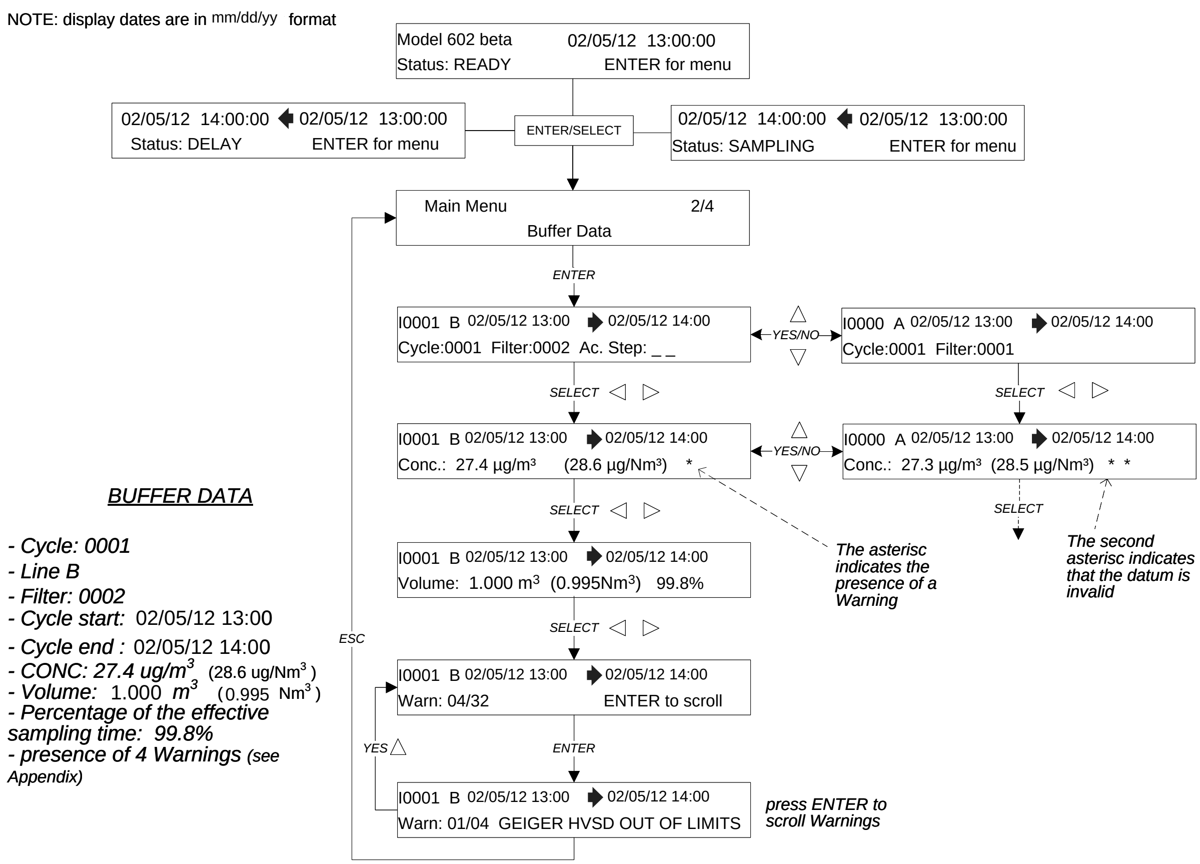
- Validation bit: valid datum indication
- Warnings pertaining to the sampling and measurement cycle

NOTE: In Hourly Mode the Automatic Leak Test and Span Test are performed in Delay Status and are repeated during the sampling and measurement cycles only on operator demand. Therefore, the record pertaining to each filter will always show the result of the last test performed on that line. To perform leak and span tests while during sampling, see section 7.2 “Request for pneumatic tests in Hourly Mode”.

6.2.1 Accessing the Data Buffer from the Display

The main information contained in the Data Buffer can also be read on the instrument's display.

The diagram below shows how to access the information contained in the Data Buffer starting from any of the three Status conditions (*READY, DELAY* and *SAMPLING*).
From this menu, information pertaining to the last stored record (in the example I0001) can be viewed.
Use the "Select" keys to scroll through the information in each record. To change the displayed record, use the "YES/NO" keys.



6.3 CONNECTING TO AN EXTERNAL PC AND DOWNLOADING BUFFER DATA

All of the instrument's functions can be controlled by an external PC. To connect a PC to the instrument, a cable must be connected to the RS232 serial port on the back of the instrument.

Using an external PC, it is also possible to display *Data Buffer* content and download data to a file using the following procedure:

1. Connect the instrument to the PC via RS232 serial port.
2. Start up the serial communication software on the PC (e.g. Windows Hyperterminal).
3. Make sure that the software has the following configuration:
   - emulation ANSI
   - port speed 19200 Baud
   - data bit 8
   - parity None
   - stop bit 1
   - flow control None
4. Once the connection is established, type the command **42xxxx**, where xxxx [0 to 1499] is the record sequential storage code of the sampling and measurement cycles and press *Enter.* The response will be a sequence corresponding to the requested record beginning with = and followed by values separated by commas (see the example below).

Note: The Buffer has a cyclical structure; therefore once its maximum capacity (1499) is reached the records are overwritten starting from number 0.

Other useful commands are **40** and **41**. The first field of command **40** shows the number of the first available record. The first field of command **41** shows the number of the last available record.

EXAMPLE: Command: 420002

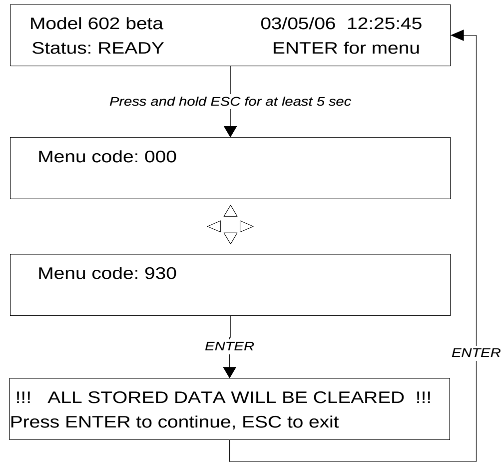
Response:

=0002,19/01/10 11:45,19/01/10 12:45,0001,0003,001,A,00:00,09.98,+00.0,000.984,000.914,098.4, 293.0,294.0,295.0,295.0,296.0,297.0,055.0,101.0,101.3,101.6,00.6,21.9,19.8,22.0,003.8,19/01/10 12:42,000:00,+02.0,0018,1394668,1397908,2138,0223071,0626,296.0,101.2,599.9,055,1392381,0297, 1397111,7488,0222137,287,295.9,101.2,600.0,054,00321,14,0026,14.1,15.2,1,02850000

See ***Appendix 1*** *for details pertaining to the Data Buffer Structure*

6.4 *CLEARING THE DATA BUFFER*

To delete all the data stored in the Data Buffer, press and hold the ESC key for at least 5 seconds to access *Menu Code* (access to the support tools). Select code *930* using the SELECT keys and press ENTER to delete the *Data Buffer* content.



NOTE 1: after this procedure it will not be possible to recover information stored in the Buffer.

NOTE 2: This procedure cannot be used if the instrument's Status is DELAY, SAMPLING or ENDING.

6.5 SMS TEXT MESSAGING SERVICE

The Model 602 Beta*PLUS* is equipped with a "Short Message System" service which allows real-time information about the instrument's operating status and measured concentration values to be received on a mobile phone. The table below lists all the information that can be sent to the "*Operator*" and "*User*" telephone numbers:

Information Sent to the "*Operator's*" Phone	Information Sent to the "*User's*" Phone
• Instrument ID and serial number • SMS sending date (in dd/mm/yy format) and time • ALARM messages causing sampling and measurement cycles to stop (see Appendix 2) • Loader is almost empty (less than 6 filters left) • Full *Unloader*	• Instrument ID and serial number • SMS sending date (in dd/mm/yy format) and time • Measured concentration values (µg/m³) on both the sampling lines • Warnings messages (8-digit hexadecimal codes) see Appendix 3

To set the two telephone numbers that will receive the SMS messages follow the procedures below:

- *Setting "Operator" telephone number*

- In "READY Status", go to the *Instrument Settings / SMS Cell Number's* menu from the main menu.
- Select *Operator's Cell Number.*
- Using the SELECT keys, type the telephone number, complete with international code (for example +39 ##########).
- Press ENTER to confirm or press the two SELECT keys simultaneously to delete the typed number.

- *Setting "User" telephone number*

- In "READY Status", go to the *Instrument Settings / SMS Cell Number's* menu from the main menu.
- Select *User's Cell Number.*
- Using the SELECT keys, type the telephone number, complete with international code (for example +39 ##########).
- Press ENTER to confirm or press the two SELECT keys simultaneously to delete the typed number.

The SMS service is available only if the SIM card installed in the modem has this capability and is correctly configured. Contact the appropriate phone service carrier or provider to configure and/or enable the SIM card.

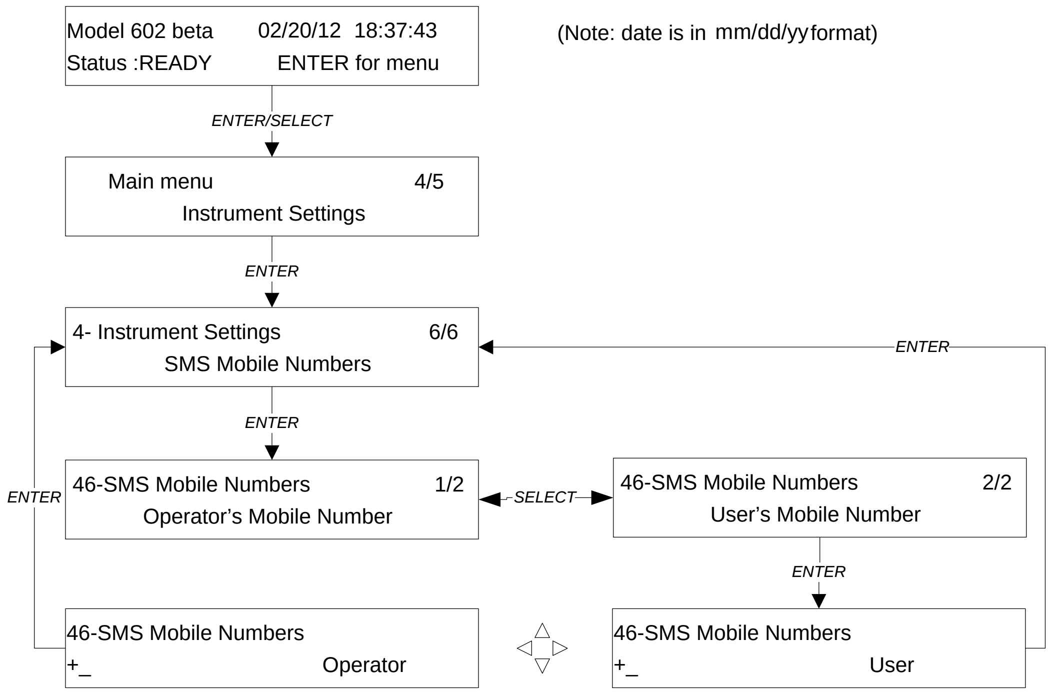


Figure 6-1. Setting SMS Messaging Service

To enable the SMS messaging service, set the "User" and "Operator" telephone numbers before starting the sampling and measurement cycles.

CHAPTER 7

7. TESTS AND QUALITY CONTROLS

The instrument implements tests and quality controls in order to ensure high quality sampling and measurement data.

The instrument can perform tests on the pneumatic system, mass measurement system, power supply system, and GSM modem. The tests can be performed automatically by the instrument or manually by the operator.

The instrument automatically performs quality controls on the sensors, mechanical system, flow rate measurement and control system, mass measurement system, power supply, and filter membrane management system. Figure 7.1 shows a sampling and measurement cycle with the main quality controls.

Running quality controls and tests may results in *Warning* and *Alarm* messages that are displayed and stored in the instrument's *Data Buffer*.

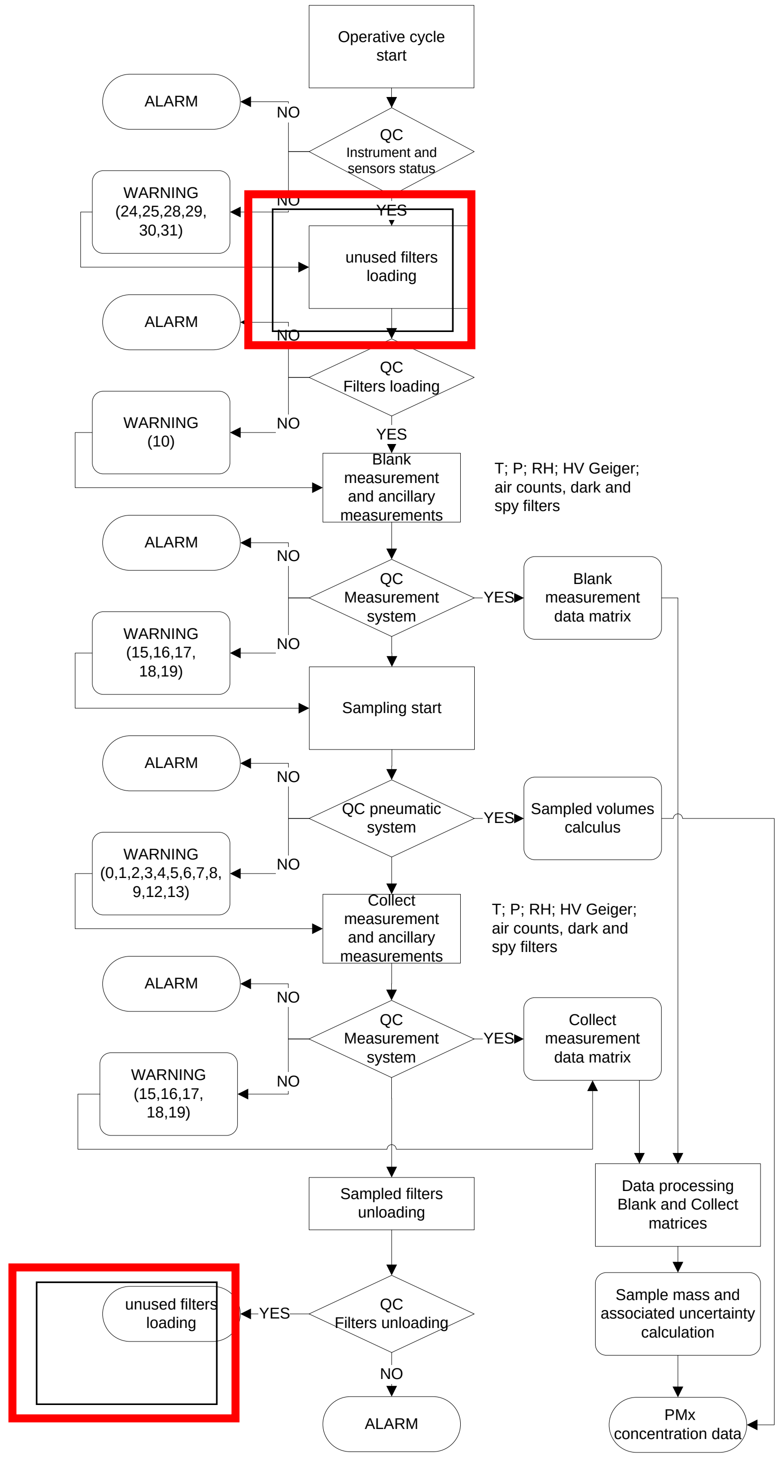


Figure 7-1. Quality Controls Quality and Measurement Cycle

7.1 CALIBRATION AND PNEUMATIC CIRCUIT SEAL CONTROL

Testing of the pneumatic circuit seal (*Leak Test*) and calibration of the operating flow rate regulation system (*Span Test*) can be performed by following the procedures described below.

7.1.1 Leak Test

Two different types of pneumatic circuit seal tests are available: the *Auto Leak Test* and the *Manual Leak Test*. The *Auto Leak Test* checks the pneumatic circuit seal downstream from the accumulation section (a solenoid valve closes the pneumatic circuit to perform the Leak Test). The *Manual Leak Test* checks the sealing of the entire pneumatic circuit (including the sampling line) or parts of it (using the accessory tools for instrument tests).

To determine the extent of a leak that is present, an equation is used that describes the equilibrium state of an ideal gas in a system with known volume. The sequence of the operations performed by the instrument is:

Leak solenoid valve closes (*Auto Leak Test* only) - see Figure 7-2.

- A blind filter is loaded (*Manual Leak Test* only), see Figure 7-3.
- Filter is loaded completely (*Manual Leak Test* only, along the entire sampling line), see Figure 7-4.
- Vacuum pump switches on until the minimum inline pressure "P_r" (residual pressure) is reached.
- Vacuum pump switches off; the inline pressure value "$P_l(t)$" will tend to increase. The rate of the increase depends on the extent of the potential leak.
- The instrument determines the mass loss using the ideal gas equation:

$$\frac{dn}{dt} = \frac{V}{RT} \cdot \frac{dP}{dt}$$

Where:

n = moles
V = volume
P = pressure
R = rydberg constant
T = temperature

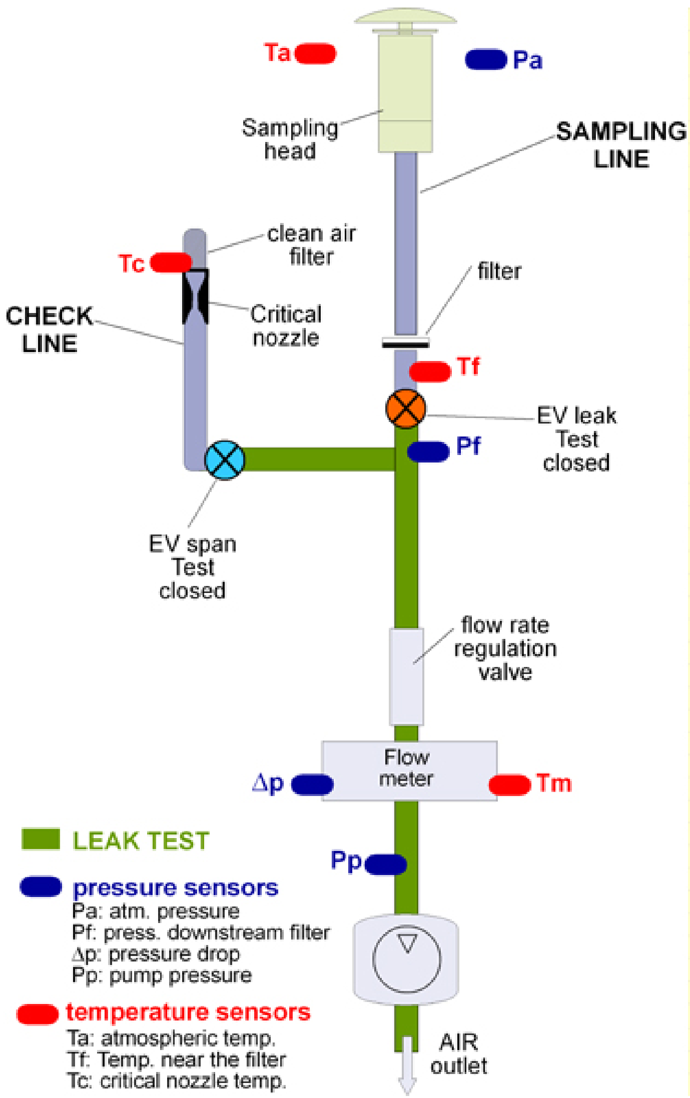
The value of this leak, expressed in mL/min under standard conditions (T=273.1 K P=101.3 kPa), is determined when the pneumatic circuit pressure is equivalent to the residual pressure. Under operating conditions the pneumatic circuit pressure is much higher than the residual pressure. Therefore, the mass flow value associated with the loss is proportionally lower and can be calculated using the formula:

$$Q_{leak}^{op} = Q_{leak}^{r} \cdot \left(\frac{P_a - P_l}{P_a - P_r} \right) = \left(\frac{Q_{leak}^{r}}{P_a - P_r} \right) \cdot \left(P_a - P_l \right)$$

By taking into consideration the pneumatic circuit type used in the instrument, it is possible to assume that the mass loss is proportional to the pressure difference between the ambient air and the pneumatic circuit. Once the atmospheric pressure values and the inline pressure values are known, it is possible to calculate the leak value under operating conditions by knowing the value of the term $\left(\frac{Q_{leak}^{r}}{P_a - P_r} \right)$. For this reason, the instrument gives the value of this term (specific leak) at the end of the test, indicated simply as "Q_{leak}" and expressed in mL/(min*kPa).

For example, assuming: Q_{leak} = 0.57 *mL/min·kPa* ; P_a=101.5 kPa; P_l=93.1kPa; $Q^{op}_{leak} = 4.79$ mL/min

Figures 7-2, 7-3 and 7-4 show the Leak Test types implemented in the instrument:



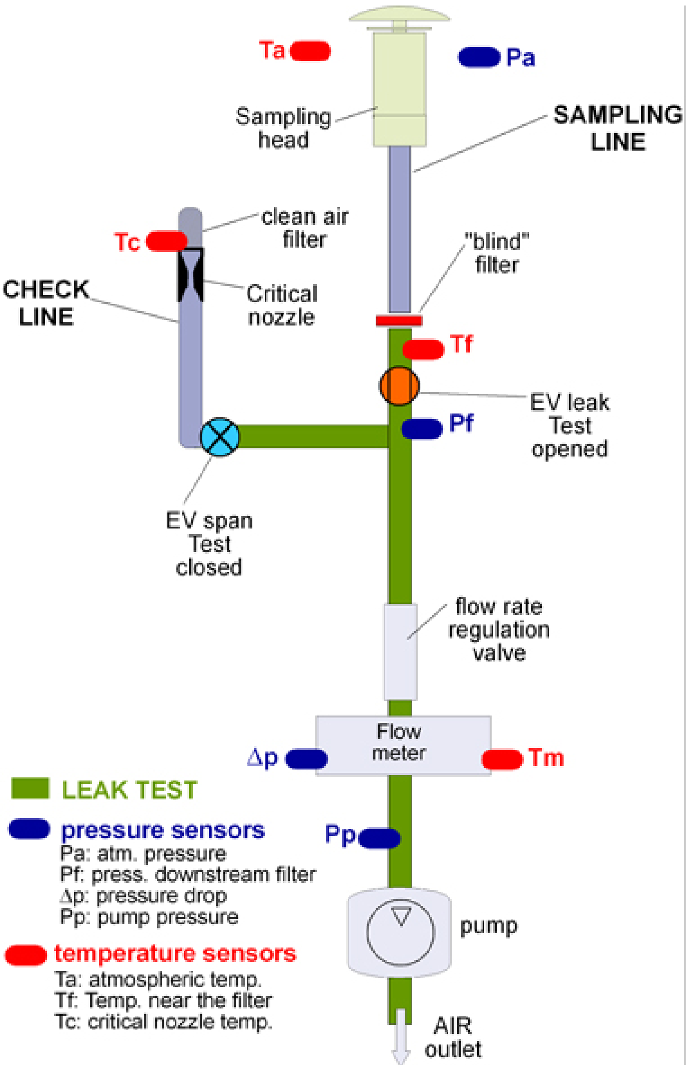
Auto Leak Test

Performed to check the pneumatic circuit seal downstream from the accumulation area.

Configuration:

- EV leak: closed
- EV: span closed

Figure 7-2. Auto Leak Test



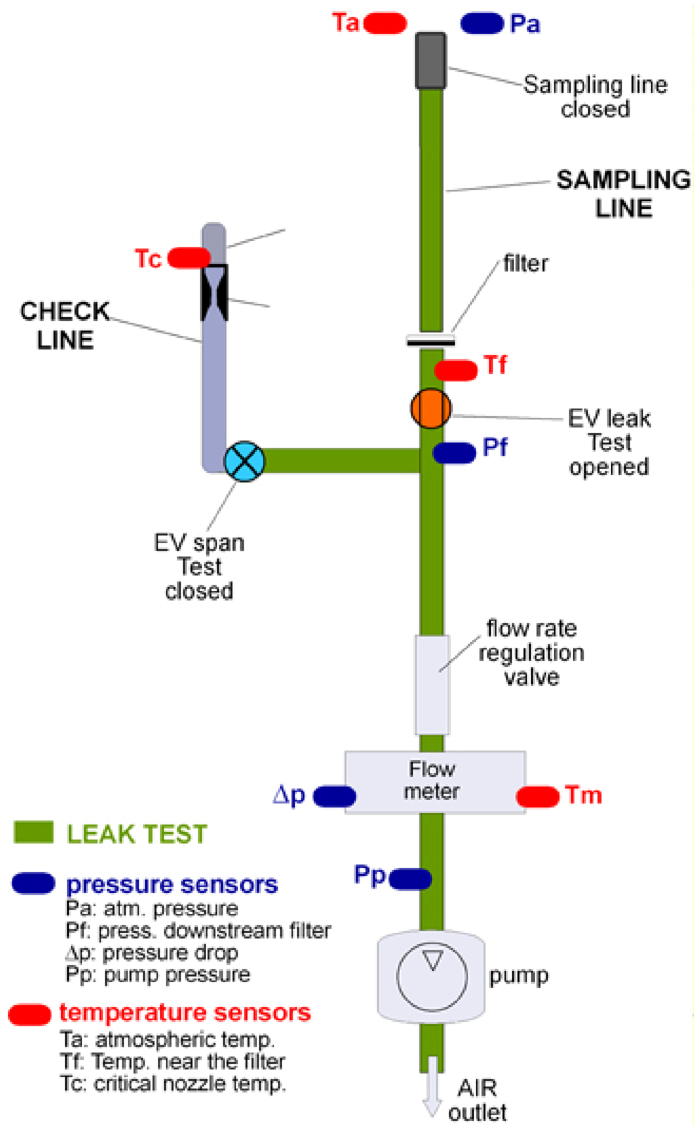
Manual Leak Test
with "blind" Filter Cartridge

Performed to check the pneumatic circuit seal between the vacuum pump and the accumulation area, and also the filter presser seal (see section 4.1).

Configuration:

- EV leak: open
- EV: span closed
- Blind filter

Figure 7-3. Manual Leak Test with Blind Filter



Manual Leak Test
Sampling Line

Performed to check the seal of the whole pneumatic circuit and proper coupling of the filter presser and the external sampling line.

Configuration:

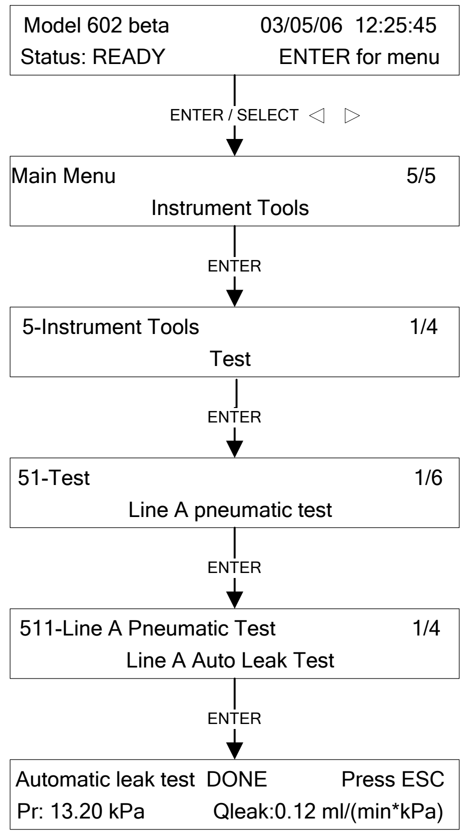
- EV leak: open
- EV: span closed
- “Operative” filter
- Accessory for closing the line

Figure 7-4. Manual Leak Test Sampling Line

Auto Leak Test Line A/B starting procedure

To start the test:

1. When status is set to READY, press ENTER and then SELECT to display the “Instrument Tools” window.
2. Press ENTER to access the “Instrument Tools” menu.
3. Press ENTER to select the “Test” menu.
4. Using the SELECT keys, select the pneumatic circuit line to be tested.
   Line A pneumatic test
   Line B pneumatic test
5. Press ENTER to confirm.
6. Press ENTER to start the test.



At the end of the test, the instrument automatically displays the values of the residual pressure “P_r” [kPa] and the specific leak “Q_{leak}” [mL/(min*kPa)].

If the specific leak value is higher than 5 mL/(min*kPa), a Warning message is automatically displayed (Warning 12, see Appendix 3). If it is higher than 10 mL/(min*kPa), an Alarm message is automatically displayed.

NOTE:
In Multi-Time Mode this test is automatically carried out by the instrument at the beginning of every sampling cycle. In Hourly Mode the test is performed in DELAY Status and it is repeated during the sampling and measurement cycles only on demand by the operator (see sec. 7.2 “Request for Pneumatic Tests in Hourly Mode). The results are stored in the Data Buffer (see Chapter 6 “Sampling and Measurement Data”) and are available in the Instrument Info menu.

__Manual Leak Test Line A/B starting procedure__

Before starting the procedure, when the instrument is in READY Status, it is necessary to perform the Unloading procedure (see section 5.11) in order to make sure that no filter is present inside the instrument.

To start the test (see Figure 7.5):

1. With Status set to READY, press ENTER and then SELECT to access the "*Instrument Tools*" window.
2. Press ENTER to access the "Instrument Tools" menu.
3. Press ENTER to select the "Test" menu.
4. Using the SELECT keys, it is possible to select the pneumatic circuit line to be tested.
   Line A pneumatic test
   Line B pneumatic test
5. Press ENTER to confirm.
6. Press SELECT to choose "Line A Manual Leak Test" and press ENTER to confirm.
7. Unlock the Loader and put the blind filter cartridge inside (accessory not supplied as standard with the instrument, see fig. 7.5a) with the hollow surface turned downwards.
8. Re-lock the loader.
9. Press ENTER to start the test.
   The values of the residual pressure "P_r" [kPa] and the specific leak "Q_{leak}" [mL/(min*kPa)] will be displayed.
10. Press ENTER to stop the test.

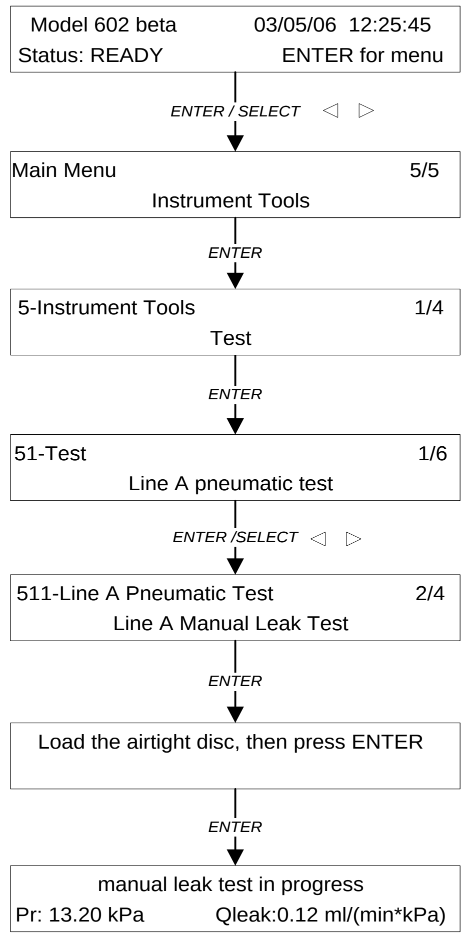
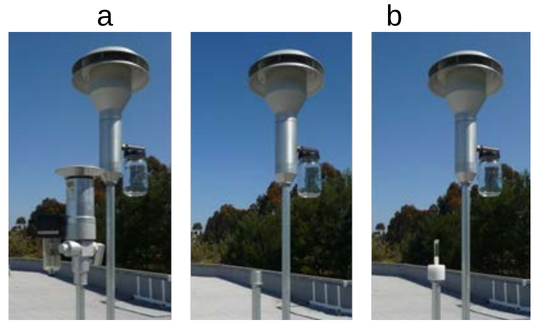


Figure 7-5. Starting Manual Leak Test Lines A/B

a

b



c

If it is necessary to check the sealing of the entire pneumatic system, including the section containing the filtering medium, follow the procedure in Figure 7-5 and replace the "blind filter cartridge" (Figure 7-5a) with a "complete filter" (the same type used for sampling). Then close the sampling line inlet with the suitable plug used for leak testing (Figures 7-5b, 7-5c). In this case it is necessary to remember that the pneumatic circuit volume value used by the instrument (1.3 liters) for the leak calculation is lower than the real one (it changes depending on the pneumatic configuration of the instrument at the sampling site).

If the specific leak value is higher than 15 mL/(min*kPa), a Warning message is automatically displayed (Warning 12, see Appendix 3; if this value is higher than 30 mL/(min*kPa), an Alarm message is automatically displayed.

7.1.2 Span Test (Flow Test)

The instrument can perform either an automatic procedure (*Auto Span Test*) or a manual procedure (*Manual Span Test*) to estimate the error in the operating flow rate measurement.

The automatic sequence of operations performed by the instrument during the *Auto Span Test* is:

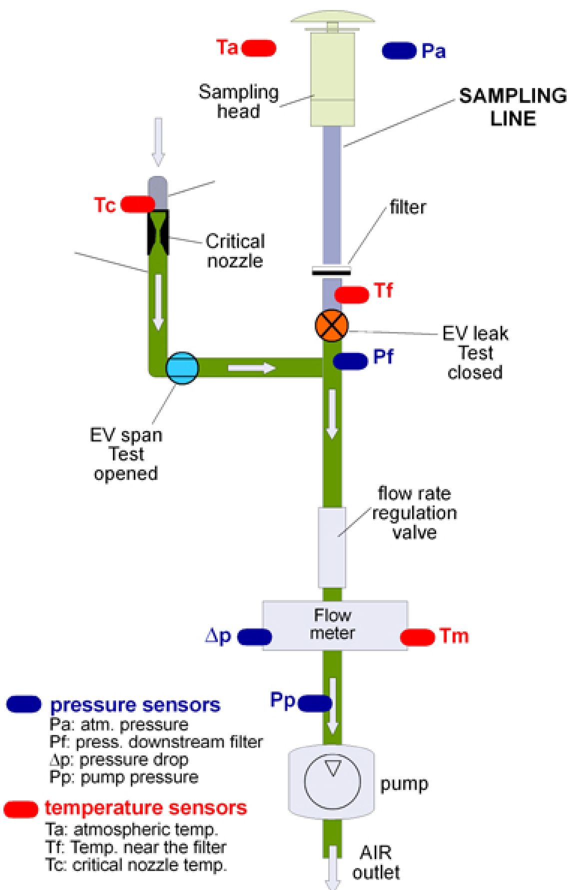


Figure 7-6. Span Test Configuration

- The span solenoid valve opens and the leak valve closes.
- The suction pump switches on.
- Automatic check to determine if critical pressure conditions have been reached, by comparing the measured values of the pressure downstream "Pf" and upstream "Pa" from the nozzle (see Note).
- The reference flow rate value, "Q_{cal}" (expressed in Nm³/h) at the programmed temperature and pressure conditions, is displayed and stored.
- The flow rate values "Q_{test}" (expressed in Nm³/h) determined by the flow rate measurement system are displayed and stored.
- The percentage deviation "*ERR%*" between the values "Q_{cal}" and "Q_{test}" is calculated and displayed.

NOTE: To protect the Test line from air flow impurities, there is a clean air filter located upstream from the critical nozzle inside the pneumatic module.

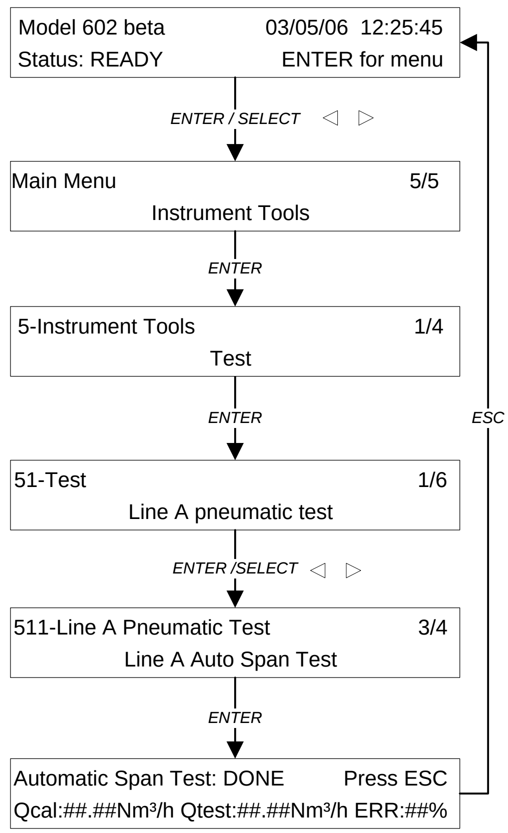
The *Manual Span Test* is used to perform the flow rate measurement system calibration and testing. To perform this test, a flow meter must be used as an external reference flow transfer standard. It is possible to choose any operating condition by moving the flow rate regulation valve. For each chosen operating condition, it is possible to associate the reference flow rate value to the corresponding values of the "z" variable (see Section 2.4 of this Manual) and the flow rate measured by the instrument (calibration check).

Auto Span Test starting procedure

1. With the instrument in READY Status, press ENTER and then SELECT until the "Instrument Tools" menu is displayed. Then press ENTER.
2. Press ENTER to access the "Test" menu.
3. Using the SELECT keys the pneumatic circuit line to be tested can be selected.

   Line A pneumatic test
   Line B pneumatic test

4. Press ENTER to confirm.
5. Using the SELECT key, select "Line A Auto Span Test" or "Line B Auto Span Test" and press ENTER to start the test.



The display will show the values of "Q_{test}", "Q_{cal}" and the percentage deviation "*ERR%*"

If the percentage deviation from the starting calibration value is greater than ± 4%, a Warning message is automatically displayed (Warning 13, see Appendix 3), and if the percentage deviation is greater than ± 10%, an Alarm message is automatically displayed.

NOTE 1:
In Multi-Time Mode this test is automatically carried out by the instrument at the beginning of every sampling cycle. In Hourly Mode the test is performed in DELAY Status and is repeated only on demand by the operator during the sampling and measurement cycles (see "Request for Pneumatic Tests in Hourly Mode). The results are stored in the *Data Buffer* (see chapter 6 "*Sampling and measurement data*") and are available in the *Instrument Info* menu.

NOTE 2:
If Err: +99.9% is displayed, it indicates that the nozzle "critical conditions" have not been reached. This implies that the test was not performed.

Starting procedure for the pneumatic calibration check performed during the Manual Span Test

For this procedure the instrument must be disconnected from the sampling line in order to insert the flow meter using the adapter for flow rate calibration (not supplied as standard with the instrument).

Figure 7-7. Flow Rate Adaptors

Before starting the test it is necessary to:

- make sure that there are no filters inside the instrument and the Loader (see *Unloading procedure*, Section 5.11)
- connect the reference instrument to the sampler using the adapter so that the same air flow passes through both instruments.

If the flow meter needs to be connected at the top of the sampling line, remember that the value of the volumetric flow rate Qi appearing on the display during the test refers to the temperature conditions inside the installation room. These conditions do not necessarily correspond to the external conditions. As a result, the standard flow rate value Qs is recommended for the test.

To connect the flow meter to the instrument, uncouple the sampling inlet from the sampling line and use the suitable adapter for external flow rate calibration (accessory not supplied as standard with the instrument).

Figure 7-8. Connecting the Flow Meter

The manual test can be started when the display shows READY status. Use the *Instrument Tools / Test* menu and follow the procedure below:

1. With the instrument in READY Status, press ENTER and then SELECT until the “Instrument Tools” menu is displayed. Then press ENTER.
2. Press ENTER to access the “Test” menu.
3. Use the SELECT keys to select the pneumatic circuit line to be calibrated.

   Line A pneumatic test
   Line B pneumatic test
4. Press ENTER to confirm.
5. Use the SELECT keys to choose “Line A Manual Span Test” or “Line B Manual Span Test” and press ENTER.
6. Insert a complete filter in the Loader and press ENTER to complete the loading process.
7. Start the pump by pressing the ENTER key.
8. Adjust the valve opening until the flow rate value displayed by the reference instrument stabilizes to the desired value $Q_{i\ ref}$. To obtain the desired flow rate, use the SELECT keys: press the right “SELECT” key to set the ***St*** parameter and use the “YES” and “NO” keys to set the flow rate value by adjusting the valve opening.

   St: H *(high) /* ***M*** *(mid) /* ***L*** *(low), the width of the regulation intervals that can be used to achieve the desired flow rate value*

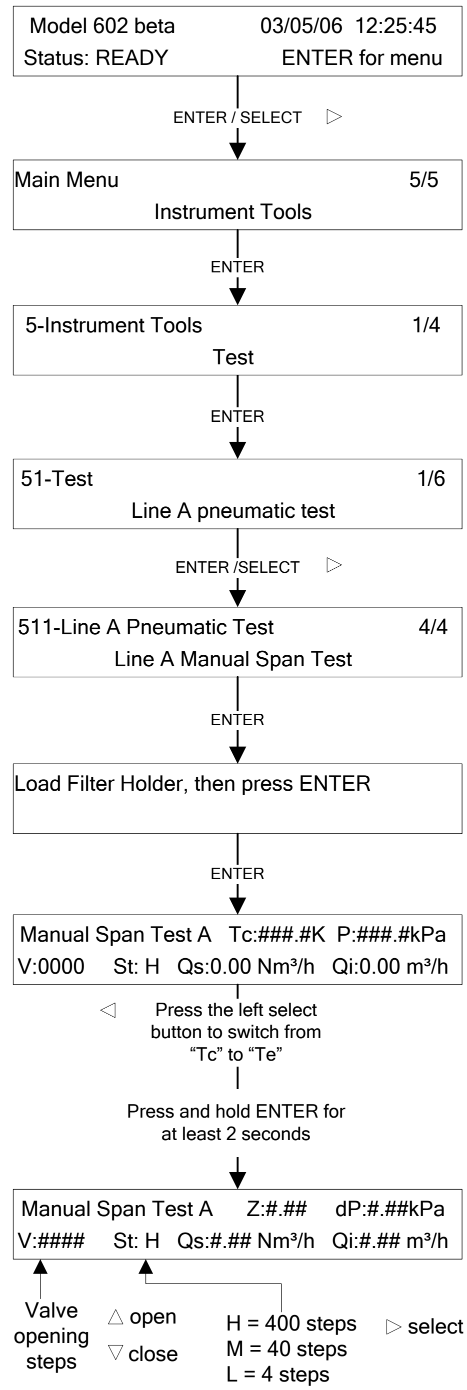
   V*: the regulation valve position with respect to the zero position*

   Qs*: the flow rate value measured by the instrument under standard conditions*

   Qi*: the inlet volumetric flow rate value that is calculated from the temperature value measured inside the installation room*

9. Repeat this operation for at least three different points on the valve regulation scale (it is recommended that these points be spread out so as to cover the entire valve range).

Press ESC to stop the test.

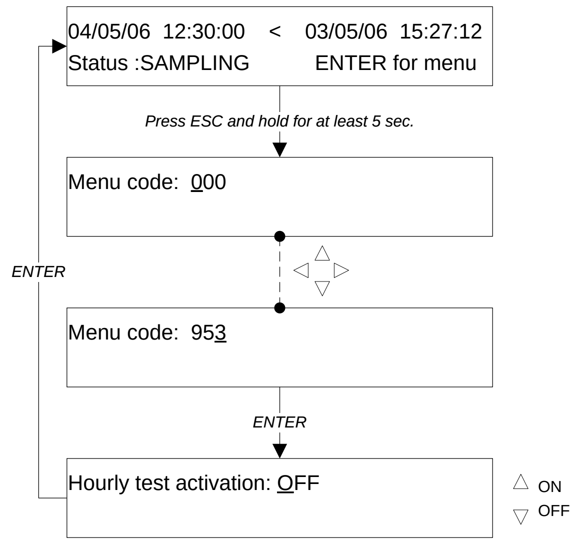


7.2 REQUEST FOR PNEUMATIC TESTS IN HOURLY MODE

In Hourly Mode the Automatic Span Test and leak Test can be performed even when the instrument is in the SAMPLING mode**.**

To request the test, follow the steps below:

1. Press the ESC key and hold it for at least 5 seconds (to access support tools).
2. Select Menu code 953.
3. Press the YES key (the message "Hourly Test activation: ON" is displayed) and press ENTER to confirm.



The pneumatic tests will be performed at the beginning of the very next sampling cycle. The results will be stored in the Data Buffer and will be available on the display.

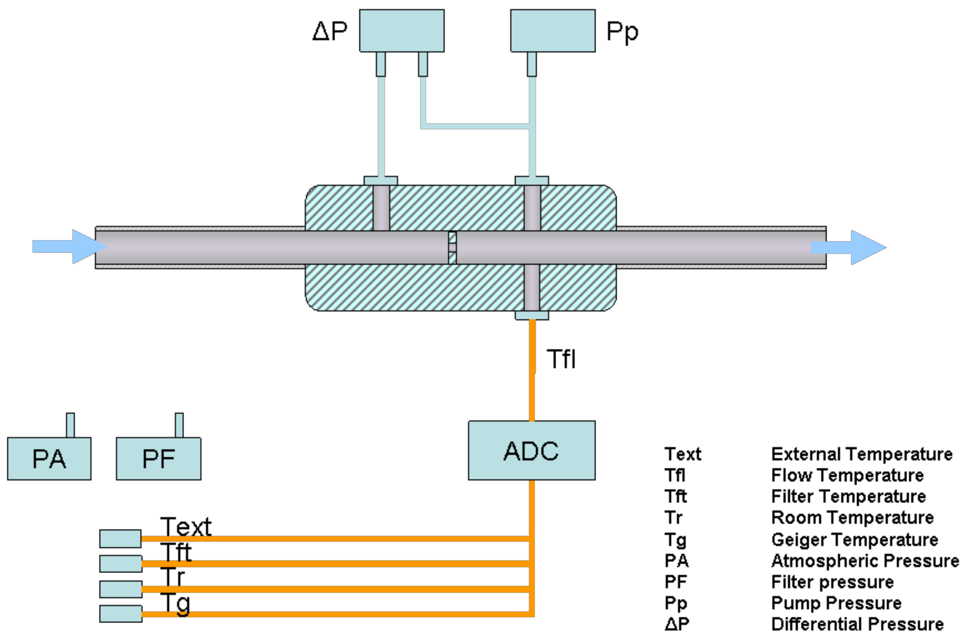
NOTE 1: In Hourly Mode the Data Buffer fields pertaining to the Pneumatic Tests are updated only when a new test is performed.

NOTE 2: Performing the Pneumatic Tests reduces the sampling time by up to 10 minutes.

To cancel the request for the pneumatic tests, repeat the procedure here above and select "Hourly Test activation: OFF".

7.3 CALIBRATION OF THE FLOW SYSTEM

The sampling flow rate measurement is based on the physical laws regulating the air mass transfer through a nozzle placed downstream of the regulation valve.



By measuring the pressure "P_p" downstream the nozzle, the nozzle pressure drop "ΔP" and the air temperature "T_m" in the measurement area, it is possible to calculate the standard flow rate value "Qs" using the relation:

$$Qs = f(z)$$

where:

$$z = \sqrt{\frac{\Delta P \cdot (2P_p - \Delta P)}{T_m}}$$

The pneumatic system calibration is carried out during the general test and inspection, using instruments for the flow rate, volume, temperature and pressure measurement provided with traceability certificates as regards primary methods. The calibration is based on a "*multipoint*" procedure. To each "z_i" value supplied by the instrument at a defined operating flow rate value the corresponding value of the reference standard flow rate "$Q_{i\ ref}$" (Default standard condition Ts=298.1K, Ps=101.3 kPa) is associated. So it is possible to calculate the coefficients *a, b* and *c* of a second-order relation in "*z*" $y=az^2+bz+c$ that describes at best the relation between "z" and the reference flow rate.

To the "z_i" variable values supplied by the instrument at known operating conditions must be associated the relative correspondent values of the reference standard flow rate "$Q_{i\ ref}$" (to the z_i and $Q_{i\ ref}$ values must be associated the relative uncertainty values).

We suggest to determine the calibration function using at least 5 "$Q_{i\ ref}$" values in the interval 0.5 - 1.5 Nm³/h. For each point the "z_i" and "$Q_{i\ ref}$" mean values are determined with their associated uncertainty values.

$\overline{z}_1$	$\sigma(z_1)$	$\overline{Q}_{1ref}$	$\sigma\left(Q_{1ref}\right)$
$\overline{z}_2$	$\sigma(z_2)$	$\overline{Q}_{2ref}$	$\sigma\left(Q_{2ref}\right)$
$\overline{z}_3$	$\sigma(z_3)$	$\overline{Q}_{3ref}$	$\sigma\left(Q_{3ref}\right)$
$\overline{z}_4$	$\sigma(z_4)$	$\overline{Q}_{4ref}$	$\sigma\left(Q_{4ref}\right)$
$\overline{z}_5$	$\sigma(z_5)$	$\overline{Q}_{5ref}$	$\sigma\left(Q_{5ref}\right)$

Therefore, using the tabular data shown above, it is possible to determine the "a", "b" and "c" calibration coefficients to be programmed in the instrument (see Chapter 3).

7.3.1 Calibration Procedure

NOTE: If both Line A and Line B need to be calibrated, then the following procedure must be performed separately for each line.

Before starting the calibration procedure it is necessary to:

- Uncouple the sampling line from the instrument
- Connect in series the instrument used for the flow rate "$Q_{i\ ref}$" determination with the instrumental pneumatic inlet, using the appropriate accessory (illustrated below).
- Make sure that no filters are left inside the instrument and inside the Loader (see "Filters Unloading" procedure in the User Manual -Section 5.11).
- Connect the instrument to a PC equipped with RS232 interface.

To start the calibration procedure:

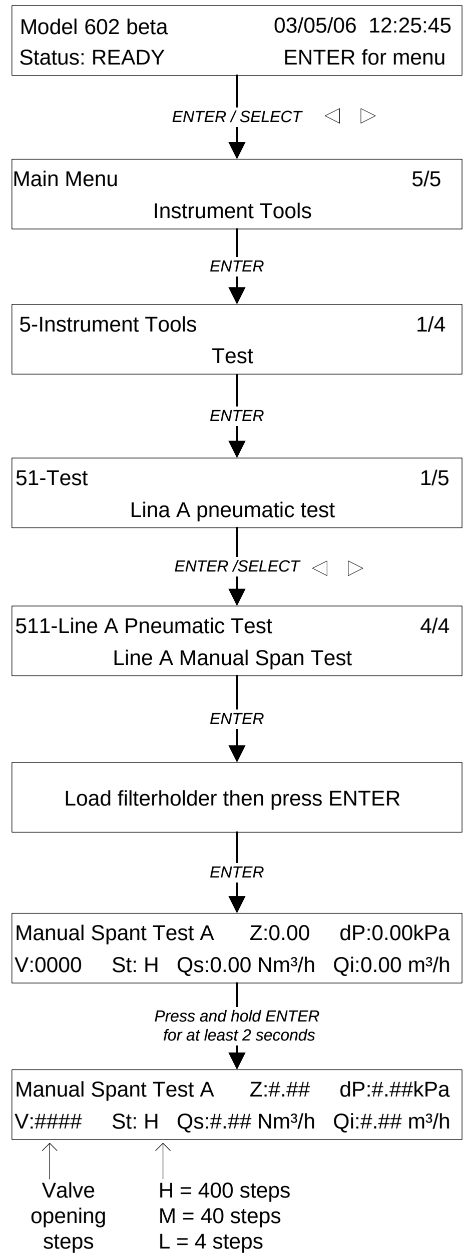
1. With the instrument in READY status, press ENTER and then SELECT till the “Instrument Tools” menu is displayed and press ENTER.
2. Press ENTER to have access to the “Test” menu.
3. Using the SELECT buttons, select the pneumatic circuit line to be involved in the calibration
   Line A pneumatic test
   Line B pneumatic test
4. Press ENTER to confirm your choice
5. Using the SELECT button, select “*Line A Manual Span Test*” or “*Line B Manual Span Test*” and press ENTER.
6. Insert a complete filter in the Loader and press ENTER to complete the loading process.
7. Start the vacuum pump pressing ENTER.
8. Regulate the valve opening till the flow rate displayed on the reference instrument has stabilized on the chosen $Q_{i\ ref}$. Value. To achieve the wanted flow rate value use the selection buttons: with the right “SELECT” button you regulate the St parameter, with the “YES” and “NO” buttons you set the flow rate value by regulating the valve opening.

   St: H (high) / M (mid) / L (low) show the wideness of the regulation intervals by which it is possible to achieve the desired flow rate value.

   V: shows the regulation valve position compared with the zero position.

   Qs: shows the flow rate value measured by the instrument in standard conditions.

   Qi: shows the inlet volumetric flow rate value measured using the temperature value measured by the instrument inside the installation room.



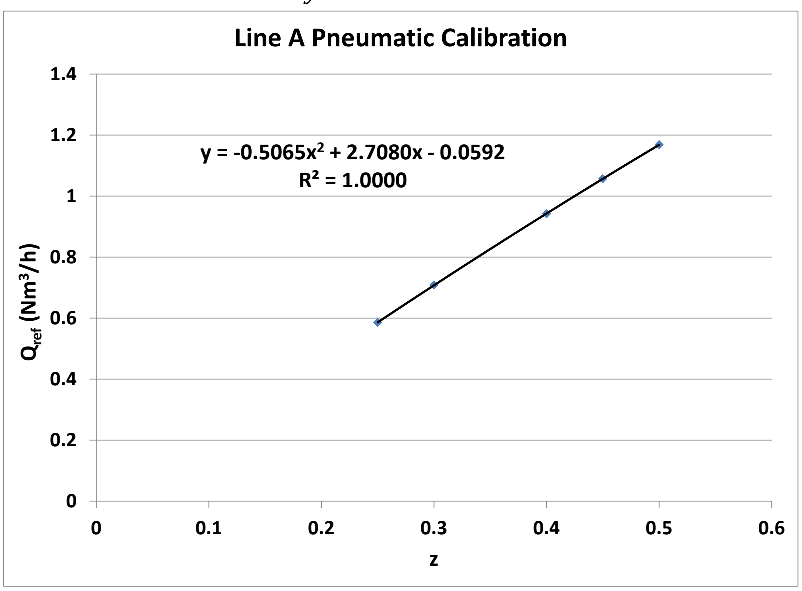
9. Record the value of “Z”, “Qs”, and “Qi”, as well as the “Qref” value (which is the measured flow from the reference flow meter)
10. Repeat the steps from point 8 and 9 on for all the chosen points in the interval 0.5 - 1.5 Nm^3/h (and up to 2.5 Nm^3/h if running the instrument at 2.3 m^3/h)
11. Press ESC to stop the calibration procedure
    Repeat this procedure for the other pneumatic line

At the end of the performed procedure you'll be able to arrange your data in a table like the one shown here below for line A:

$\bar{z}_i$	$\overline{Q}_{i\,ref}$ (Nm³/h)
0.25	0.5856
0.30	0.7086
0.40	0.9420
0.45	1.0572
0.50	1.1682

Placing the data couples of this table on a *xy* Cartesian plan, it is possible to determine the best fit function using a second-order polynomial in "*z*":

$$y = az^2 + bz + c$$



This gives the following values for the coefficients of the pneumatic calibration equation for line A:
a = -0.5065
b = +2.7080
c = -0.0592

Using a program such as Microsoft Excel is the simplest way to make such a plot. In Excel, plot the data as an xy scatter plot. Once the plot has been made, add a trendline; make sure to select the options to show the trendline equation and R^2 values.

To set the values of the six calibration coefficients obtained for Line A and Line B, connect the instrument to a PC equipped with RS232 serial interface and send the commands (via Hyperterminal) shown in the following table:

Model 602 serial number	Parameter	Command	Confirmation response
Sn0127	Coeff ***a*** line A	04SHABCH014#.####	**!**
	Coeff ***b*** line A	04SHABCH015#.####	**!**
	Coeff ***c*** line A	04SHABCH016#.####	**!**
Sn0131	Coeff ***a*** line B	04SHABDB017#.####	**!**
	Coeff ***b*** line B	04SHABDB018#.####	**!**
	Coeff ***c*** line B	04SHABDB019#.####	**!**

Where #.#### represents the coefficients value format
The serial number of the instrument is entered as an alphanumeric code number, where 0 = A, 1 = B, 2 = C, and so on…
So, for SN0127, the instrument alphanumeric code is ABCH
And, for SN0131, the instrument alphanumeric code is ABDB

Example of pneumatic calibration parameters setting of Model 602 sn 0131:
Line A
Coefficient **a** 04SHABBD014-0.5065
Coefficient **b** 04SHABBD0152.7080
Coefficient **c** 04SHABBD016-0.0592
To check the correct setting of the calibration coefficients, send the command **050** and check the response fields comparing the table here below:

Programmed parameter	Response field
Coeff a line A	15
Coeff b line A	16
Coeff c line A	17
Coeff a line B	18
Coeff b line B	19
Coeff c line B	20

For example:
Command:
050
Response:
16/03/07,16/03/07,001,0127,101.5,4.213,2.320,-0.005,0.1624,2.623,-0.051,0.1605,0,2000, **-0.5065, +2.7080, -0.0592,-0.3475,2.5879,-0.0464**,0.062000,-0.779300,5.278300,0.005539, 0.007007,160000,1600,1.007,1.007,1.000,1.000,0.000,5,2.8,0.100,0.28,10,10
coefficients line A:
a = -0.5065

b = +2.7080
c = -0.0592
coefficients line B:
a = -0.3475
b = +2.5879
c = -0.0464

7.3.2 "Auto Span Test Constant" Setting

The "Auto Span Test constant" setting must be performed at the end of the flow rate measurement system calibration. This setting can be performed following the procedure below:

1. Set at zero the memorized "Auto Span Test constant" value, using the commands 04SHXXXX0080 and 04SHXXXX0110:

Model 602 serial number	Parameter	Command	Confirmation response
Sn0127	Span Test Line A zero setting	04SHABCH0080	!
	Span Test Line B zero setting	04SHABCH0110	!
Sn0131	Span Test Line A zero setting	04SHABDB0080	!
	Span Test Line B zero setting	04SHABDB0110	!

2. Start the Auto Span Test (see below). The instrument calculates and automatically set the new "Auto Span Test constant".

7.3.3 Automatic Check of the Flow Rate Measurement System Calibration (Auto Span Test)

The automatic sequence of operations carried out by the instrument to perform the *Auto Span Test* can be summarized as follows:

- Span solenoid valve opening and leak valve closing
- Suction pump switching on
- Automatic check of the achievement of the critical pressure conditions, comparing the measured values of the pressure downstream "Pf" and upstream "Pa" the nozzle (see note 1).
- Displaying and storage of the reference flow rate value "Q_{cal}" expressed in Nm³/h at the programmed temperature and pressure conditions (see User Manual par. 5.5).
- Displaying and storage of the flow rate values "Q_{test}" (expressed in Nm³/h), determined by the flow rate measurement system
- Calculation and displaying of the percentage deviation "*ERR%*" between the values "Q_{cal}" and "Q_{test}".

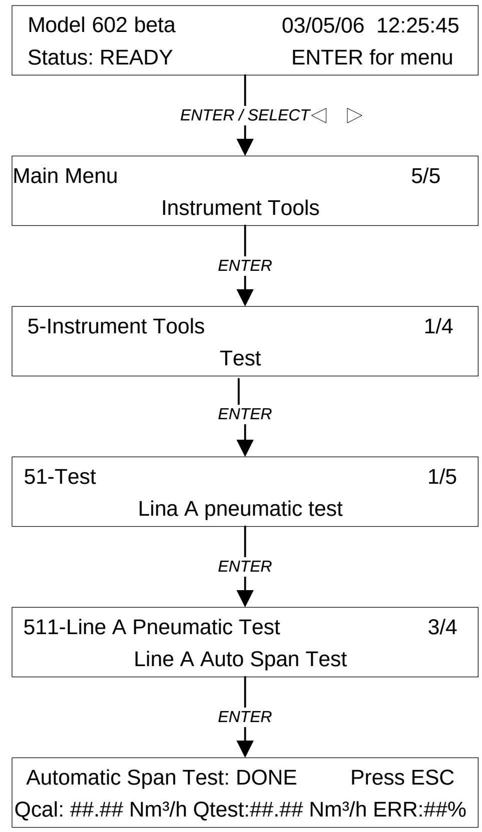
To start the Auto Span Test, follow the procedure below:

1. With the instrument in READY status press ENTER and then SELECT till the “Instrument Tools” menu will be displayed and press ENTER.
2. Press ENTER to have access to the “Test” menu.
3. Using the SELECT buttons, select the pneumatic circuit line to be involved in the test
   Line A pneumatic test
   Line B pneumatic test
4. Press ENTER to confirm your choice
5. Using the SELECT button, select “*Line A Auto Span Test*” or “*Line B Auto Span Test*” and press ENTER to start the test

   The “Q_{test}”, “Q_{cal}” values and the percentage deviation “*ERR%*” will be displayed

   If the percentage deviation from the starting calibration value is out of the interval ± 4%, a Warning message is automatically displayed (Warning 13, see Appendix H). If the percentage deviation is out of the interval ±10%, an Alarm message will be automatically displayed.

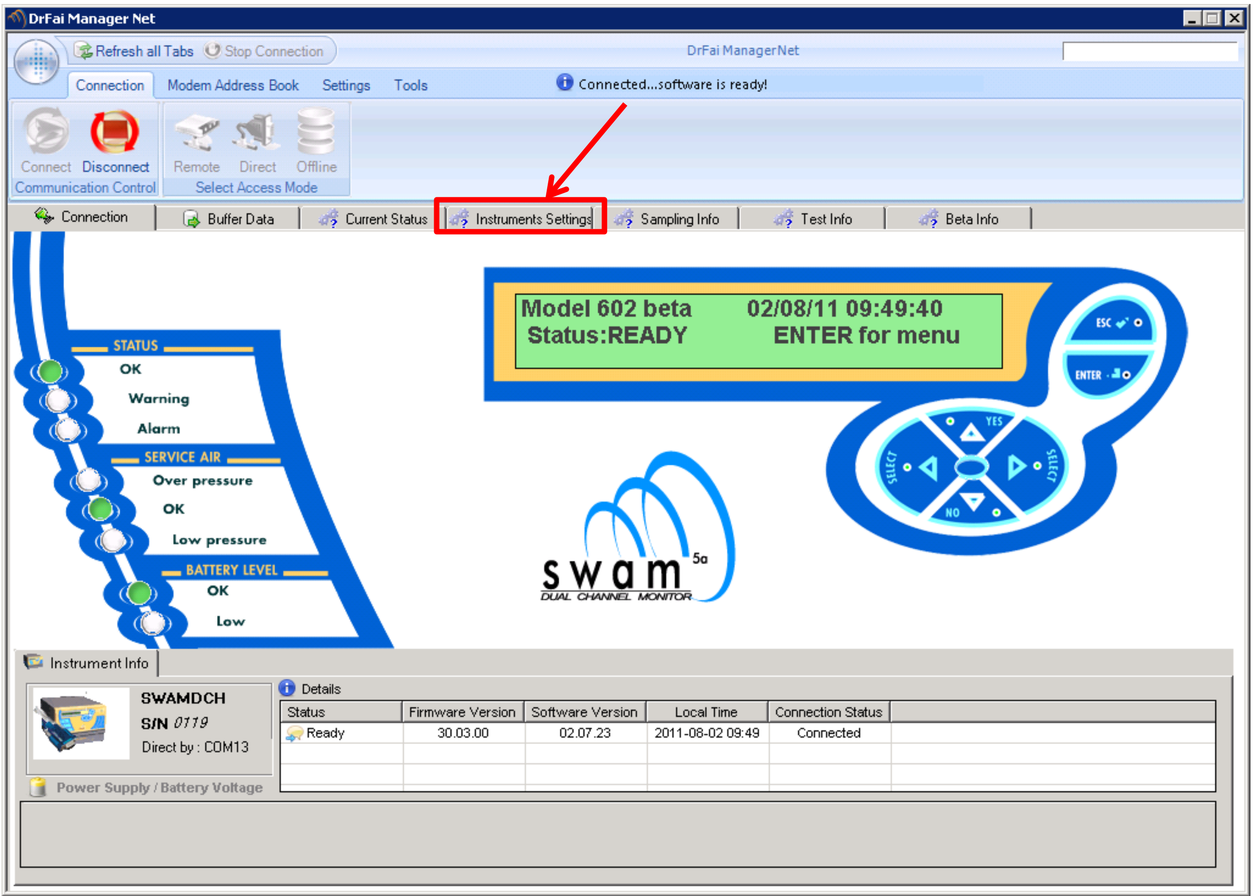
   NOTE: Err:+99.9% displaying means that the pressure downstream the nozzle did not achieve the “critical condition”. This implies that the test will not be performed.



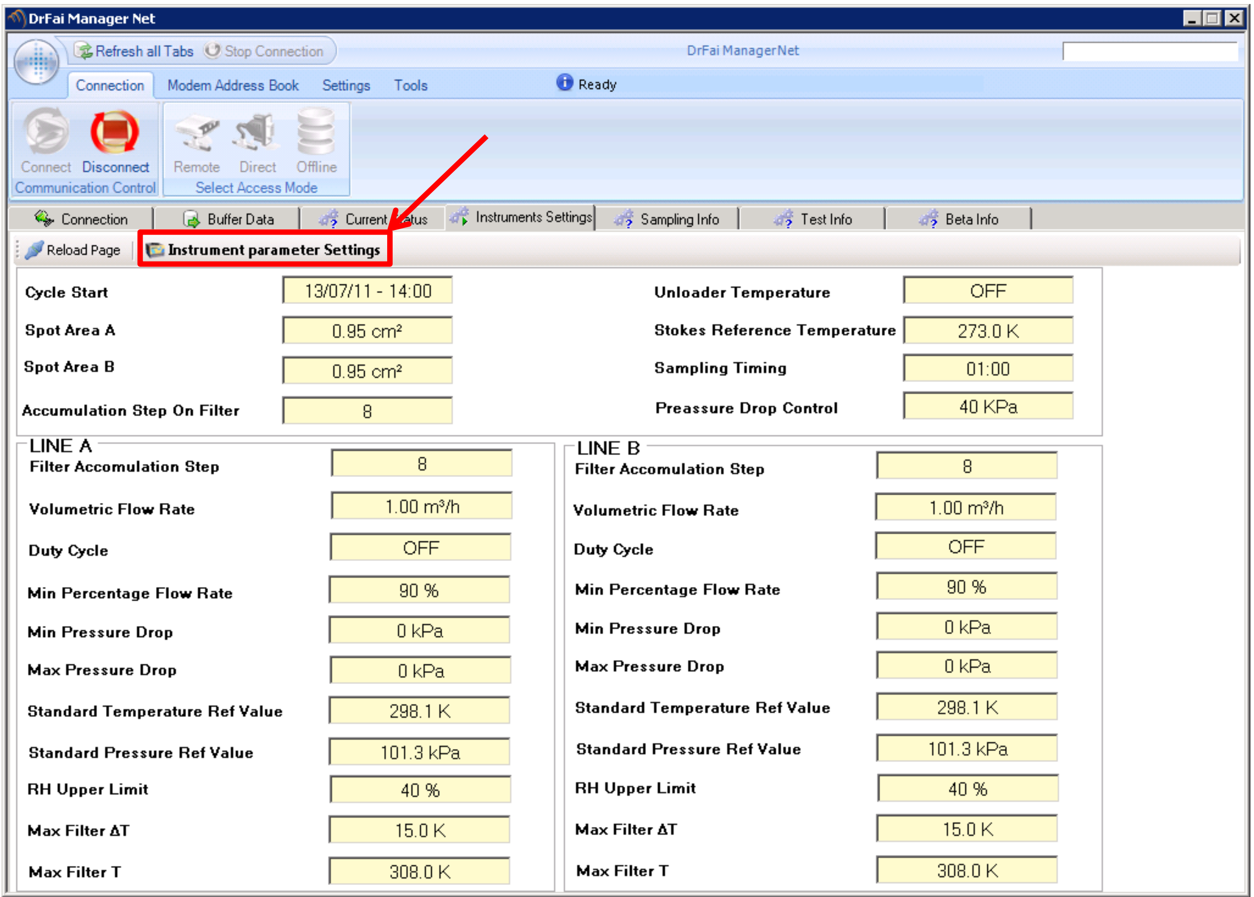
7.3.4 Using the Dr. FAI Program to Edit the Flow Calibration Parameters

Once you have obtained the calibration parameters following the procedure in Section 7.3 of this manual, you can choose to enter the parameters using the Dr. FAI program rather than manually over Hyperterminal (as described in Section 3) if you prefer…

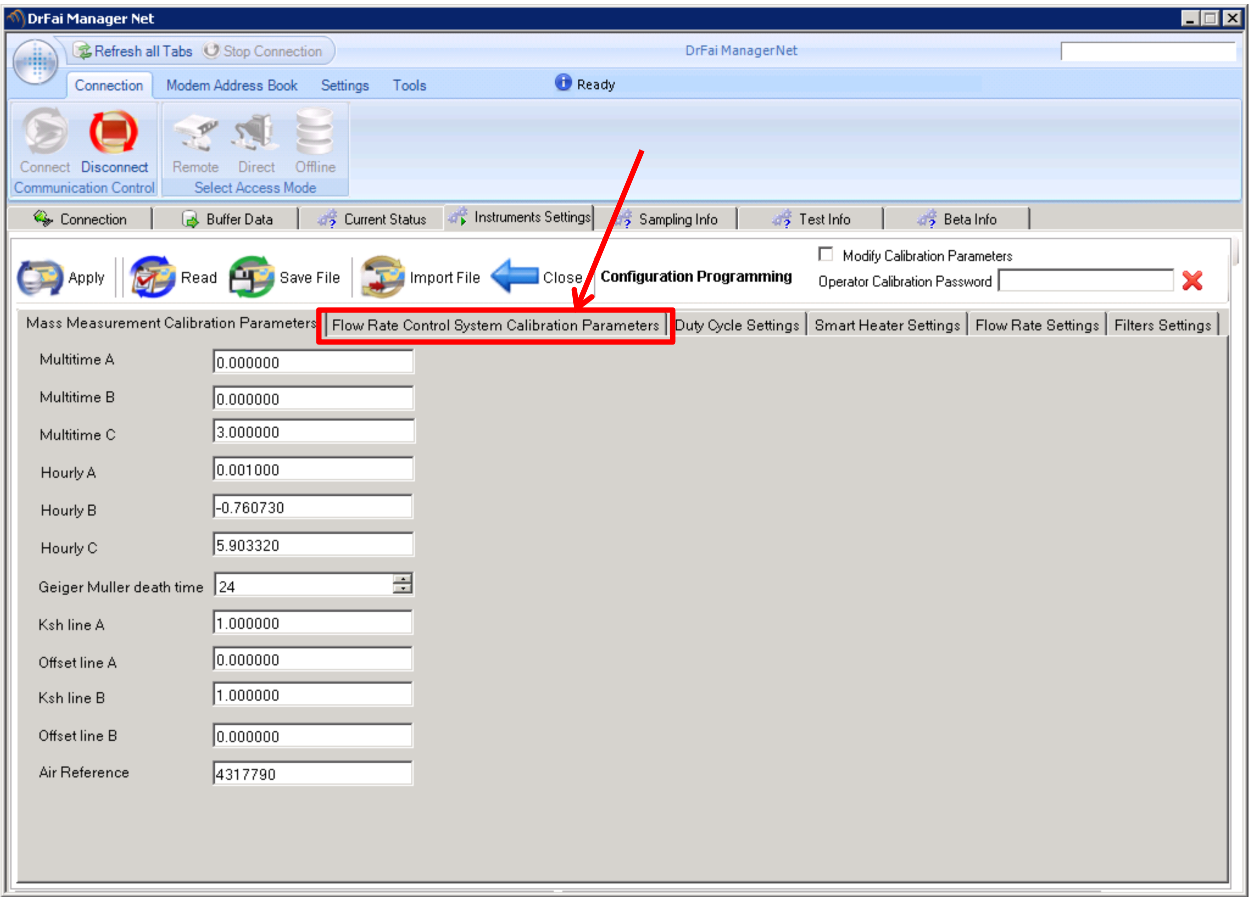
1. Connect to the instrument (via RS-232) using the Dr. FAI program
2. Once Dr. FAI has connected to the instrument and is “Ready”, click the “Instrument Settings” tab:



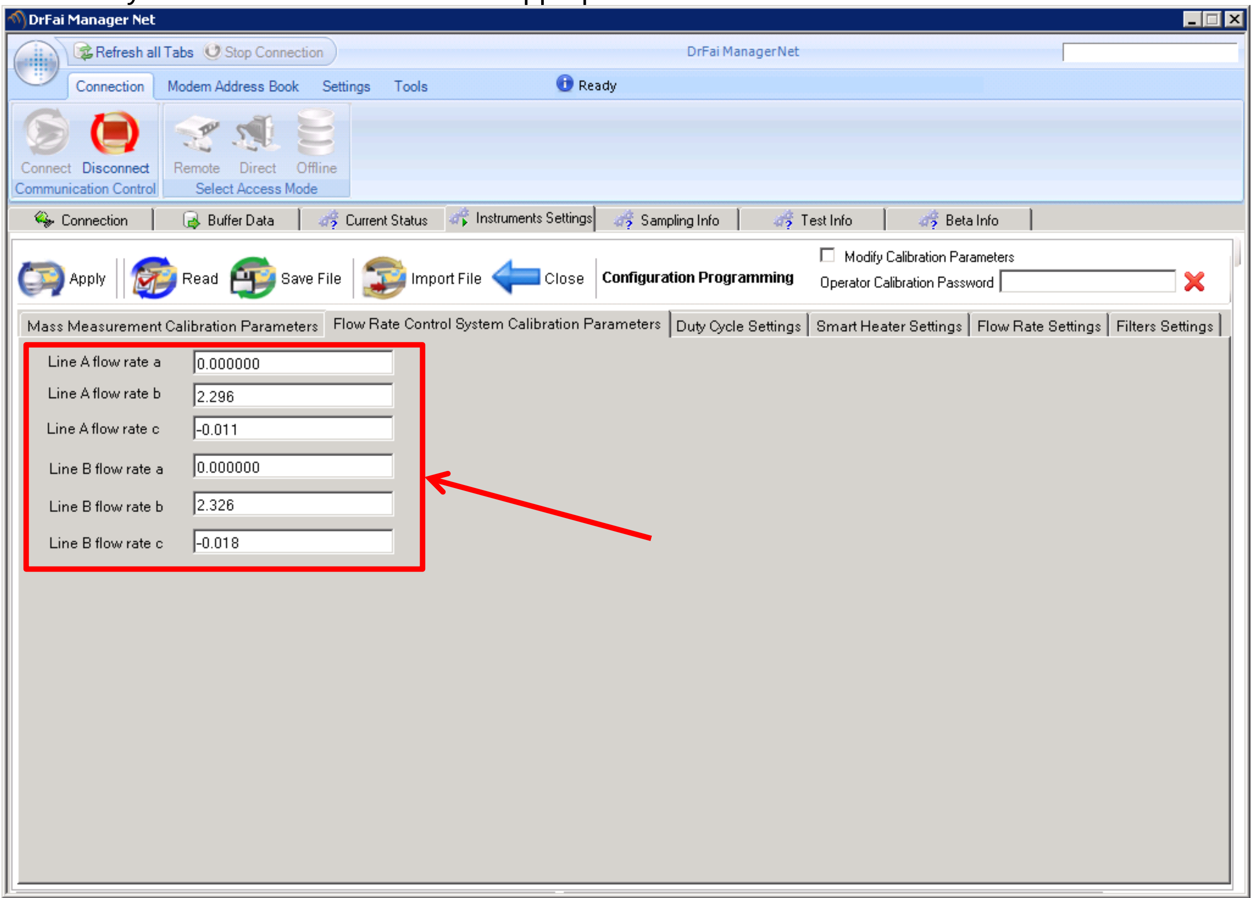
3. Next, click on the “Instrument Parameter Settings” tab that is within the “Instrument Settings” tab:



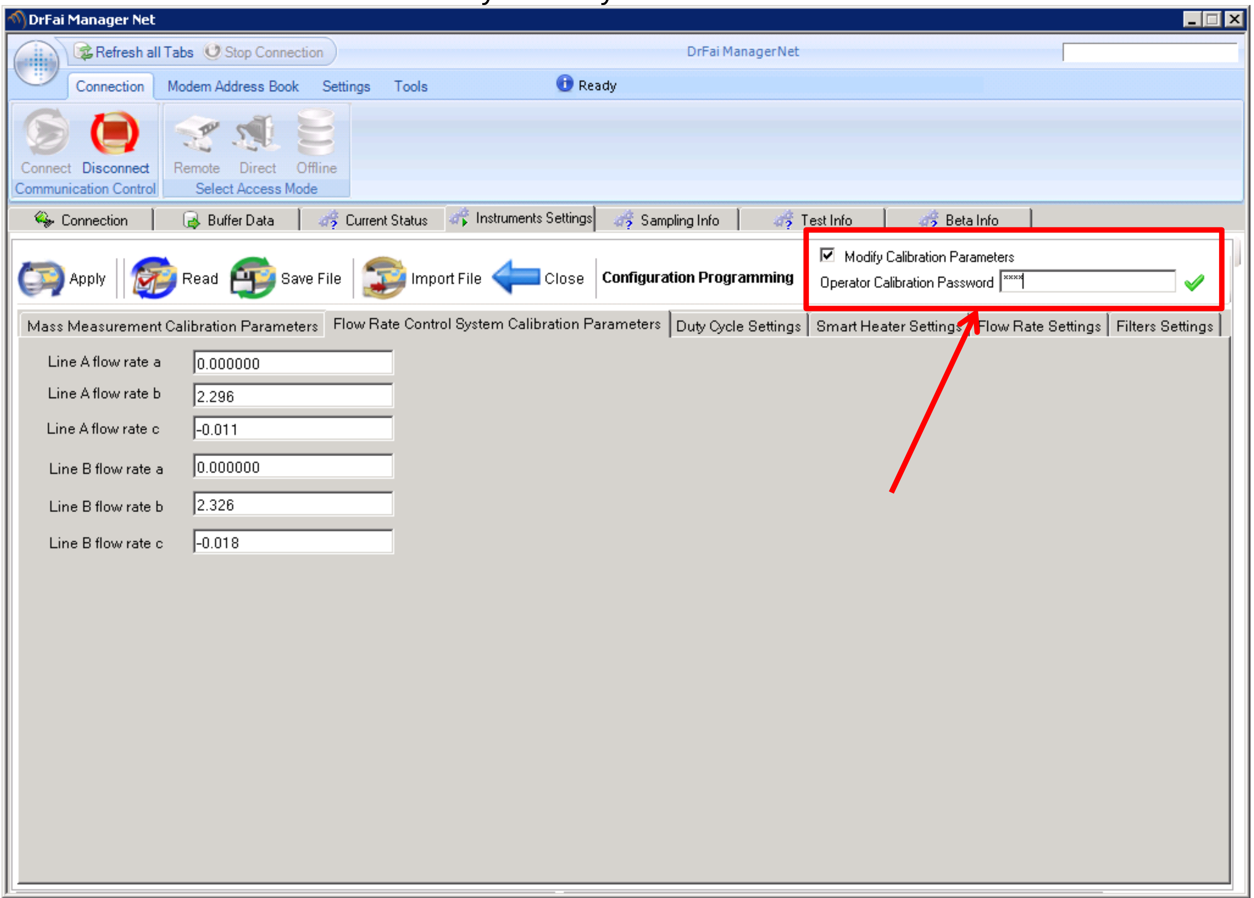
4. Within the “Instrument Parameter Settings” screen, click the “Flow Rate Control System Calibration Parameters” tab:



5. Enter your calibration values in the appropriate boxes:

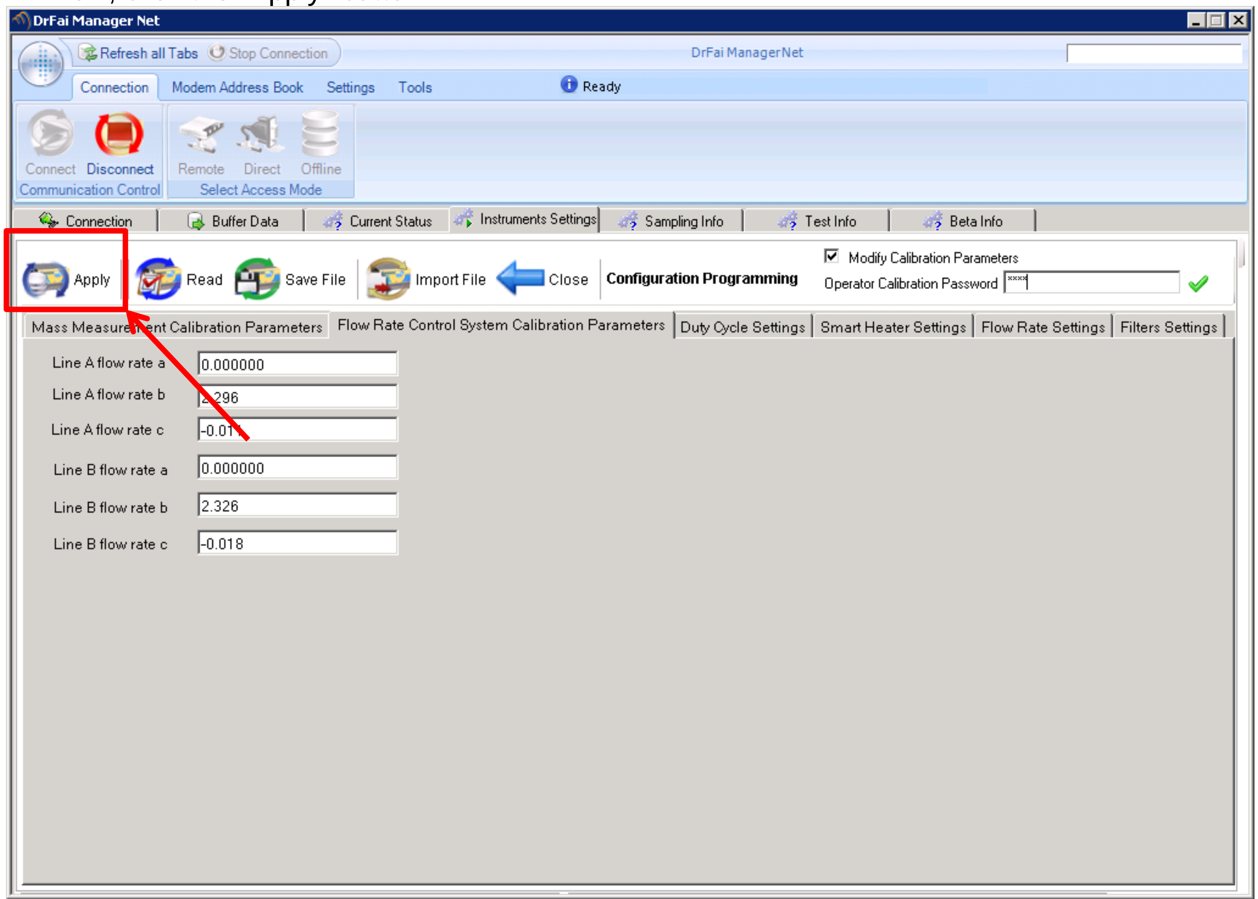


6. Before exiting or clicking the “Apply” button, you must enter the alphanumeric code for your instrument and check the box that says “Modify Calibration Parameters”.

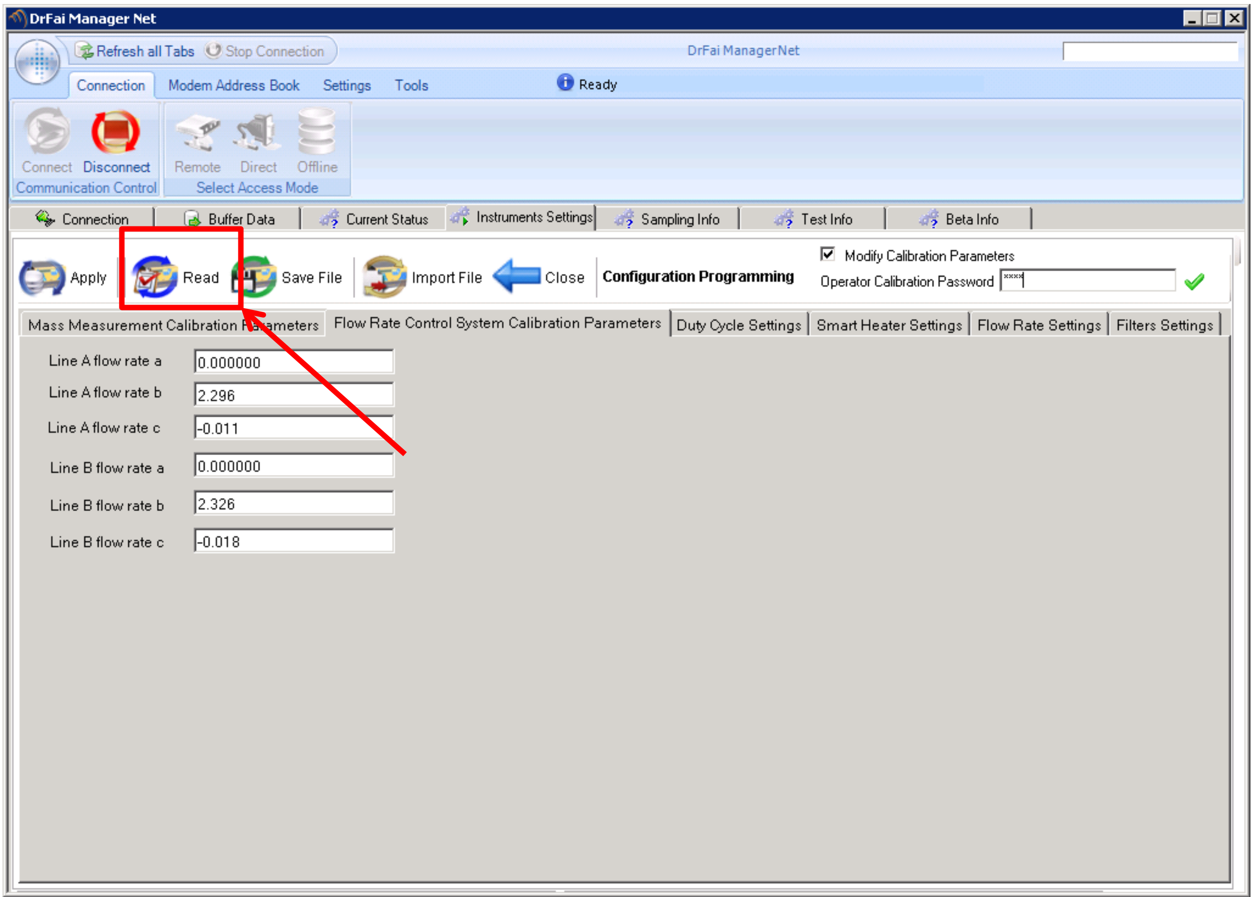


The alphanumeric code for the instrument is as follows... 0=A, 1=B, 2=C, etc..., so if you have instrument SN0127, the Operation Calibration Password would be ABCH (must be in CAPS when you enter the code)

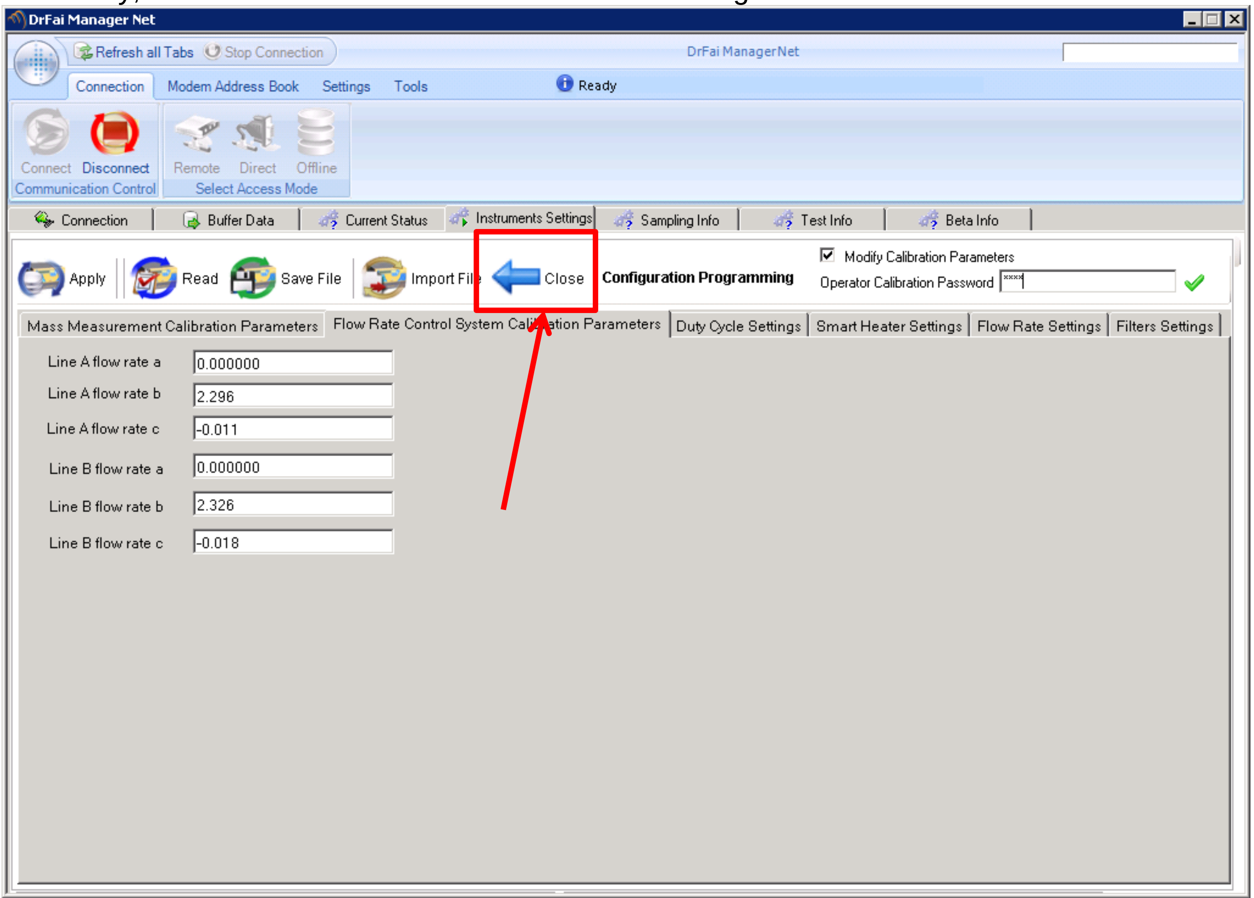
7. Now, click the “Apply” button:



8. To confirm that the values you entered were properly delivered to the instrument, click the "Read" button:



9. Finally, close out of the “Instrument Parameter Settings” tab and exit Dr. FAI:



7.4 MASS MEASUREMENT SYSTEM CALIBRATION CHECK (Beta Span Test)

Periodic calibration of the instrument is not required, but instrument failure or measurement errors may indicate that one or more components (the Geiger-Müller detector and/or associated electronics) need to be replaced.

The calibration function determined during the final acceptance test will always remain valid over the Geiger-Müller (GM) detector's lifetime.

Under operating conditions proper implementation of the measurement procedure and accuracy of the calibration function are guaranteed by the implemented quality controls (see section 2.6 "*QC Mass Measurement System Calibration*").

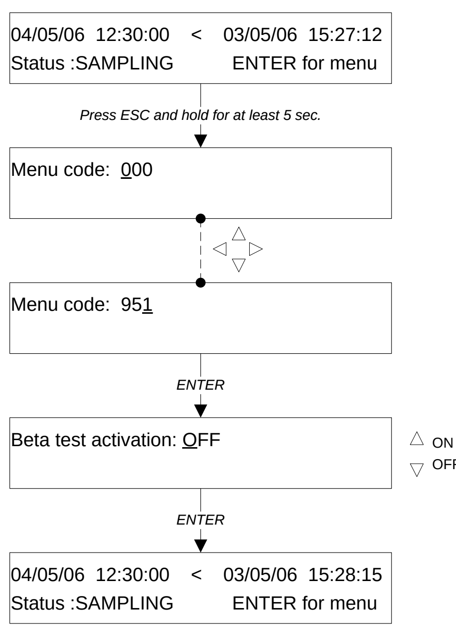
The instrument can automatically perform a ß calibration check (*Beta span test*) by measuring alternately the ß flux in air and the ß flux passing through the reference aluminum membranes. The calculated mass thickness values of the two membranes, are compared with their associated nominal values. The test gives the calculated mass thickness values and the percentage deviations from the respective nominal values.

7.4.1 Starting the test (STATUS: Sampling)

At the beginning of every operating cycle the instrument automatically performs the *beta span test* (see section 2.6 "*QC Mass Measurement System Calibration*").

The *beta span test* can even be performed during the normal sampling and measurement cycles without stopping the operating cycles. Following the procedure described below, it is possible to choose whether the instrument will be programmed to perform the *beta span test* at the beginning of the following mass measurement cycle.

- With the instrument in SAMPLING Status, press and hold the ESC key for at least 5 seconds to access the *Menu code* (access to support *tools*).
- Enter *code 951* using the Select keys and press ENTER to access the function that activates or deactivates the beta span test at the beginning of the next sampling cycle.
- Using the YES/NO keys, select "ON" to activate the test or "OFF" to deactivate it and press ENTER to confirm. **If "ON" is selected, the *beta span test* will be performed only at the beginning of the cycle following the current sampling cycle.**



NOTE 1: the test takes 10 minutes in Hourly Mode and 25 minutes in Multi-Time Mode. That time will be deducted from the programmed sampling time (*timing*) of the cycle in progress

NOTE 2: In Hourly Mode the test is performed only if a blank session is not expected during the cycle.

7.4.2 Starting the Test (STATUS: Ready)

Before performing the test, make sure that the reference membranes have been inserted as required during instrument setup (see section 5.8 "Insertion or replacement of the reference aluminum foils").

To start the test:

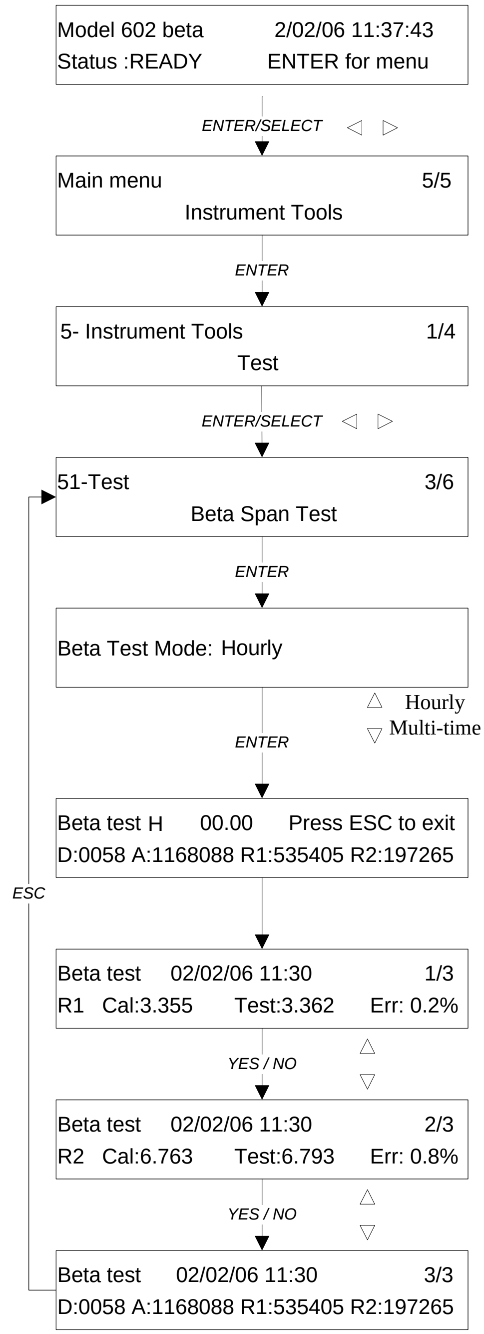
1. With the instrument set to READY Status, press ENTER and then SELECT until the "Instrument Tools" menu is displayed.
2. Press ENTER to access the menu.
3. Press ENTER and then SELECT until the "Beta Span Test" menu is displayed.
4. Using the YES and NO keys, select the Mode in which the test must be performed (Hourly or Multi-Time).
5. Press ENTER to start the test.

At the beginning of the test, the display shows the counts corresponding to the background radioactivity (D), air (A), and reference membranes R1 and R2.

The effective value of the counts measured by the Geiger Müller (GM) is displayed during the test. At the end of the test, the correct counts for the GM dead time are stored and displayed. The value of the used dead time is the one given by the GM manufacturer (because the calibration function is empirical, effective values of dead time different from the one given by the producer do not affect the mass measurement quality).

At the end of the test, the following parameters will be displayed for both of the reference membranes:

Cal: *Nominal value of the reference membrane's mass surface density (mg/cm²)*
Test: *Measured value of the membrane's mass surface density (mg/cm²)*
Err*:* *Percentage error*



NOTE 1: If the percentage deviation (Err) between the nominal surface mass density and the measured value of one or both of the reference membranes is greater than 5%, a Warning message is automatically activated (Warning 14, see Appendix 3).

NOTE 2: The Hourly and Multi-Time Modes use two different calibration functions and test procedures, because in Hourly Mode the source moving piston is UP while in Multi-Time Mode it is in the DOWN position.

7.5 MASS MEASUREMENT SYSTEM CALIBRATION

NOTE:
Due to the high level of stability of the mass measurement system, there is no need for any periodical calibration, unless in case of measurement system failures that would require the replacement of one or more components (GM detector and associated electronics).

In the unlikely event that there is a shift in the mass measurement system calibration, the following procedure should be used as a guide for recalibrating the mass measurement system.

The goal of the calibration procedure is to determination the function *g(z)* (see Sections 2.5 & 2.6 of this manual), using a *multipoint* calibration approach.

The calibration procedure used during the final acceptance test allows to make quantitatively negligible all the uncertainties associated with the beta measurement reproducibility (Poisson statistics of the beta emission, reproducibility of the mechanical repositioning, detector efficiency fluctuations, density variations of the air interposed between source and detector).
In order to correctly determine the calibration function, during the final acceptance test the Geiger Muller counter response stability is evaluated.

7.5.1 Calibration Procedure

To calibrate the mass measurement system, use the six aluminum reference membranes (TAPI P/N DU0000015) with known surface mass density “x_i”. The mass thickness values usually used are in the range 0 – 10 mg/cm² and they are shown below.

Reference membrane	Reference mass thickness (mg/cm²)
F11	2.963
F12	3.405
F13	5.926
F14	6.810
F15	8.889
F16	9.773

The Model 602 instrument performs five measurement cycles on the reference membranes. Each cycle is preceded by the background noise measurement “DRK” and by the natural radioactivity measurement “NAT” and it is structured as follows:

$$\left.\begin{array}{lllll} DRK & NAT & & & \\ A_{11} & F_{11} & A_{1X} & F_{12} & A_{12} \\ A_{13} & F_{13} & A_{1Y} & F_{14} & A_{14} \\ A_{15} & F_{15} & A_{1Z} & F_{16} & A_{16} \end{array}\right\} 1\, cycle$$

where “F” are the reference membranes and “A” are the “air” counts associated with the single membranes. The total duration of a measurement cycle is about of 97 minutes (the following table shows the duration of each single flux measurement):

Measure	**Duration [mm.ss]**
DRK	02.30
NAT	02.30
A	03.30
F	10.00

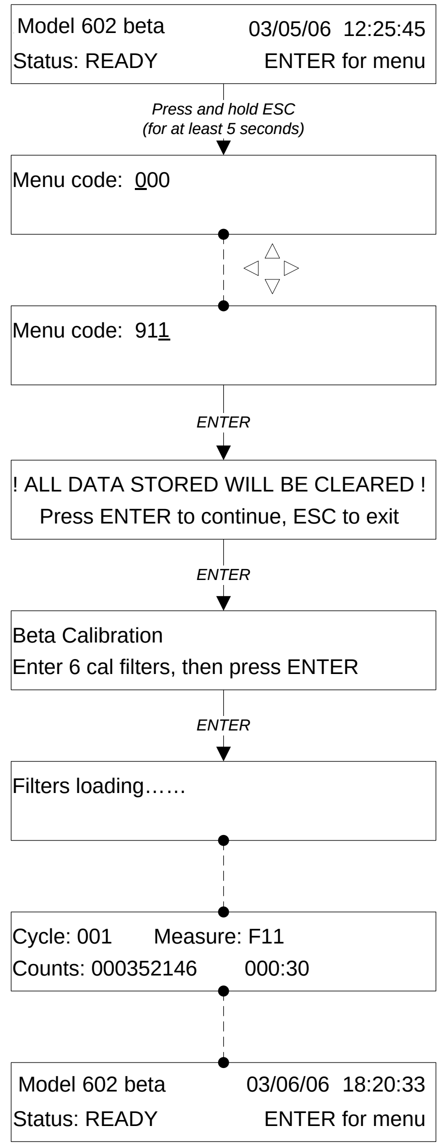
Each of the 17 beta flux measurements (constituting a cycle) are compared with the ancillary measures of temperature, pressure and humidity relative to the measurement area, and the Geiger Muller high voltage value.

Therefore, at the end of the calibration procedure it will be possible to associate to each “x_i” nominal value the corresponding $z_i = \ln\left(\frac{\Phi_0}{\Phi(x_i)}\right)$ value and to determine the best fit function by a third-order homogeneous polynomial “*g(z)*” whose coefficients will be the calibration parameters, see par. 7.5.5.

In the considered interval, the derivative “*k(z)*” of the function “*g(z)*” must be decreasing monotonly.

To perform the mass measurement system calibration follow the procedure below:

1. Make sure that the instrument is installed in a conditioned room so that the temperature range is not higher than 3 K.
2. With the instrument in READY status, follow the “Filters Unloading” procedure (see User Manual par. 5.11).
3. Remove the spy filters in case they are still inside the instrument (see User Manual par. 5.7 & 5.8).
4. Download all data stored in the “Buffer Data” (see User Manual Appendix B), since during the calibration process the “Buffer Data” will be automatically deleted.
5. With the instrument in READY status, press and hold for at least 5 seconds the ESC button to have access to the menus for the support “tools” management.
6. Using the SELECT, YES and NO buttons, select the “*menu code*” 911 and press ENTER to confirm.
7. Press ENTER again to have access to the calibration menu.
8. Unlock the virgin filters “Loader” and insert inside it the six reference aluminum membranes (optional accessory for the instrument), see par. 4.5.
9. Lock the “Loader” and press ENTER



NOTE 1: During the calibration process the real time value of the counts measured by the Geiger Muller will be displayed (for the data download see par. 7.5.3)

NOTE 2: If one or more reference membranes are incorrectly loaded, the message “Filter not loaded, Test aborted” will be displayed. In this case press ESC to go back to the main menu and perform the “Filters Unloading” procedure (see User Manual par. 5.10). This will move all of the calibration membranes to the Unloader. The calibration procedure must be repeated from step 5 on.

NOTE 3: If you want to stop the calibration procedure before it ends, press the ESC button.

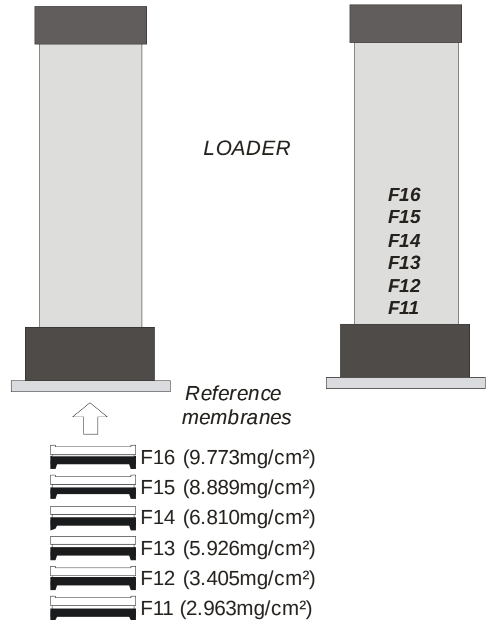
NOTE 4: At the end of the calibration procedure the instrument will set to READY status and the reference aluminum membranes will be automatically moved to the “Unloader”.

7.5.2 Inserting the Reference Membranes in the Loader

Before inserting the reference membranes in the *Loader*, make sure that it is empty. If some filters are present inside the Loader, remove them using the procedure described in Sections 4.8 & 5.11 of the Manual.

To insert the reference membranes in the *Loader*, unlock it rotating it anticlockwise and make sure that each filter cartridge enter in it with the hollow part turned downwards (see Manual Section 4.7).

The membranes insertion sequence must be the one shown in the illustration to the right. It's important to load the membranes in this order, since they will be loaded into the instrument following their order inside the *Loader*.



7.5.3 Calibration Data Download

The calibration data must be downloaded before performing the other operations on the instrument, otherwise they will be deleted. To download the data connect the instrument to a PC and send the command 44 (each line of the response is made up of 8 fields separated by commas). This can also be done using the Dr. FAI instrument software.

Command	Response	Response fields	Format
44	14/06/07 11.11,1,DRK,300.4,100.7,625.4,50,27 14/06/07 11.14,1,NAT,300.4,100.7,625.2,50,21 14/06/07 11.17,1,A11,300.4,100.7,625.2,49,1562139 14/06/07 11.27,1,F11,300.5,100.6,625.3,49,848937 14/06/07 11.29,1,A1X,300.6,100.6,625.2,49,1564526 14/06/07 11.39,1,F12,300.6,100.6,625.3,48,780896 14/06/07 11.42,1,A12,300.6,100.7,625.2,48,1563670 14/06/07 11.45,1,A13,300.6,100.7,625.3,48,1566319 14/06/07 11.55,1,F13,300.7,100.7,625.3,48,404091 14/06/07 11.57,1,A1Y,300.7,100.6,625.2,47,1565320 14/06/07 12.07,1,F14,300.8,100.6,625.3,47,315841 14/06/07 12.10,1,A14,300.8,100.6,625.2,47,1565510 14/06/07 12.13,1,A15,300.8,100.6,625.2,47,1566012 14/06/07 12.23,1,F15,300.8,100.6,625.3,47,156669 14/06/07 12.25,1,A1Z,300.8,100.6,625.2,47,1566158 14/06/07 12.35,1,F16,300.8,100.6,625.3,46,114971 14/06/07 12.38,1,A16,300.8,100.6,625.3,46,1564537 14/06/07 12.39,2,DRK,300.8,100.6,625.3,46,19 14/06/07 12.42,2,NAT,300.8,100.6,625.2,46,23 14/06/07 12.45,2,A11,300.8,100.6,625.2,46,1566836 14/06/07 12.55,2,F11,300.8,100.6,625.2,46,849988 14/06/07 12.57,2,A1X,300.8,100.6,625.3,46,1565628 14/06/07 13.07,2,F12,300.9,100.6,625.3,46,781543 14/06/07 13.10,2,A12,300.9,100.6,625.3,46,1567422 14/06/07 13.13,2,A13,300.9,100.6,625.3,46,1566733 14/06/07 13.23,2,F13,300.9,100.6,625.2,46,404250 14/06/07 13.25,2,A1Y,301,100.6,625.2,46,1567796 14/06/07 13.35,2,F14,301,100.6,625.3,45,315914 14/06/07 13.38,2,A14,301.1,100.6,625.2,45,1567645 14/06/07 13.41,2,A15,301,100.6,625.2,45,1567144 14/06/07 13.51,2,F15,301,100.5,625.3,45,157133 14/06/07 13.53,2,A1Z,301.1,100.6,625.2,45,1565642 14/06/07 14.03,2,F16,301.1,100.6,625.2,45,115268 14/06/07 14.06,2,A16,301.1,100.6,625.3,45,1566931 14/06/07 14.07,3,DRK,301.1,100.6,625.2,45,17 14/06/07 14.10,3,NAT,301.2,100.6,625.2,45,22 14/06/07 14.13,3,A11,301.1,100.6,625.3,45,1568870 14/06/07 14.23,3,F11,301.2,100.6,625.2,45,850998 14/06/07 14.25,3,A1X,301.2,100.6,625.3,45,1568016 14/06/07 14.35,3,F12,301.2,100.5,625.2,45,782035 14/06/07 14.38,3,A12,301.3,100.5,625.3,45,1566755 14/06/07 14.41,3,A13,301.3,100.5,625.3,45,1567122 14/06/07 14.51,3,F13,301.3,100.5,625.2,45,404902 14/06/07 14.53,3,A1Y,301.3,100.5,625.4,45,1567510 14/06/07 15.03,3,F14,301.4,100.5,625.2,45,315996 14/06/07 15.06,3,A14,301.5,100.5,625.3,45,1567756 14/06/07 15.09,3,A15,301.5,100.5,625.2,45,1567631 14/06/07 15.19,3,F15,301.5,100.5,625.2,45,157034 14/06/07 15.21,3,A1Z,301.6,100.5,625.2,45,1567096 14/06/07 15.31,3,F16,301.7,100.6,625.2,45,115378 14/06/07 15.34,3,A16,301.7,100.6,625.4,45,1568269 14/06/07 15.35,4,DRK,301.7,100.6,625.3,45,21 14/06/07 15.38,4,NAT,301.6,100.6,625.3,45,19 14/06/07 15.41,4,A11,301.7,100.6,625.2,45,1569175 14/06/07 15.51,4,F11,301.7,100.6,625.2,45,850583 14/06/07 15.53,4,A1X,301.8,100.6,625.2,45,1567023 14/06/07 16.03,4,F12,301.7,100.6,625.2,45,782240 14/06/07 16.06,4,A12,301.8,100.6,625.1,45,1567832 14/06/07 16.09,4,A13,301.8,100.6,625.2,45,1566488 14/06/07 16.19,4,F13,301.8,100.6,625.3,45,405102 14/06/07 16.21,4,A1Y,301.7,100.6,625.1,45,1567437 14/06/07 16.31,4,F14,301.7,100.6,625.2,44,316351 14/06/07 16.34,4,A14,301.7,100.6,625.2,44,1566832 14/06/07 16.37,4,A15,301.7,100.6,625.2,44,1568896 14/06/07 16.47,4,F15,301.8,100.6,625.3,44,157410 14/06/07 16.49,4,A1Z,301.7,100.6,625.3,44,1568005 14/06/07 16.59,4,F16,301.7,100.6,625.3,44,115333 14/06/07 17.02,4,A16,301.7,100.6,625.2,44,1567367 14/06/07 17.03,5,DRK,301.7,100.6,625.3,44,21 14/06/07 17.06,5,NAT,301.7,100.6,625.3,44,25 14/06/07 17.09,5,A11,301.8,100.6,625.3,44,1568276 14/06/07 17.19,5,F11,301.7,100.6,625.3,44,850599 14/06/07 17.21,5,A1X,301.8,100.6,625.2,44,1567386 14/06/07 17.32,5,F12,301.8,100.6,625.2,44,782066 14/06/07 17.34,5,A12,301.8,100.6,625.1,44,1567499 14/06/07 17.37,5,A13,301.8,100.6,625.2,44,1568672 14/06/07 17.47,5,F13,301.7,100.6,625.2,44,405318 14/06/07 17.49,5,A1Y,301.8,100.6,625.2,44,1568445 14/06/07 18.00,5,F14,301.7,100.6,625.2,44,316672 14/06/07 18.02,5,A14,301.8,100.6,625.2,44,1567880 14/06/07 18.05,5,A15,301.8,100.6,625.2,44,1568368 14/06/07 18.15,5,F15,301.8,100.6,625.1,44,157620 14/06/07 18.17,5,A1Z,301.7,100.6,625.2,44,1568430 14/06/07 18.27,5,F16,301.7,100.6,625.2,44,115309 14/06/07 18.30,5,A16,301.7,100.6,625.2,44,1566173.	Date and Time	dd/mm/yy hh:mm:ss
		Measurement cycle number	###
		Performed measurement *DRK*= background noise *NAT*= natural radioactivity *A11*= "air" flux *F11*= membrane1 (2.963 mg/cm²) *A1X*= "air" flux *F12*= membrane2 (3.405 mg/cm²) *A12*= "air" flux *A13*= "air" flux *F13*= membrane 3 (5.926 mg/cm²) *A1Y*= "air" flux *F14*= membrane 4 (6.810 mg/cm²) *A14*= "air" flux *A15*= "air" flux" *F15*= membrane 5 (8.889 mg/cm²) *A1Z*= "air" flux *F16*= membrane 6 (9.773 mg/cm²) *A16*= "air" flux	XXX
		Average temperature during the measurement [K]	###.#
		Average pressure during the measurement [kPa]	###.#
		Geiger Muller high voltage[V]	###.#
		Relative Humidity mean value during the measurement [%]	###
		Measured counts [counts/min]	#########

7.5.4 Calibration Data Analysis

After the data download and before determining the coefficients of the calibration curve of the mass measurement system, it is possible to perform some fundamental quality controls on the calibration procedure:

- ***Background noise***

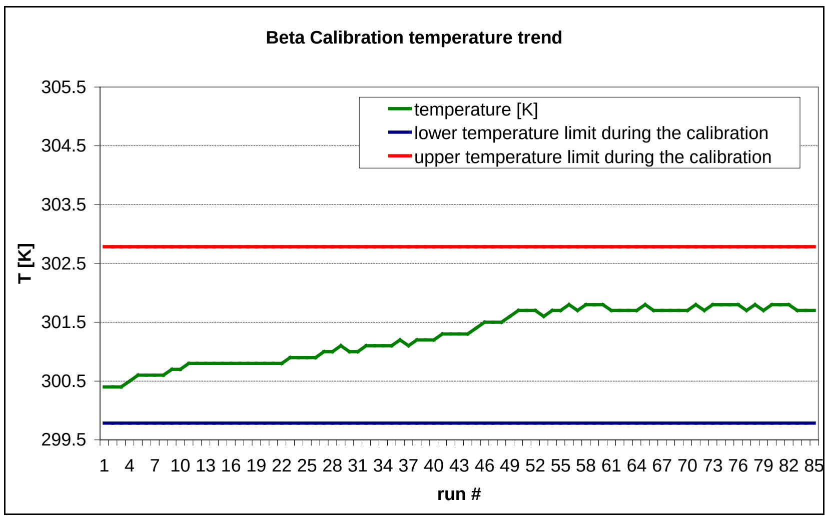
  If during the calibration procedure the background noise exceeds the limit of 150cmp, the procedure must be repeated. If the failure persists, contact Teledyne API Technical Support.

- ***Temperature***

  Ideally, the maximum difference between the temperature values is not higher than 3 K during the calibration process.

  For example, see the Temperature table and graph below.

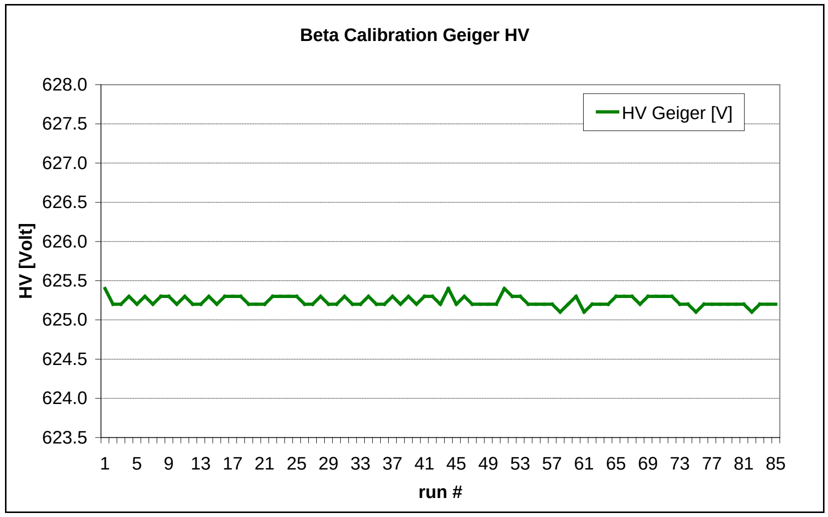
Temperature [K]	
avg.	301.3
max	301.8
min	300.4
max diff.	1.4
# run	85
s.d.	0.452



- ***Geiger Muller High Voltage***

The quality of the Geiger detector response is strictly connected with the stability of its high voltage value. The high voltage power supply is able to supply a stabilized voltage within 1‰ of the mean value. If the standard deviation of the Geiger high voltage value is higher than the 2‰ , the calibration procedure must be repeated. For an example see the HV Geiger table and graph below.

Geiger Muller H.V.[Volt]	
avg.	625.2
max	625.4
min	625.1
# run	85
s.d. %	0.010



Geiger Muller Stability

The Geiger detector response stability can be calculated, using the flux of the “air counts” and checking that the percentage difference between the mean value of the air count flux and the single values measured is not higher than the 1.5%.

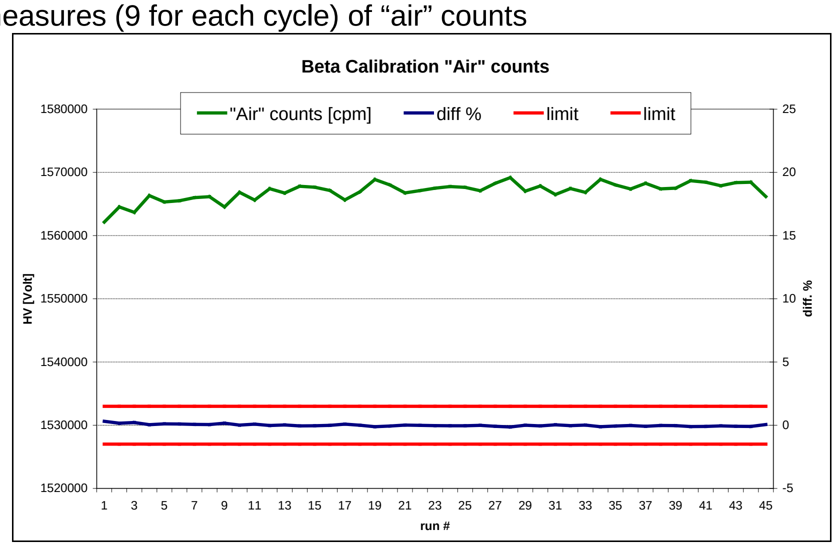
$$-1.5\% < \left[\left(\frac{A_{measured} - \overline{A}}{A_{measured}} \right) \cdot 100 \right] < +1.5\%$$

Where:

$A_{measured}$ is the single measure of “air” counts

$\overline{A}$ is the mean value of the 45 measures (9 for each cycle) of “air” counts

"Air" counts [cpm]	
avg.	1567003
max	1569175
min	1562139
# run	45
s.d.	1427
diff. % max	0.31

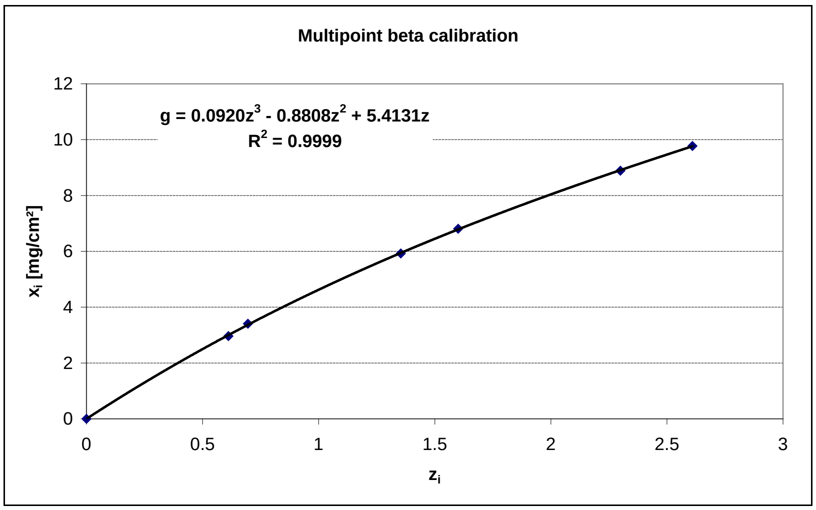


7.5.5 Determination of the Calibration Curve Coefficients

To determine the calibration curve coefficients, it is necessary to associate to each nominal value "x_i" (Reference mass thickness) the correspondent "z_i" value with $z_i = \ln\left(\frac{\Phi_0}{\Phi(x_i)}\right)$, where "$\Phi_0$" corresponds to $\overline{A}$ (mean value of the 45 measures of "air flux") and "$\Phi(x_i)$" is the mean value of the fluxes associated with each single membrane "F".
For example:

measure	counts avg. [cpm]	z_i	x_i [mg/cm²]
air	1567004	0	0
F11	850221	0.611424	2.963
F12	781756	0.695378	3.405
F13	404733	1.353694	5.926
F14	316155	1.600689	6.810
F15	157173	2.299572	8.889
F16	115252	2.609801	9.773

Associating to each nominal value "x_i" the correspondent value $z_i = \ln\left(\frac{\Phi_0}{\Phi(x_i)}\right)$, the *best fit* function is determined by a third-order homogeneous polynomial "*g(z)*" (passing through the origin) whose coefficients represent the calibration parameters.



$$g(z) = az^3 + bz^2 + cz$$

The coefficients "*a*", "*b*" and "*c*" represent the calibration parameters of the mass measurement system to be programmed in the instrument.

7.5.6 Setting of the Calibration Curve Coefficients

To set the coefficients of the calibration curve that were experimentally determined, connect the instrument to a PC equipped with RS232 serial interface. The commands needed for setting the coefficients on each instrument are as follows:

Instrument serial number	Coefficient	Command	Confirmation response
0127	*a*	04SHABCH020#.######	!
	b	04SHABCH021#.######	!
	c	04SHABCH022#.######	!
0131	*a*	04SHABDB020#.######	!
	b	04SHABDB021#.######	!
	c	04SHABDB022#.######	!

With #.###### = coefficient value

For example, if we want to set *b* = -0.8808 on Model 602 Beta^{PLUS} sn0127, we have to send the command: 04SHABCH021-0.8808

To check that the calibration coefficients have been correctly programmed, send the command 050, the fields 21, 22 and 23 of the response correspond respectively to the coefficients "*a*", "*b*" and "*c*".

For example
Command:
050
Response:
16/03/07,16/03/07,001,0127,101.5,4.213,2.320,-0.005,0.1624,2.623,-0.051,0.1605,0,2000,
-0.032200,2.320,-0.005,-0.173000,2.623,-0.051,**0.0920**, -0.8808,**5.4131**,0.005539,
0.007007,160000,1600,1.007,1.007,1.000,1.000,0.000,5,2.8,0.100,0.28,10,10
Coefficients:
a =0.0920
b =-0.8808
c =5.4131

7.5.7 Automatic Calibration Check

The instrument can automatically perform a ß calibration check (*Beta span test*) by measuring alternately the ß flux in air and the ß flux passing through the two reference aluminum membranes placed inside the instrument (see User Manual par. 5.8).

To start the beta span test, follow the procedure below:

1. Make sure that the internal reference membranes have been correctly loaded inside the instrument (see User Manual par. 5.6)
2. With the instrument in READY status, press ENTER and then SELECT till the "Instrument Tools" menu will be displayed.
3. Press ENTER to have access to the menu.
4. Press ENTER and then SELECT till the "Beta Span Test" menu will be displayed.
5. Press ENTER to start the test

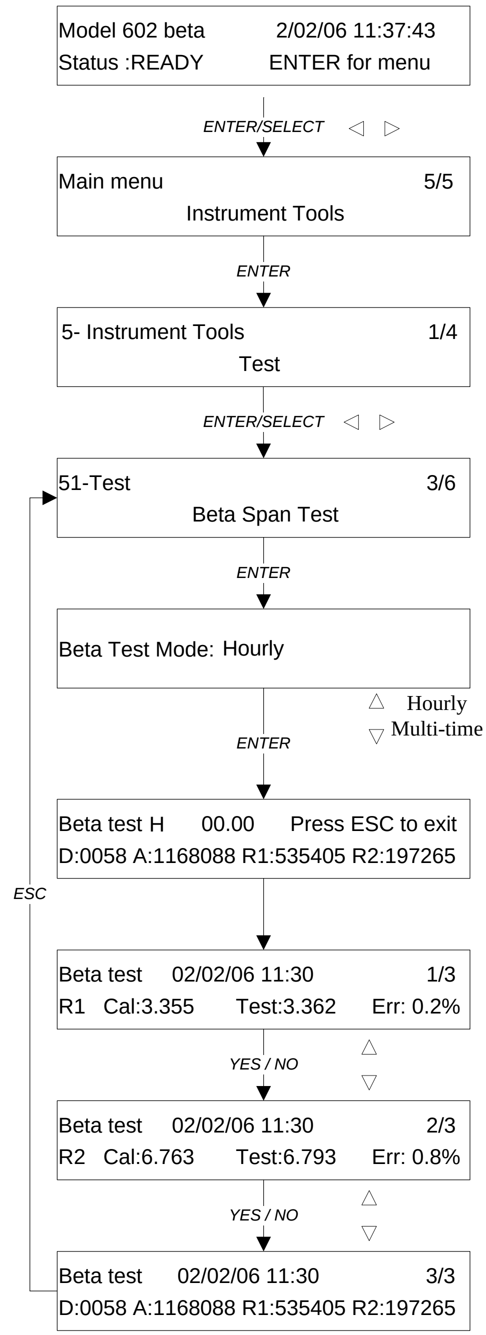
   Once the test started, the display will show the fluxes relative to the background radioactivity (D), to the air (A), to the reference membranes R1 and R2.

   At the end of the test the following parameters will be displayed for both the membranes:

- *Cal*: mass surface density value of the reference membrane (mg/cm²)

- *Test*: mass surface density value of the membrane measured by the instrument (mg/cm²)

- *Err*: percentage deviation



7.6 BATTERY TEST

To check the battery charge status follow this procedure:

1. With the instrument in READY Status, press ENTER and then SELECT until the “Instrument Tools” menu is displayed
2. Press ENTER to access the menu.
3. Press ENTER and then SELECT until the “Battery Test” menu is displayed.
4. Press ENTER to start the test.

The display shows the values of the following parameters:

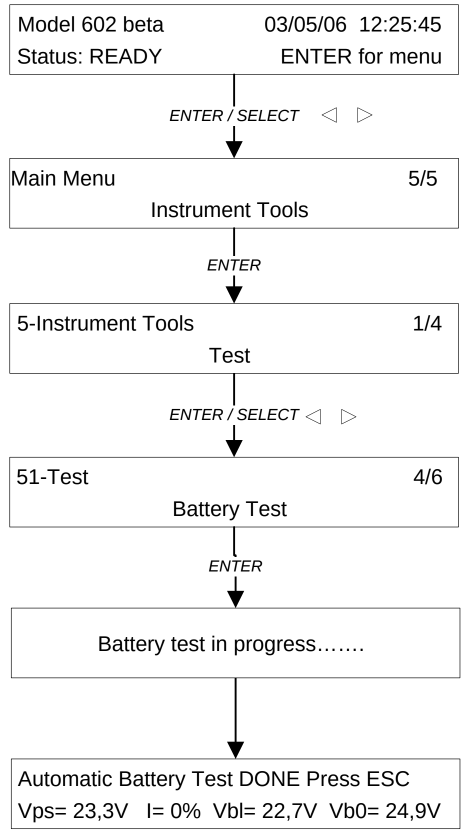
Vps: *internal operating voltage*

I: *battery charging current*

Vbl: *“Load” battery voltage*

Vb0: *“No-load” battery voltage*

If the instrument fails the test (battery charge is insufficient to keep it in operation), the red “*Battery Level Low”* LED and the yellow “*Warning*” LED on the frontal control panel will turn on.



NOTE: The instrument is also able to automatically perform the battery voltage test during the sampling and measurement cycles. If the battery voltage is too low and unable to keep the instrument in operation, a Warning message will be displayed and stored in the Data Buffer (Warning 28, see Appendix 3).

7.7 MODEM SIGNAL

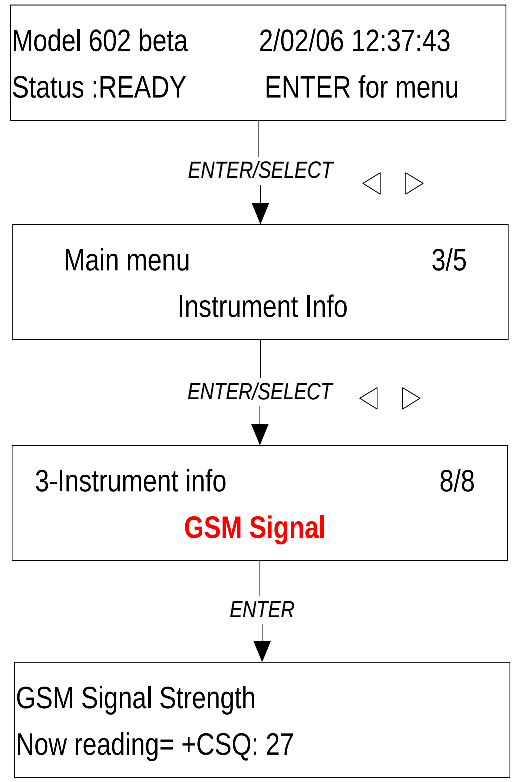
When the instrument is equipped with a modem (PSTN, ISDN, GSM, GPRS), the following tasks can be performed remotely:

- setting the operating parameters
- access to the sampling and measurement data
- mechanical functionality checks
- access to the “trace files”
- the instrument can automatically send diagnostic SMSs

Use the 9-pin RS232 serial port located on the back of the instrument and the corresponding cable to connect the modem.

The signal intensity value detected by the modem can be checked directly on the display following the steps below:

1. With the instrument in READY Status, press ENTER and then SELECT until the “Instrument Info” menu is displayed.
2. Press ENTER to access the menu.
3. Press SELECT until “GSM Signal” is displayed.
4. Press ENTER to start the test.



The signal intensity value is displayed and updated once per second, and the instrument produces an audible ‘beeping’ sound.

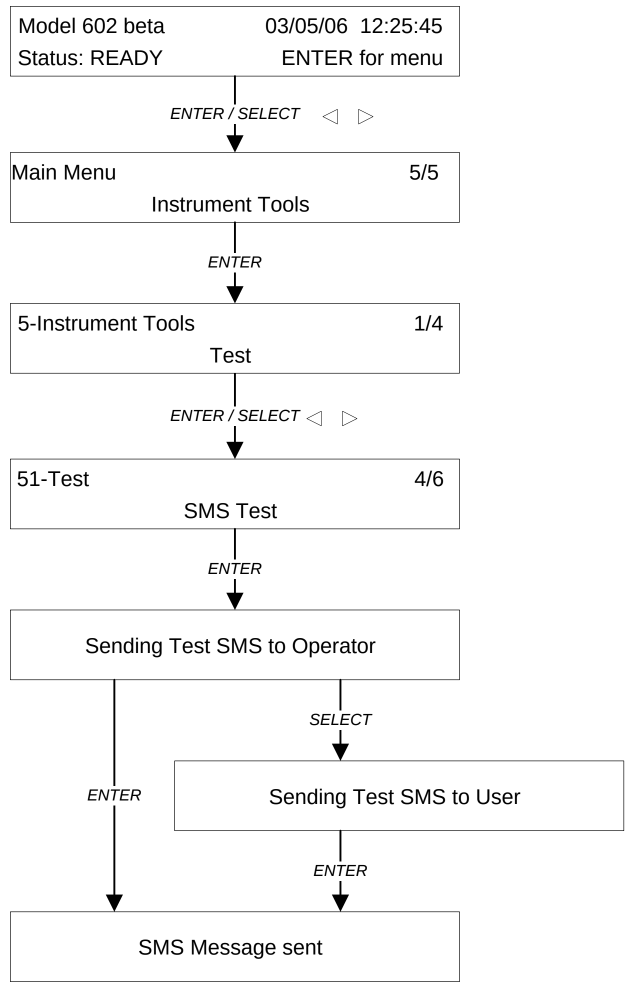
- signal between 0-10 (weak signal)
- signal between 10-98 (operating range)
- signal 99 (no signal)

NOTE: For best results, position the GSM modem to get a signal level > 15

7.8 SMS TEST

The *SMS Test* checks for correct operation of the SMS messaging service that sends messages to the Operator's and User's mobile phones (see Section 6.5 "*SMS Messaging Service*").
Follow the procedure below to perform the test:

1. From the main menu, in READY Status, press ENTER and select the Instrument Tools menu using the SELECT keys.
2. Press ENTER to access the Test menu.
3. Press ENTER again and select the SMS Test menu using the SELECT keys.
4. Press ENTER and, using the SELECT keys, select the user to whom the instrument will send the messages (Operator or User). Press ENTER again to confirm.



If the user does not receive the SMS message, check the following:

- *the GSM modem is correctly installed (see section 7.5)*
- *the Modem Test gives the correct result*
- *the GSM card contracts (modem and operator) have not expired*

NOTE: The SMS service is available only if the SIM card installed in the modem provides that function and is correctly configured. Contact the SIM telephone operator to enable service on and/or configure the SIM card.

7.9 FULL MECHANICAL SYSTEM TEST

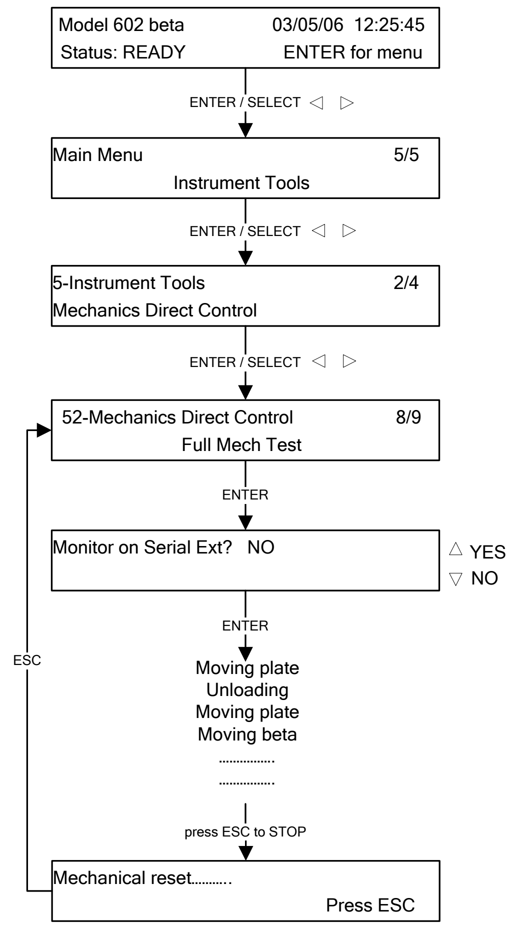
The *Full Mechanical Test* is performed to check the functionality of all of the instrument's servomechanisms.

Before beginning the test, make sure that at least one filter is inside the Loader, then follow the procedure shown in the figure on the right.

After selecting the *Full Mech Test*, the test results can be sent to an external PC connected to the RS232 serial port (*Monitor on Serial Ext? YES or NO*).

The test continues until all the filters inside the Loader have been unloaded. The test can be stopped by pressing ESC.

If the test gives correct results, **Err: 00** appears on the display. If anomalous operating conditions are detected during the test, an error message will be displayed identifying the type of anomaly and the corresponding servomechanism.



7.10 ZERO TEST: Offset Check

The zero test is performed to verify the mass measurement system response when the particulate matter present on the sample is removed from the sampling flow.
Under those conditions the measured mass and consequently the relative “expected” concentration value are equal to zero.

Connect the absolute filters kit (Figure 7-9) to the sampling lines instead of the sampling heads, using the adapter “*a*” (Figure 7-10). Another option is to connect the absolute filters directly to the instrument using the adapter “*b*” (Figure 7-11).

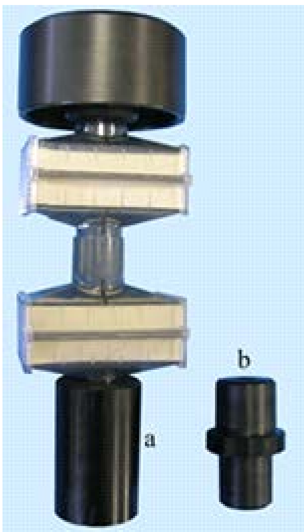


Figure 7-9. Absolute Filters Kit

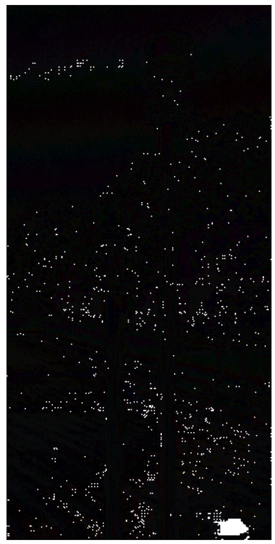


Figure 710. Absolute Filter Connected to Sampling Lines

Figure 7-11. Absolute Filters Connected to Instrument

1. Assemble and load a suitable number of filters into the instrument, using the same type of filter membranes that will be used for sampling and, in Multi-Time Mode, the same “Beta equivalent spot area” that will be used.

2. Start the instrument in “Monitor Mode Line A&B” and set the “Timing” to 12 hours (Multi-Time Mode zero test) or Hourly (Hourly Mode zero test).

3. At the end of the programmed sampling cycles, download the “Buffer Data” (see Appendix 1).

7.10.1 Interpretation of the Zero Test Data

The experimental mass and concentration data that are obtained are expected to be scattered around the zero value and to have both negative and positive values.

Table 7-1 shows a typical data set for one of the two sampling lines.

Table 7-1. Data Set Example

Inlet volume [m³]	Buffer mass [µg]	Buffer concentration [µg/m³]	
54.955	-19	-0.3	
54.710	-3	-0.1	
54.646	-2	0.0	
54.626	3	0.1	
54.646	21	0.4	
54.648	4	0.1	
54.665	13	0.2	
54.681	-25	-0.5	
54.656	3	0.1	
54.687	-14	-0.3	
54.602	13	0.2	
54.657	8	0.1	
54.584	16	0.3	
54.617	-12	-0.2	
54.598	16	0.3	
54.611	13	0.2	
54.670	-10	-0.2	
54.593	6	0.1	
54.699	-4	-0.1	
54.643	9	0.2	
54.649	-7	-0.1	
average mass value [µg]			1.3
Std [µg]			12.5

The result of the zero test will be the average mass value in µg and the relative standard deviation.

CHAPTER 8

8. MAINTENANCE

8.1 ROUTINE PREVENTIVE MAINTENANCE

Preventive maintenance is a part of routine system management, which includes cleaning the instrument and all of the checks that the operators will perform during normal instrument operation.

The recommended checks and preventive maintenance steps are listed in the table below:

Table 8-1. Maintenance Schedule

Maintenance Procedure	Recurrence
Clean and grease sampling inlet	bi-weekly/ monthly
Drain condensation trap	As needed
Inspect sampling line	annually
Inspect oil level and service air compressor filter	semi-annually
Rebuild Vacuum Pump (carbon vane rebuild kit supplied separately)	every 8 months

The instrument operating conditions vary drastically over time. For this reason, it is recommended that maintenance be performed at intervals appropriate to the actual usage conditions, using the table above as a reference.

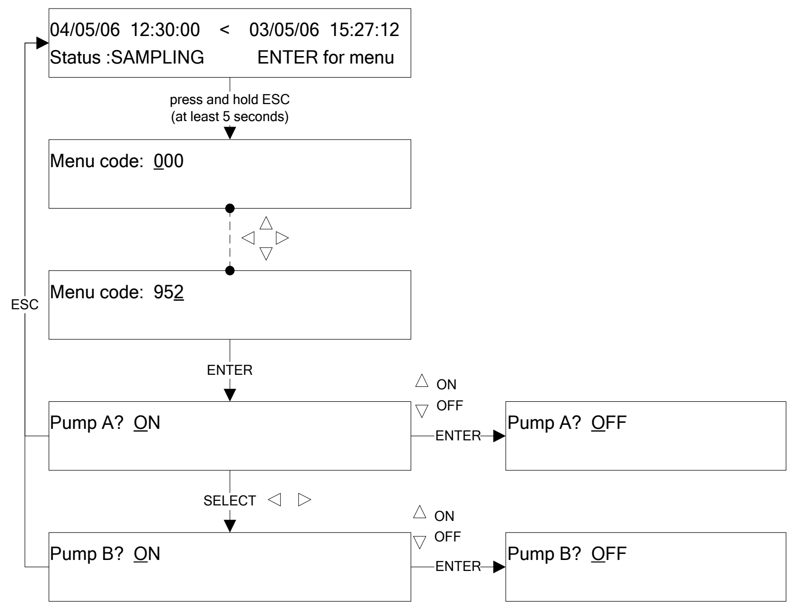
8.1.1 Cleaning the Sampling Inlet

The sampling inlets can be cleaned when the instrument is in Ready, Sampling or Ending Status. If the instrument is in Sampling or Ending Status the vacuum pumps must be switched off before removing the sampling inlet from the sampling line.

NOTE: Cleaning should be performed at least monthly or according to EPA or local monitoring agency guidelines.

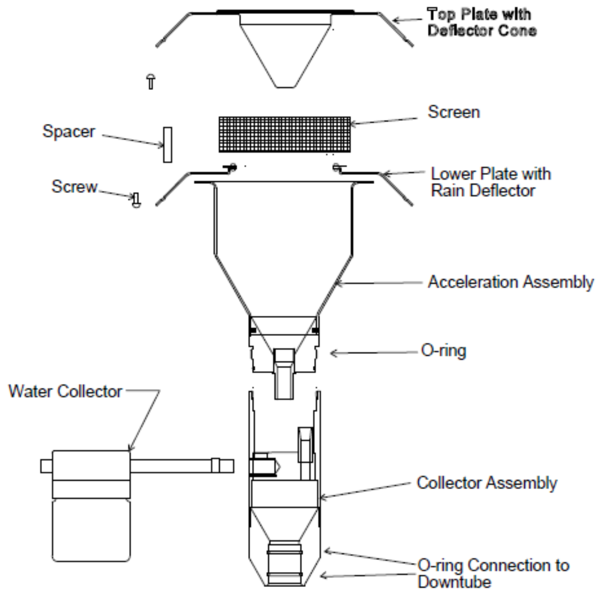
Follow the procedure below to switch off the pumps:

1. From the main screen press and hold the ESC key for at least 5 seconds to access the Menu code (access to support tools).
2. Enter code 952 using the Select keys and press ENTER to access the pump control function.
3. Choose the pump to be switched off using the Select keys.
4. Press NO to select OFF.
5. Press ENTER to confirm.



After switching the pump off, follow the next procedure to continue with the removal and cleaning of the corresponding sampling head(s).

8.1.2 Dismantling and Cleaning the US EPA PM10 Inlet



1. Mark each assembly point of the sampler inlet with a pen or pencil to provide “match marks” during reassembly. Critical assembly points are already “keyed.”

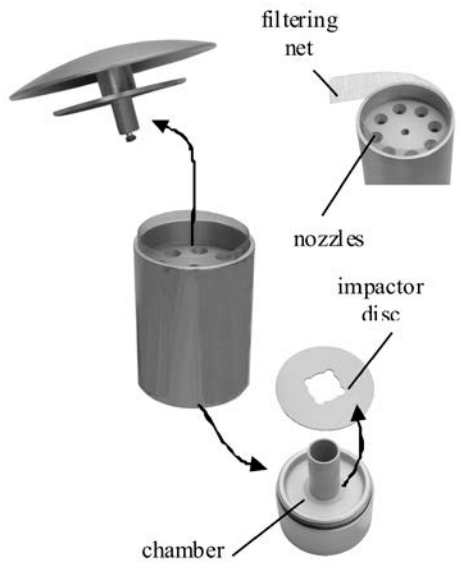
2. Disassemble the sample inlet unit according to the figure above, taking care to retain all the parts. Note: If the assembly screws appear frozen, the application of penetrating oil or commercial lubricant will make removal easier.

3. Using a soft brush, cloth, and cotton swabs, lightly scrub all interior surfaces and the bug screen with distilled water and/or the general-purpose cleaner. Pay particular attention to small openings and crevices. Cotton swabs and/or a small soft brush are most helpful in these areas. Using laboratory tissue and cotton swabs moistened with distilled water, wipe all surfaces to remove any remaining deposits. Completely dry all components.

4. Check all the O-rings for distortion, cracks, fraying, lack of lubricating grease, or other problems. Apply a thin coating of vacuum grease or replace the O-rings as necessary.

5. Reassemble the unit in accordance with the previously scribed match marks. Take particular care to ensure that all O-ring seals are properly sealed and that all screws are uniformly tightened.

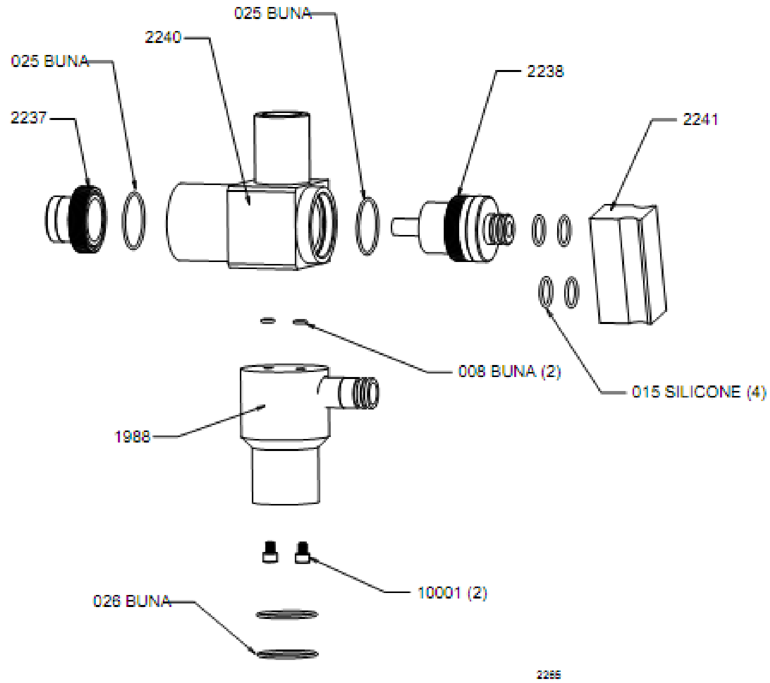
8.1.3 Dismantling and Cleaning the PM_{10} Pre-impactor for the $PM_{2.5}$ Inlet



1. Remove the sampling inlet from the sampling line
2. Disassemble the sampling inlet
3. Carefully and thoroughly remove any dust deposits from the impactor disc and any condensation accumulated in the chamber below.
4. Clean all the components using water and a mild detergent.
5. Dry all components with a clean cloth and blow compressed air through nozzles.
6. Apply a thin coat of non-outgassing vacuum grease on the impactor disc.
7. Remove any insects or other debris from the filtering net.
8. Check and, if needed, replace the two o-rings and grease them with vacuum grease.
9. Re-assemble the sampling inlet.

This procedure should be repeated on a biweekly to a monthly basis per the maintenance schedule.

8.1.4 Dismantling and Cleaning the BGI VSCC-A PM2.5 Cyclone



1. Remove the VSCC-A cyclone from its installed position in the instrument.

2. Pull off the side transfer tube. If it is too tight to remove by hand, pry it off with a rigid plastic lever. Care should be taken to not damage the two “O” ring seals.

3. Remove the top cap and grit pot by unscrewing.

4. Wet a lint free wipe with water and remove all visible deposits. These are most likely to be found at the bottom of the cone and inside the grit pot.

5. Inspect all “O” rings for shape and integrity. If at all suspect, replace. Lubricate all “O” rings with light grease. It is important to well lubricate the transfer tube to avoid difficult disassembly.

6. It is not necessary to remove the two hex head screws (pn 10001), but make sure they are tightly positioned.

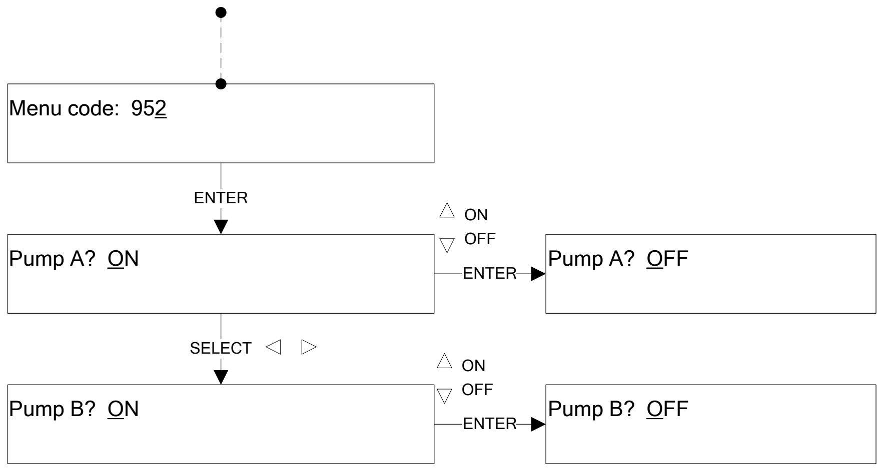
7. Assemble in reverse order and reinstall.

8. Perform a leak check according to manufacturers operating manual specifications.

8.1.5 Reactivating the Pumps after Inlet Cleaning

After re-assembling the sampling head(s), use the pump control *function* to turn the pumps back on.

1. Select the pump you wish to switch on using the Select keys.
2. Press YES to select ON.
3. Press ENTER to confirm.



NOTE: At the beginning of every sampling and measurement cycle and after unloading the sampled filters (at the end of the mass measurement collection session), the suction pumps are automatically activated.

8.1.6 Inspecting the Sampling Line

Check the sampling line conditions yearly as follows:

- Switch off the instrument.
- Remove the protective thermal insulation sleeve and disconnect the sampling lines from the top of the instrument.
- Remove any insects or other debris from the inlet screen located below the air intake's protective sleeve.
- <u>Make sure that there is no water inside the sampling line or the sampler.</u>
- Dry and remove any visible deposits from the surfaces.
- Check, grease and, if needed, replace the two o-rings on the sleeve of the inlet coupling
- Re-connect the sampling lines to the top of the instrument and reapply the protective thermal insulation sleeve.

Contact Technical Assistance immediately if water has entered the sampler.

8.1.7 Service Air Compressor Check

Check the following on the service air compressor every six months:

- the condition of the sampler's flexible air feeder pipe
- the air filter (clean if necessary)

8.1.8 Vacuum Pump Maintenance

Replace any vacuum pump parts subject to wear every eight months, using the rebuild kit supplied as a spare part by Teledyne API.

Carefully follow the instructions.

8.2 REPAIRS

Repairs consist of any work needed to restore normal operating conditions after failures or long periods of inactivity.

WARNING:

Only qualified and authorized technical personnel are allowed open the instrument and access its internal parts.

The instrument contains dangerous high voltage contacts and a radioactive source.

CAUTION: Do not modify the instrument.

Any modification to the instrument is strictly prohibited and shall void the warranty. The user must take full responsibility for any consequences resulting from modifications.

Maintenance repairs can be carried out only by:

- **Qualified Technicians** who have been trained to perform maintenance and repairs to the instrument
- **Teledyne API Technical Staff**
- **An authorized technical assistance center**

8.3 STORAGE AND DISPOSAL

If the instrument needs to be stored temporarily, deactivate the system and apply an “OUT OF SERVICE” tag or label.

The instrument must be stored indoors, horizontally, with no weight on top of it, and if possible, in its original packaging.

CAUTION: Maintain a proper environment for the instrument.

The storage temperature must be kept between - 10 °C and + 55 °C in order to avoid damage to any of the internal components and the electronics.
The relative humidity in the storage area must kept low to avoid condensation.

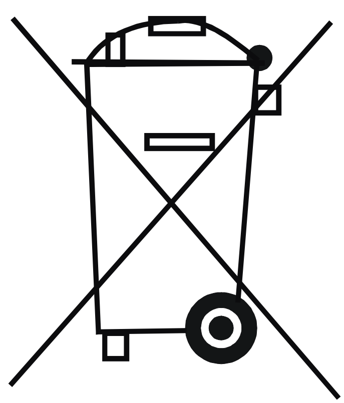
At the end of the instrument’s operating life, it must be disposed of in a manner that **minimizes the risk of harm to the public and the environment**.

During final dismantling of the instrument, bear in mind that the instrument contains the following types of components/materials:

- Ionizing radiation source
- Various metallic materials (aluminum, carbon and stainless steel, copper)
- Plastic materials (PVC, Polyethylene, ABS, Nylon, Teflon)
- Electrical and electronic components (metals and parts in synthetic material)
- Elastomers (Viton, Rubber)
- Lead-acid batteries

In accordance with current regulations, some of the components may need to be sent to specialized firms for disposal. If possible, the material must be recycled.

WARNING: Do not disassemble, store or dispose of the radiactive source.
The radioactive source must be disassembled by qualified and authorized personnel. Storage or disposal must be performed in accordance with the specific enforceable safety regulations in your state/country.



CHAPTER 9

9 ELECTRO-STATIC DISCHARGE (ESD)

Teledyne API considers the prevention of damage caused by the discharge of static electricity to be extremely important part of making sure that your analyzer continues to provide reliable service for a long time. This section describes how static electricity occurs, why it is so dangerous to electronic components and assemblies as well as how to prevent that damage from occurring.

9.1 HOW STATIC CHARGES ARE CREATED

Modern electronic devices such as the types used in the various electronic assemblies of your analyzer, are very small, require very little power and operate very quickly. Unfortunately, the same characteristics that allow them to do these things also make them very susceptible to damage from the discharge of static electricity. Controlling electrostatic discharge begins with understanding how electro-static charges occur in the first place.

Static electricity is the result of something called triboelectric charging which happens whenever the atoms of the surface layers of two materials rub against each other. As the atoms of the two surfaces move together and separate, some electrons from one surface are retained by the other.

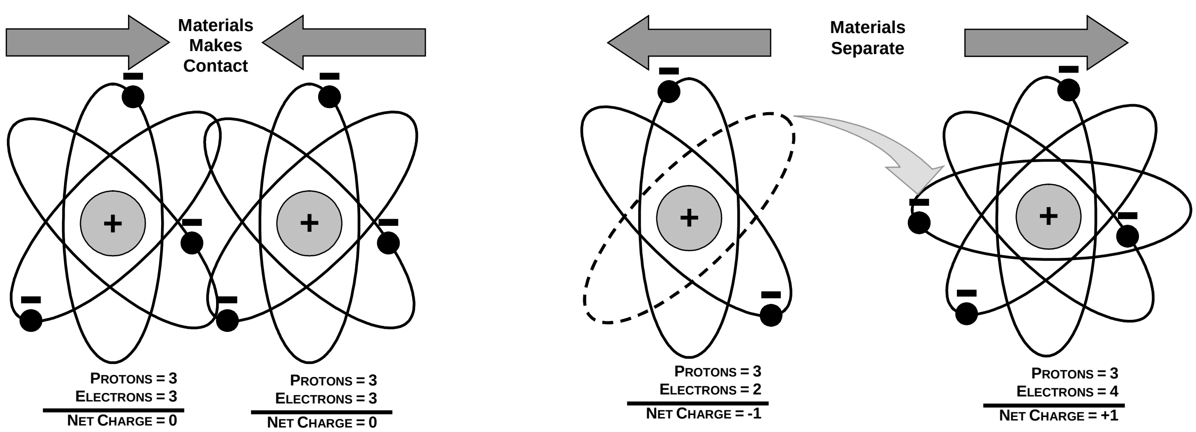


Figure 9-1. Triboelectric Charging

If one of the surfaces is a poor conductor or even a good conductor that is not grounded, the resulting positive or negative charge cannot bleed off and becomes trapped in place, or static. The most common example of triboelectric charging happens when someone wearing leather or rubber soled shoes walks across a nylon carpet or linoleum tiled floor. With each step, electrons change places and the resulting electro-static charge builds up, quickly reaching significant levels. Pushing an epoxy printed circuit board across a workbench, using a plastic handled screwdriver or even the constant jostling of Styrofoam™ pellets during shipment can also build hefty static charges

Table 9-1. Static Generation Voltages for Typical Activities

MEANS OF GENERATION	65-90% RH	10-25% RH
Walking across nylon carpet	1,500V	35,000V
Walking across vinyl tile	250V	12,000V
Worker at bench	100V	6,000V
Poly bag picked up from bench	1,200V	20,000V
Moving around in a chair padded with urethane foam	1,500V	18,000V

9.2 HOW ELECTRO-STATIC CHARGES CAUSE DAMAGE

Damage to components occurs when these static charges come into contact with an electronic device. Current flows as the charge moves along the conductive circuitry of the device and the typically very high voltage levels of the charge overheat the delicate traces of the integrated circuits, melting them or even vaporizing parts of them. When examined by microscope the damage caused by electro-static discharge looks a lot like tiny bomb craters littered across the landscape of the component's circuitry.

A quick comparison of the values in Table 9-1 with the those shown in the Table 9-2, listing device susceptibility levels, shows why *Semiconductor Reliability News* estimates that approximately 60% of device failures are the result of damage due to electro-static discharge.

Table 9-2. Sensitivity of Electronic Devices to Damage by ESD

DEVICE	DAMAGE SUSCEPTIBILITY VOLTAGE RANGE	
	DAMAGE BEGINS OCCURRING AT	CATASTROPHIC DAMAGE AT
MOSFET	10	100
VMOS	30	1800
NMOS	60	100
GaAsFET	60	2000
EPROM	100	100
JFET	140	7000
SAW	150	500
Op-AMP	190	2500
CMOS	200	3000
Schottky Diodes	300	2500
Film Resistors	300	3000
This Film Resistors	300	7000
ECL	500	500
SCR	500	1000
Schottky TTL	500	2500

Potentially damaging electro-static discharges can occur:

Any time a charged surface (including the human body) discharges to a device. Even simple contact of a finger to the leads of a sensitive device or assembly can allow enough discharge to cause damage. A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture.

When static charges accumulated on a sensitive device discharges from the device to another surface such as packaging materials, work surfaces, machine surfaces or other device. In some cases, charged device discharges can be the most destructive.

A typical example of this is the simple act of installing an electronic assembly into the connector or wiring harness of the equipment in which it is to function. If the assembly is carrying a static charge, as it is connected to ground a discharge will occur.

Whenever a sensitive device is moved into the field of an existing electro-static field, a charge may be induced on the device in effect discharging the field onto the device. If the device is then momentarily grounded while within the electrostatic field or removed from the region of the electrostatic field and grounded somewhere else, a second discharge will occur as the charge is transferred from the device to ground.

9.3 COMMON MYTHS ABOUT ESD DAMAGE

I didn't feel a shock so there was no electro-static discharge: The human nervous system isn't able to feel a static discharge of less than 3500 volts. Most devices are damaged by discharge levels much lower than that.

I didn't touch it so there was no electro-static discharge: Electro-static charges are fields whose lines of force can extend several inches or sometimes even feet away from the surface bearing the charge.

It still works so there was no damage: Sometimes the damaged caused by electro-static discharge can completely sever a circuit trace causing the device to fail immediately. More likely, the trace will be only partially occluded by the damage causing degraded performance of the device or worse, weakening the trace. This weakened circuit may seem to function fine for a short time, but even the very low voltage and current levels of the device's normal operating levels will eat away at the defect over time causing the device to fail well before its designed lifetime is reached.

These latent failures are often the most costly since the failure of the equipment in which the damaged device is installed causes down time, lost data, lost productivity, as well as possible failure and damage to other pieces of equipment or property.

Static Charges can't build up on a conductive surface: There are two errors in this statement.

Conductive devices can build static charges if they are not grounded. The charge will be equalized across the entire device, but without access to earth ground, they are still trapped and can still build to high enough levels to cause damage when they are discharged.

A charge can be induced onto the conductive surface and/or discharge triggered in the presence of a charged field such as a large static charge clinging to the surface of a nylon jacket of someone walking up to a workbench.

As long as my analyzer is properly installed, it is safe from damage caused by static discharges: It is true that when properly installed the chassis ground of your analyzer is tied to earth ground and its electronic components are prevented from building static electric charges themselves. This does not prevent discharges from static fields built up on other things, like you and your clothing, from discharging through the instrument and damaging it.

9.4 BASIC PRINCIPLES OF STATIC CONTROL

It is impossible to stop the creation of instantaneous static electric charges. It is not, however difficult to prevent those charges from building to dangerous levels or prevent damage due to electro-static discharge from occurring.

9.4.1 General Rules

Only handle or work on all electronic assemblies at a properly set up ESD station. Setting up an ESD safe workstation need not be complicated. A protective mat properly tied to ground and a wrist strap are all that is needed to create a basic anti-ESD workstation (refer to figure 12-2).

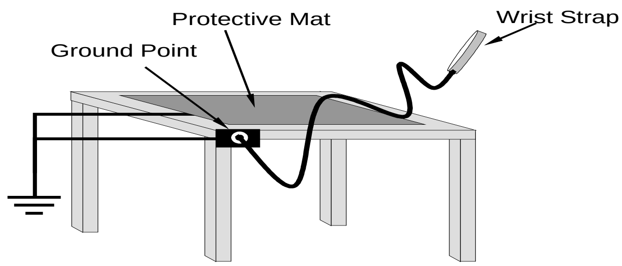


Figure 9-2: Basic anti-ESD Work Station

For technicians that work in the field, special lightweight and portable anti-ESD kits are available from most suppliers of ESD protection gear. These include everything needed to create a temporary anti-ESD work area anywhere.

Always wear an Anti-ESD wrist strap when working on the electronic assemblies of your analyzer. An anti-ESD wrist strap keeps the person wearing it at or near the same potential as other grounded objects in the work area and allows static charges to dissipate before they can build to dangerous levels. Anti-ESD wrist straps terminated with alligator clips are available for use in work areas where there is no available grounded plug.

Also, anti-ESD wrist straps include a current limiting resistor (usually around one meg-ohm) that protects you should you accidentally short yourself to the instrument's power supply.

Simply touching a grounded piece of metal is insufficient. While this may temporarily bleed off static charges present at the time, once you stop touching the grounded metal new static charges will immediately begin to re-build. In some conditions, a charge large enough to damage a component can rebuild in just a few seconds.

Always store sensitive components and assemblies in anti-ESD storage bags or bins: Even when you are not working on them, store all devices and assemblies in a closed anti-Static bag or bin. This will prevent induced charges from building up on the device or assembly and nearby static fields from discharging through it.

Use metallic anti-ESD bags for storing and shipping ESD sensitive components and assemblies rather than pink-poly bags. The famous, "pink-poly" bags are made of a plastic that is impregnated with a liquid (similar to liquid laundry detergent) which very slowly sweats onto the surface of the plastic creating a slightly conductive layer over the surface of the bag.

While this layer may equalizes any charges that occur across the whole bag, it does not prevent the build up of static charges. If laying on a conductive, grounded surface, these bags will allow charges to bleed away but the very charges that build up on the surface of the bag itself can be transferred through the bag by induction onto the circuits of your ESD sensitive device. Also, the liquid impregnating the plastic is eventually used up after which the bag is as useless for preventing damage from ESD as any ordinary plastic bag.

Anti-Static bags made of plastic impregnated with metal (usually silvery in color) provide all of the charge equalizing abilities of the pink-poly bags but also, when properly sealed, create a Faraday cage that completely isolates the contents from discharges and the inductive transfer of static charges.

Storage bins made of plastic impregnated with carbon (usually black in color) are also excellent at dissipating static charges and isolating their contents from field effects and discharges.

Never use ordinary plastic adhesive tape near an ESD sensitive device or to close an anti-ESD bag. The act of pulling a piece of standard plastic adhesive tape, such as Scotch® tape, from its roll will generate a static charge of several thousand or even tens of thousands of volts on the tape itself and an associated field effect that can discharge through or be induced upon items up to a foot away.

9.5 BASIC ANTI-ESD PROCEDURES FOR ANALYZER REPAIR AND MAINTENANCE

9.5.1 Working at the Instrument Rack

When working on the analyzer while it is in the instrument rack and plugged into a properly grounded power supply.

1. Attach your anti-ESD wrist strap to ground before doing anything else.

   Use a wrist strap terminated with an alligator clip and attach it to a bare metal portion of the instrument chassis. This will safely connect you to the same ground level to which the instrument and all of its components are connected.
2. Pause for a second or two to allow any static charges to bleed away.
3. Open the casing of the analyzer and begin work. Up to this point, the closed metal casing of your analyzer has isolated the components and assemblies inside from any conducted or induced static charges.
4. If you must remove a component from the instrument, do not lay it down on a non-ESD preventative surface where static charges may lie in wait.
5. Only disconnect your wrist strap after you have finished work and closed the case of the analyzer.

9.5.2 Working at an Anti-ESD Work Bench

When working on an instrument of an electronic assembly while it is resting on an anti-ESD work bench:

1. Plug your anti-ESD wrist strap into the grounded receptacle of the work station before touching any items on the work station and while standing at least a foot or so away. This will allow any charges you are carrying to bleed away through the ground connection of the workstation and prevent discharges due to field effects and induction from occurring.
2. Pause for a second or two to allow any static charges to bleed away.
3. Only open any anti-ESD storage bins or bags containing sensitive devices or assemblies after you have plugged your wrist strap into the workstation.
   - Lay the bag or bin on the workbench surface.
   - Before opening the container, wait several seconds for any static charges on the outside surface of the container to be bled away by the workstation's grounded protective mat.
4. Do not pick up tools that may be carrying static charges while also touching or holding an ESD Sensitive Device.

- Only lay tools or ESD-sensitive devices and assemblies on the conductive surface of your workstation. Never lay them down on any non-ESD preventative surface.

5. Place any static sensitive devices or assemblies in anti-static storage bags or bins and close the bag or bin before unplugging your wrist strap.
6. Disconnecting your wrist strap is always the last action taken before leaving the workbench.

9.5.3 Transferring Components from Rack to Bench and Back

When transferring a sensitive device from an installed Teledyne API analyzer to an Anti-ESD workbench or back:

1. Follow the instructions listed above for working at the instrument rack and workstation.
2. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
3. Before using the bag or container allow any surface charges on it to dissipate:
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
   - In either case wait several seconds.
4. Place the item in the container.
5. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
   - Folding the open end over isolates the component(s) inside from the effects of static fields.
   - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.
6. Once you have arrived at your destination, allow any surface charges that may have built up on the bag or bin during travel to dissipate:
   - Connect your wrist strap to ground.
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at a anti-ESD work bench, lay the container down on the conductive work surface
   - In either case wait several seconds
7. Open the container.

9.5.4 Opening Shipments from Teledyne API's Customer Service

Packing materials such as bubble pack and Styrofoam pellets are extremely efficient generators of static electric charges. To prevent damage from ESD, Teledyne API ships all electronic components and assemblies in properly sealed anti-ESD containers.

Static charges will build up on the outer surface of the anti-ESD container during shipping as the packing materials vibrate and rub against each other. To prevent these static charges from damaging the components or assemblies being shipped ensure that you always unpack shipments from Teledyne API's Customer Service by:

1. Opening the outer shipping box away from the anti-ESD work area.
2. Carry the still sealed ant-ESD bag, tube or bin to the anti-ESD work area.

3. Follow steps 6 and 7 of Section 9.5.3 above when opening the anti-ESD container at the work station.
4. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne API.

9.5.5 Packing Components for Return to Teledyne API's Customer Service

Always pack electronic components and assemblies to be sent to Teledyne API's Customer Service in anti-ESD bins, tubes or bags.

Caution

- **DO NOT use pink-poly bags.**
- **NEVER allow any standard plastic packaging materials to touch the electronic component / assembly directly.**
  - **This includes, but is not limited to, plastic bubble-pack, Styrofoam peanuts, open cell foam, closed cell foam, and adhesive tape.**
- **DO NOT use standard adhesive tape as a sealer. Use ONLY anti-ESD tape.**

1. Opening the outer shipping box away from the anti-ESD work area.
2. Carry the still sealed ant-ESD bag, tube or bin to the anti-ESD work area.
3. Follow steps 6 and 7 of Section 9.5.3 above when opening the anti-ESD container at the work station.
4. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne API.
5. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
6. Before using the bag or container allow any surface charges on it to dissipate:
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
   - In either case wait several seconds.
7. Place the item in the container.
8. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
   - Folding the open end over isolates the component(s) inside from the effects of static fields.
   - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

NOTE

If you do not already have an adequate supply of anti-ESD bags or containers available, Teledyne API's Customer Service department will supply them. Follow the instructions listed above for working at the instrument rack and workstation.

APPENDICES

Appendix 1	Data Buffer Structure	List of the sampling and measurement data contained in the Buffer
Appendix 2	ALARM Message Codes	How to interpret the Alarm message codes
Appendix 3	WARNING Message Codes	How to interpret the Warning message codes
Appendix 4	Spare Parts	List of spare parts for the instrument

APPENDIX 1: Data Buffer Structure

The table below shows the structure of the data stored in the instrument's Data Buffer. Note that dates are in European format.

Term	Description	Format	Unit
Record	Record number (internal index number)	####	
Sampling start	Sampling start date/time	##/##/## ##:##	mm/dd/yy hh:mm
Sampling end	Sampling end date/time	##/##/## ##:##	mm/dd/yy hh:mm
Cycle	Cycle number	####	
Filter	Filter number	####	
Accumulation Step	Number of samplings performed on the filter	###	
Line	Sampling line	A or B	
Power down	Duration of the power loss or outage relative to the cycle (battery operation)	##.##	hours:min
Leak test	Leak test result	##.##	mL/(min kPa)
Span test	Span test result	##.#	%
Inlet volume	Total sampled volume	###.###	m^3
Standard Volume	Total sampled volume under standard conditions(default:273.1K;101.3kPa)	###.###	Nm^3
Sampling time ratio	Percentage of the actual sampling time compared to the programmed time	###.#	%
Min.Ext.Temp.	Minimum external temperature during the sampling process	###.#	K
Avg.Ext.Temp.	Average external temperature during the sampling process	###.#	K
Max.Ext.Temp.	Maximum external temperature during the sampling process	###.#	K
Min.Filter Temp.	Minimum temperature in the accumulation area during the sampling process	###.#	K

Term	Description	Format	Unit
Filter RH	Average RH value in the accumulation area during the sampling	###.#	%
Avg.Filter Temp.	Average temperature in the accumulation area during the sampling process	###.#	K
Max.Filter Temp.	Maximum temperature in the accumulation area during the sampling process	###.#	K
Min.Atm.Press.	Minimum atmospheric pressure	###.#	kPa
Avg.Atm.Press.	Average atmospheric pressure	###.#	kPa
Max.Atm.Press.	Maximum atmospheric pressure	###.#	kPa
RSD	*RSD* variable value (see Section 2.4)	##.#	%
Initial Press.Drop	Initial filter pressure drop	##.#	kPa
Final Press.Drop	Final filter pressure drop	##.#	kPa
Max.Press.Drop	Maximum filter pressure drop	##.#	kPa
max.DT	Maximum difference between the external temperature and the temperature in the accumulation area(Maximum ΔT value)	± ###.#	K
max.DT Time	Maximum ΔT date and time	##/##/## ##:##	mm/dd/yy hh:mm
DT>5 K Time	Time for which max ΔT exceeded the threshold value of 5K	###:##	hhh:mm
Avg.DT	Average ΔT value during the sampling process	##.#	K
Dark	ß flux background radioactivity	####	Counts/min
Air (Blank)	ß flux in air (blank session)	#########	Counts/min
Spy Blank	β flux through the spy filterduring the *blank* measurement session	#########	Counts/min
Spy Blank SD	Standard deviation of the β flux through the spy filter during the *blank* measurement session	######	Counts/min
Blank	β flux through the blank filter	#########	Counts/min
Blank SD	Standard deviation of the β flux through the blank filter	####	Counts/min
Temp.Blank	Temperature at the blank filter measurement location	###.#	K
Press.Blank	Pressure at the blank filter measurement location	###.#	kPa
Geiger HV Blank	Geiger voltage during the *blank* measurement session	###.#	V
RH Blank	RH during the *blank* measurement session	###	%
Air (Collect)	β flux in air (Collect session)	#########	Counts/min
Nat.Rad.	β flux natural radioactivity	#####	Counts/min
Spy Collect	β flux through the spy filter during the *collect* measurement session	#########	Counts/min

Term	Description	Format	Unit
Spy Collect SD	Standard deviation of the β flux through the spy filter during the *collect* measurement session	######	Counts/min
Collect	β flux through the sampled filter	#########	Counts/min
Collect SD	Standard deviation of the β flux through the collect filter	####	Counts/min
Temp. Collect	Temperature at the sampled filter measurement location	###.#	K
Press. Collect	Pressure at the sampled filter measurement location	###.#	kPa
Geiger HV Collect	Geiger voltage during the *collect* measurement session	###.#	V
RH Collect	RH during the *collect* measurement session	###	%
PBL	PBL mixing status counts	#####	Counts/min
Mass	Sample mass	+/- #######	μg
Mass Error	Mass calculation error	###	μg
Conc.	Sample concentration	+/- ####.#	μg/m³
Standard Conc.	Concentration under standard conditions	+/- ####.#	μg/Nm³
Validation bit	Datum validation bit (0=valid; 1=invalid)	#	
Warnings	Warning bits	########	

APPENDIX 2: Alarms

If the instrument stops due to a failure, the display will show a message ("ALARM") specifying the type of the error in the following form:

*** SYSTEM ALARM***	DATE	HOUR
20 FILTER	ERROR 2	

If the Alarm message pertains to the "plate", the following codes will be added to the error message:

- "128" if a sensor reading error has occurred
- "16" if a repositioning attempt occurred
- "144" if both the preceding conditions occurred

The table below provides the meanings of the alarm codes

SYSTEM ALARM	ERROR
System alarm 10: PLATE Plate movement	1= Communication timeout 2= Invalid position 3= Final position different from the requested position 4= Position code not identified 5= Starting code achieved after the programmed number of steps 6= Code not reached within the programmed number of steps 7= Code reading error 8= Deceleration not performed within the programmed number of steps 9= Position not reached within the programmed number of steps 10= Movement hampered by an incorrect cylinder position
System alarm 20: FILTER (loader) Filter loading	1= Communication timeout (*) 2= Insufficient service pressure 3= Starting cylinder position RUN (*) 4= Starting cylinder position UP (*) 5= Unlocked Loader (*) 6= Filter not ready (*) 7= Plate is in the wrong position 8= Upward movement timeout 9= Downward movement timeout 10= Second cylinder up attempt has occurred (*) 11= Second cylinder down attempt has occurred (*) 12= Filter not loaded at the end of the attempts (*) 13=Loader empty (reserve on) (*) 14=Loader empty (reserve off) (*)
System alarm 31 : FILTER A UP Cylinder Up positioning Line A	1= Communication timeout (*) 2= Service pressure lower than 140 kPa 3= Filter presser piston already moving (*) 4= Filter presser piston already UP (*) 6= Piston stuck in DOWN position 7= Plate in wrong position 8= Piston upward movement timeout (*) 10= Second piston up attempt has occurred (*)

(*) Alarm messages displayed only in the system LOG and available only to Technical Assistance Service

SYSTEM ALARM	ERROR
System alarm 32: FILTER A DOWN Cylinder Down positioning Line A	1= Communication timeout (*) 2= Service pressure lower than 140 kPa 3= Filter presser piston already moving (*) 5= Filter presser piston already DOWN (*) 6= Piston stuck in UP position 7= Plate in wrong position 9= Piston downward movement timeout (*) 11= Second piston down attempt has occurred (*)
System alarm 34: FILTER B UP Cylinder Up positioning Line B	1= Communication timeout (*) 2= Service pressure lower than 140 kPa 3= Filter presser piston already moving (*) 4= Filter presser piston already UP (*) 6= Piston stuck in DOWN position 7= Plate in wrong position 8= Piston upward movement timeout (*) 10= Second piston up attempt has occurred (*)
System alarm 35: FILTER B DOWN Cylinder Down positioning Line B	1= Communication timeout (*) 2= Service pressure lower than 140 kPa 3= Filter presser piston already moving (*) 5= Filter presser piston already DOWN (*) 6= Piston stuck in UP position 7= Plate in wrong position 9= Piston downward movement timeout (*) 11= Second piston down attempt has occurred (*)
System alarm 50: UNLOADER Filter unloading	1= Communication timeout (*) 2= Service pressure lower than 140 kPa 3= Filter unloading piston already moving (*) 4= Filter unloading piston already UP (*) 6= The Unloader is not correctly locked (*) 7= Plate in wrong position 8= piston upward movement timeout 9= piston downward movement timeout 10= Second cylinder up attempt has occurred (*) 11= Second cylinder down attempt has occurred (*)
System alarm 70: VALVE A Regulation valve Line A	1= Communication timeout during the reset process 2= Valve limit switch closed 5= First reset attempt has occurred 6= Second reset attempt has occurred
System alarm 71: VALVE B Regulation valve Line B	1= Communication timeout during the reset process 2= Valve limit switch closed 5= First reset attempt has occurred 6= Second reset attempt has occurred
System alarm 80: ADC ADC converter	9= Sensor reference voltage outside the limit of 4.62 to 4.98 volts (for 10 consecutive readings)
System alarm 92: LEAKTEST A LeakTest Line A	1= Leak exceeds the allowable limit
System alarm 93: LEAKTEST B LeakTest Line B	1= Leak exceeds the allowable limit
System alarm 94: MANUAL LEAKTEST A Manual LeakTest Line A	1= Leak exceeds the allowable limit
System alarm 95: MANUAL LEAKTEST B Manual LeakTest Line B	1= Leak exceeds the allowable limit
System alarm 96: SPANTEST A SpanTest Line A	2= Deviation exceeds the allowable limit
System alarm 97: SPANTEST B SpanTest Line B	2= Deviation exceeds the allowable limit

SYSTEM ALARM	ERROR
System alarm 63: BETA MOVE Beta measurement system movement	1=Communication timeout 2=Position sensor reading invalid 3=Beta position sensor reading invalid 4=Arrival position identification code invalid 5=Wrong position (*) 6=Final position not reached 7=Stuck in starting position 8=Shield movement end position not achieved
System alarm 64: BETA RESET Beta measurement system movement	3= Maximum number of reset attempts exceeded
System alarm 100: SLAVE Master-slave communication	1= Number of consecutive failed communications exceeds the allowable limit

(*) Alarm messages displayed only in the system LOG and available only to Technical Assistance Service

APPENDIX 3: Warnings

When some parameters do not satisfy the applied quality standards the instrument generates a **Warning** message. These conditions do not cause interruption to the normal sampling and measurement operation cycles, but can affect data quality. Warnings are for informing the user and/or the maintenance engineer about the need for targeted controls (automatic indication of "Warning" causes). They are signaled by a yellow LED on the control panel, displayed in the *Instrument Info* menu, and stored in the *Data Buffer*.

The WARNING message appearing in the "Data Buffer" consists of 8 hexadecimal digits.
Each digit represents 4 bits (0=0000 and F=1111), therefore 8*4 bits = 32 bits. The order of the bits, from left to right, is from the most significant (bit31) to the least significant one (bit0).

Hexadecimal to Binary conversion:

0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Use the following table to identify the relevant error code(s);

Digit	Value	Bit	Status	
1	8	**31**	Service air pressure higher than 300 kPa	SERVICE PRESSURE HIGH
	4	**30**	Service air pressure lower than 140 kPa [≤ 100 kPa → Alarm]	SERVICE PRESSURE LOW
	2	**29**	Loss of Power condition – battery running	POWER DOWN CONDITION
	1	**28**	Low auxiliary battery voltage (*Battery Test*, default 22V)	LOW BATTERY VOLTAGE
2	8	**27**	Not used	
	4	**26**	Optical Particle Counter Alarm	OPC ALARM
	2	**25**	Internal cooling fan failure	INTERNAL FAN FAILURE
	1	**24**	Temperature sensor failure. The instrument uses the default value 293 K (programmable value) if the temperature sensors are incorrectly connected or malfunctioning (see section 5.5).	TEMPERATURE SENSOR FAILURE
3	8	**23**	Invalid data. Activated if Warning 16 or 17 is active or if the actual sampling time percentage is less than the programmed value (default is 75%).	QC: CHECK DATA
	4	**22**	Long term Geiger instability. The percentage difference between the air counts value and the reference value is higher than the expected threshold.	GEIGER ZERO DRIFT
	2	**21**	The sampling and measurement cycle has been stopped by the operator	CYCLE ABORT
	1	**20**	Not used	
4	8	**19**	The measured value of the background noise is outside the range of 1 to 250 cpm	DARK COUNTS OUT OF LIMITS
	4	**18**	Short Term Geiger Instability The measured counts ratio for the β flux is not compatible with Poisson statistics (which describe radioactive decay).	GEIGER INSTABILITY
	2	**17**	The measured value of the Blank counts is not between 20.000 cpm and the air beta flux counts	BLANK COUNTS OUT OF LIMITS
	1	**16**	The Geiger detector voltage is outside the range of 585 to 615 volts	GEIGER VOLTAGE OUT OF LIMITS
5	8	**15**	During the mass measurement cycle, the standard deviation value of the Geiger detector voltage is greater than 1 Volt	GEIGER VOLTAGE STDEV OUT OF LIMITS
	4	**14**	In the “Beta Auto Span Test” the percentage deviation between the nominal and the measured value of one or both the reference membranes is greater than ± 5%	BETA TEST OUT OF LIMITS
	2	**13**	In the “Pneumatic Auto Span Test” performed at the beginning of the sampling process, the percentage deviation from the starting calibration value is greater than ± 4% [± 10% → Alarm]	SPAN TEST OUT OF LIMITS
	1	**12**	In the “Pneumatic Auto Leak Test” performed at the beginning of the sampling process, the specific leak is higher than 5 mL/(min*kPa) [10 mL/(min*kPa) → Alarm] In the “Pneumatic Manual Leak Test” performed by the operator, the specific leak is higher than 15 mL/(min*kPa) [30 mL/(min*kPa) → Alarm]	LEAK TEST OUT OF LIMITS

Digit	Value	Bit	Status	
6	8	**11**	Not used	
	4	**10**	Upside-down filter cartridge. During filter loading, the instrument noticed an upside-down filter cartridge. The pair of filters containing the upside-down filter cartridge has been discarded and replaced with the following pair.	UPSIDE-DOWN FILTER
	2	**9**	Pressure sensor malfunction. The condition P(pump)<P(line)<P(atmospheric) was violated	PRESSURE SENSOR FAILURE
	1	**8**	Maximum filter pressure drop limit reached (60 kPa)	MAX. PRESSURE DROP LIMIT
7	8	**7**	Minimum filter pressure drop limit reached (2 kPa at $2.3m^3/h$)	MIN. PRESSURE DROP LIMIT
	4	**6**	Minimum flow rate limit reached (value programmed by the operator)	MIN. SET FLOW RATE LIMIT
	2	**5**	Maximum filter pressure drop limit reached (programmed by the operator)	MAX. SET PRESSURE DROP LIMIT
	1	**4**	Minimum filter pressure drop limit reached (programmed by the operator)	MIN. SET PRESSURE DROP LIMIT
8	8	**3**	The value of the differential pressure transducer offset is unstable. During transducer offset control, the difference between two consecutive readings (2 second intervals) is greater than 5 mV	OFFSET INSTABILITY
	4	**2**	Pressure sensor calibration constants out of range (the pressure transducer offset is outside the range of 0.2 to 0.6 volts or the constant is outside the range of 120 to 135)	PRESSURE SENSOR CALIBRATION
	2	**1**	The upper limit of the sampling flow rate regulation valve has been reached	VALVE UPPER LIMIT
	1	**0**	The lower limit of the sampling flow rate regulation valve has been reached	VALVE LOWER LIMIT

<u>EXAMPLES</u>:

Warning message	Digit/Weight	Bit	Status
0 0 0 8 0 0 0 0	4th digit = 8	19	DARK counts outside the range of 1 to 250 cpm
0 0 0 0 0 0 2 0	7th digit = 2	5	Maximum filter pressure drop limit reached
0 4 0 0 0 0 0 1	2nd digit = 4	26	Optical Particle Counter Alarm
	8th digit = 1	0	Valve lower limit reached
0 0 0 0 0 0 5 0	7th digit = 5 = 4 + 1	6	Minimum flow rate limit reached
		4	Minimum filter pressure drop limit reached

APPENDIX 4: Spare Parts List

(Reference) 073120000 3/19/2012 2:13:37 PM

PARTNUMBER	DESCRIPTION
067010000	SAMPLE INLET, BGI VSCC-A PM 2.5 CYCLONE
072200000	INLET, 1ST STAGE, US EPA PM10 16.7 LPM
073100000	ASSY, PM2.5 INLET SYSTEM (PM10+PM2.5)
073110000	SAMPLE INLET, BGI VSCC-A PM 1 CYCLONE
073140000	REMOTE COMMUNICATIONS SOFTWARE
073160000	AKIT, AUDIT KIT
073170000	AKIT, REFERENCE (R1/R2) FILTER HANDLING
DU0000001	ADAPTER, FLOW RATE CAL CHECK @ INSTRUMEN
DU0000002	ADAPTER, FLOW RATE CAL CHK @ SAMPLING
DU0000003	FILTER, 'BLIND' FOR LEAK TEST
DU0000004	PLUG, LEAK TEST
DU0000005	KIT, ZERO TEST
DU0000006	KEY, CLAMPING, FILTER CART LOCK
DU0000007	TWEEZERS, REF MEMBRANE FILTR CART
DU0000008	DINKING DIE, REF MEMBRANE
DU0000009	ROOF FLANGE KIT, 3PC
DU0000010	SUPPORT QUADRAPROD FOR PIPING KIT
DU0000015	KIT, REF MEMBRANE, MASS CAL CHECK, HM
DU0000016	KIT, REF MEMBRANE, MASS CAL CHECK
DU0000017	ASSY, PNEU BOX W/FLOW CHK LINES, M602
DU0000018	ASSY, SOLENOID VALVE
DU0000019	BATTERY, 12V, 3.5Ah
DU0000020	KIT, FUSES FOR M602
DU0000021	PCA, GEIGER BOARD FOR M602-HM
DU0000022	PUMP, ROTARY VANE VACUUM, 110V
DU0000023	KIT, ROTARY VANE VAC PUMP MAINTENANCE*
DU0000024	PCA, PUMP ACTIVATION 110V
DU0000025	PCA, -02 POWER SUPPLY
DU0000026	PCA, CPU MB, W/O MASTER PROGRAM'D
DU0000027	PCA, CPU MB,ADD ON PROGRAMMED
DU0000028	PCA, GEIGER HIGH VOLTAGE
DU0000029	PCA, SENSOR 1 PRESS & TEMP
DU0000030	PCA, SENSOR 2 PRESS & TEMP
DU0000031	PCA, MASTER MICROPRSSR, PROGRAMMED
DU0000032	ASSY, EXT TEMP SENSOR
DU0000033	ASSY, STRAP GROUP, M602-HM
DU0000034	ASSY, COMPRESSOR, SERVICE AIR, 110V
DU0000038	FILTER, REF1, BETA TEST W/KNOWN MASS, HM
DU0000039	FILTER, REF1, BETA TEST IN AIR, HM
DU0000044	CONN, INLET SUCTION, 1 HR MEAS
DU0000045	CONN, INLET SUCTION, 24 HR MEAS
DU0000046	ASSY, HEATER, SMART
DU0000047	ASSY, PM10 PRE-IMPACTOR USA 1M3/H NOZZ
DU0000049	TOOL, PRESSURE COUPLED FILTER CARTRIDGES
DU0000050	ROOF FLANGE, SAMPLING LINES TO SHELTER
DU0000051	Sample Tube Extension Kit, 0.5m

PARTNUMBER	DESCRIPTION
DU0000052	Sample Tube Extension Kit, 0.75m
DU0000053	Sample Tube Extension Kit, 1m
DU0000054	SUPPORT, TRIPOD FOR PIPING KIT, FAI
DU0000055	FILTER, SPAN TEST AIR LINLET
DU0000056	RING, W/POROUS SPPRT, IN-SAMP FILTER
DU0000057	POROUS SUPPORT W/O RING 5 PK
DU0000058	FILTER, VACUUM PUMP SILENCER*
DU0000059	SENSOR, PNEU CYL POSITION MECH MOVE
DU0000060	FILTER, POWER SUPPLY
DU0000061	PIPE, CONNECTION FOR SERVICE AIR
DU0000062	CLUTCH, 01, RAPID FOR SERVICE AIR CONN
DU0000063	CLUTCH, 02, RAPID FOR SERVICE AIR CONN
DU0000064	PCA, DISPLAY
DU0000065	TUBE, GEIGER MULLER
DU0000066	MODULE, GEIGER MULLER, CMPLT, SWAM5a-DC
DU0000067	WIRING, HV BD TO GEIGER BD
DU0000068	BELT, TOOTHED, ROTATING PLATE
DU0000069	BELT, TOOTHED, GEIGER ARM
DU0000070	PUMP, ROTARY VANE VACUUM, DUST SUC 230V
DU0000071	PIPE, SAMPLER TO SUCTION PUMP W/FILTER
DU0000072	PIPE, SAMPLER TO SUCTION PUMP W/O FILTER
DU0000073	PCA, CONT-01 ANALOG OUTPUTS
DU0000074	FILTER, LED, CN2-02 LOWER PCA ON PLATE
DU0000075	FILTER, PHOTOSENSOR, CN3-02 UPPER PCA
DU0000076	FILTER, LED, CN4 RIGHT PCA, RESERVE
DU0000077	FILTER, LED, CN5 LEFT PCA, RESERVE
DU0000078	SENSORS W/PCA, MAG, SOURCE SHIELD POSITI
DU0000079	PCA, OC1 PLATE POSITION PHOTOSENSOR
DU0000080	PCA, OC2A UNLOADER PRESENCE PHOTOSENSOR
DU0000081	PCA, OC2B LOADER PRESENCE PHOTOSENSOR
DU0000082	PCA, PROGRAMMED MASTER MICROPROCESSOR
DU0000083	PCA, INTERCONNECTION, SWAM5a-DC
DU0000084	PCA, MOTEV, SWAM5a-DC
DU0000085	PCA, ACDRV-01 PUMP ACTIVATION & AUX 110V
DU0000086	PCA, SENSOR-02 PRESS & TEMP SENSORS
DU0000087	PCA, ADDITIONAL SENSORS
DU0000088	PCA, SENSORS 2
DU0000089	PCA, G-01 GEIGER, SWAM5a-DC
DU0000090	SENSOR, ATMOSPHERIC PRESSURE
DU0000091	SENSOR, FLOW TEMPERATURE
DU0000092	SENSOR, DIFFERENTIAL PRESSURE
DU0000093	SENSOR, FILTER TEMPERATURE
DU0000094	SENSOR, DRAWER TEMPERATURE
DU0000095	SENSOR, INTERNAL FAN TEMPERATURE
DU0000096	FAN, INTERNAL
DU0000097	PROBE, GEIGER TEMPERATURE
DU0000098	KIT, SAMPLING INLET O-RING SET
DU0000099	SWITCH, POWER SUPPLY
DU0000100	VALVE, FLOW REGULATION SWAM5a-DC

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PARTNUMBER	DESCRIPTION
DU0000101	WIRING, GEIGER, SWAM5a-DC
DU0000102	WIRING, SOURCE SHIELD POSITION SWAM5a-DC
DU0000103	WIRING, FLW REG VLV END-OF-STROKE LINE A
DU0000104	WIRING, FLW REG VLV END-OF-STROKE LINE B
DU0000105	KEYBOARD, MEMBRANE (TELEDYNE BRAND)
DU0000106	VALVE, SOLENOID N/A FOR LEAK TEST
DU0000107	VALVE, SOLENOID N/C FOR SPAN TEST
DU0000108	BETA SOURCE HOLDER SWAM DC
DU0000109	COUPLING, THERMIC INSUL, LINE/INSTR CONN
DU0000110	WIRING, 24V BATTERIES
DU0000111	MANIFOLD, SAMPLING LINE
DU0000112	SPHERIC JOINT
DU0000113	KIT, PIPING NO 1
DU0000114	MODEM, GSM FOR REMOTE CONNECTION
DU0000115	SUPPORT, FILTER INSERTION INTO LOADER
DU0000116	TOOL, AUX, FILTERS INSERT INSIDE LOADER
DU0000117	CASE, REFERENCE FILTERS
DU0000118	CARTRIDGE, WHT FILTER 5.20CM2 INT AREA
DU0000119	CARTRIDGE, WHT FILTER 7.07CM2 INT AREA
DU0000120	CARTRIDGE, WHT/BLK FILTER 5.20CM2
DU0000121	CARTRIDGE, WHT/BLK FILTER 7.07CM2
DU0000122	CARTRIDGE, WHT/WHT FILTER 47MM
DU0000123	CARTRIDGE, WHT/BLK FILTER 47MM
DU0000124	VIRGIN FILTER LOADER
DU0000125	SAMPLED FILTER LOADER
DU0000142	Standard Sampling Tubing Install Kit - 2
DU0000143	Inlet to Sample Tube Coupler Assembly
DU0000144	1" Sample Tube Coupler Assembly
DU0000184	PARTICLE SCRUBBER FILTERS, M602*
DU0000185	CLEAR TUBING, PUMP OUTPUT, M602*
DU0000187	HIGH HUMIDITY ANTI-CONDENSATION DEVICE (602)
FL0000045	FILTER, GF10, 200 PACK, WHATMAN
HW0000712	1U ADJUSTABLE ANGLE BRACKET