COLORADO
Department of Public Health & Environment

Air Pollution Control Division

Technical Services Program

APPENDIX PM4

STANDARD OPERATING PROCEDURE FOR THE DETERMINATION OF PM_{10} AND $PM_{2.5}$ IN AMBIENT AIR USING A GRIMM EDM 180

GENERAL INFORMATION

1.1. Purpose

These procedures are intended to supplement the GRIMM EDM 180 operating manual. It is recommended that the GRIMM Manual be utilized in conjunction with these written procedures during installation, operation, service, and calibration.

2.0 GENERAL DESCRIPTION

2.1. Safety

2.1.1. Electric Safety

Prior to powering on the instrument verify the voltage from the circuit supplying power is within the manufacturer's guidelines. Operate the GRIMM only with the designated voltage and the original external power supply. The Lithium battery (SL-389; 3,6V; 1AH) on the digital circuit board provides power for the operation of the internal clock. This battery should have an operational life of at least two years but should only be replaced by trained personnel. Fuses built into the instrument may only be changed by trained service personnel.

2.1.2. Laser safety

Caution! The GRIMM uses a Class 3B Optical laser. The instrument should only be opened by GRIMM trained service personnel. During the opening of the laser unit, especially the sample chamber, laser radiation can be released. Looking directly into the laser can result in eye damage.

2.2. Overview

The GRIMM EDM 180 was developed by GRIMM AEROSOL Technik GmbH & Co. to measure particulate matter mass concentrations continuously and report PM_{10}, $PM_{2.5}$, and (where appropriate) PM_1. There are not cut points to maintain with the GRIMM, it counts particles in 31 different size bins, converts the counts to mass and utilizes controlled flow to report mass concentration in units of $\mu g/m^3$. The microprocessor-based unit accommodates all siting requirements and provides internal data storage and analog and serial data input/output capabilities. In March 2011 the United States Environmental Protection Agency (U.S. EPA) designated the GRIMM EDM 180 Monitors as an equivalent method for the determination of $PM_{2.5}$ concentrations in ambient air. The GRIMM EDM180 draws the sample through a stainless steel downtube (d_i=3mm) into the detection chamber. The particulate matter in the sample stream are classified by size and counted inside the detection chamber through scattering light measurement.

A laser collimator generates a homogeneous optical field; a light trap is used to assure low noise due to scattered light. An inlet on the sample chamber focus' particles into this optical field (see
Figure 2). Every particle scatters light; when the particulate-laden sample air is pulled through the sample chamber the scattered light is sent via a mirror to a detector where the light intensity is measured. The particle size is proportional to the intensity of the reflected light beam. The count rate is determined from the particle count and the volumetric flow rate. Having known particle diameters and an assumed density(s) the particle mass can be calculated from the particle count, the method assumes the particles are spherical. The intensity of the scattered light can be influenced by the particle shape and its refractive index. However, this influence is very small at typical atmospheric concentrations. The GRIMM generates mass concentrations for PM_{10}, $PM_{2.5}$, and PM_1 with six seconds of resolution.

3.0 GENERAL OPERATION

3.1. Key Pad

The GRIMM EDM 180 is equipped with an external keypad on the front panel (see **Error! Reference source not found.**). The following is a summary of the functions of the keypad in various modes of operation:

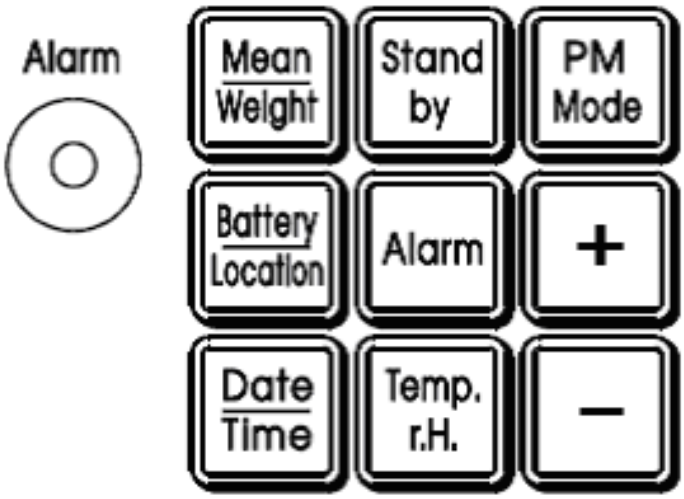

Figure 1: GRIMM EDM 180 Keypad

Keypad functions

Immediately after powering up the GRIMM EDM 180

Mean/Weight	Display of the net weight of all measurements and the accompanying sample volume. It will remain on the display as long as the key pressed.
Stand-by	Display of the serial number and the operation time.
+	Filter changed. The filter weight and averages will be deleted. The device starts the self-test.
-	Filter not changed. The averages will be deleted. The device starts the self-test.

Keypad functions while instrument is running

Mean/Weight	Displays the averages of the dust concentration of all valued measurements (PM_{10}, $PM_{2.5}$, PM_1) after switching on the device or deleting the averages with the related sample volume. The averages related sample volume appears after approximately 5 seconds and remains displayed as long as the key is being pressed. By pressing the [Mean Value] key and the [+] key at the same time the filter weight and its related sample volume can be displayed.
Stand-by	Pressing this key the places the instrument into stand-by mode.
PM Mode	Pressing this key will temporarily halt measurement and output.
Battery/Location	Pressing this key will show the set measuring location number. This number can be changed by pressing + and – at the same time. As the GRIMM is only operated by line voltage (e.g. no battery) the battery capacity will constantly be shown with 130%.
Alarm	Pressing this key will display the current alarm state.
+	Will enable cyclic display of the sensor values.
Date/Time	Pressing this key will show the current date and time.
Temp./r.H.	Display the current state of temperature and relative humidity by pressing this key.
-	Pressing this key will disable the cyclic display of the sensor values.

Keypad functions within the stand-by mode

Mean/Weight	Displays the averages of the dust concentration of all valued measurements. Holding the key and pressing '-'at the same time will reset the mass and volume averages.
Stand-by	Will initiate operation of the sampler from stand-by mode.
PM Mode	Additional pressing of the key [+] or [-] enables the user to select two preferred PM values to display.
Battery/Location	Pressing the keys [Battery/Location] and [+] or [-] at the same time lets you change the measurement location number. It serves the identification of different measurements and can be set from 1 through 99.
Alarm	Pressing this key in connection with the [+] or [-] key the mass level can be set from which on the alarm will be going off (0 means Off).
+	Enhance the memory interval (only with installed storage card) respectively displaying the mailbox and scroll up (only with installed modem).

Date/Time	Pressing this key will display the date and time. Pressing and holding this key will allow the user to set the date and time. The blinking cursor can be moved by the keys [+] or [-]. Pressing Date/Time again will move the cursor on. Pressing no key for a longer period of time will switch the device back into the stand-by mode. Changing the minutes will zero the seconds.
Temp./R.H	Pressing this key will display the current sensor values on the display (upper line) and the time (lower line). Pressing it again will halt the display of the current sensor values. In this mode it is possible to switch on the vacuum pump with pressing [-] and the sample pump with pressing [+].
-	Decrease the storage interval (only with installed storage card) respectively displaying the mailbox and scrolling down (only with installed modem).

3.2. Drying

The ambient relative humidity and the temperature are measured by the external sensor. The default setting for dryer activation is when relative humidity exceeds 55%. When the dryer flow is switched on the sample is redirected over a Nafion membrane. Nafion enables the removal of humidity from the sample by drawing water molecules through ion channels in the membrane. A vacuum pump then removes the humidity via a condensate outlet. The dryer shuts off automatically when the ambient relative humidity drops below 50%. The default setting for dryer activation can be changed through the RS232 interface, see the RS232 detail below for more detail.

3.3. Software Configuration

The GRIMM EDM 180 arrives after having undergone extensive checks at the factory and again when the unit arrives in the United States. The GRIMM can be configured to report PM concentrations or PM counts in 31 separate size bins. Unless there is a specific reason to report counts APCD configures all GRIMMs to report PM concentrations. Consult the manual for additional specific options.

3.4. GRIMM EDM 180 Data Output

The GRIMM EDM can be configured to output a line of data (sensor data and mass concentrations) from an interval of six seconds to 1 minute. These settings can be changed using the RS232 interface. An example of data output can be found in the GRIMM EDM 180 Operating Manual and presented here (Fast Output = OFF):

P 15 7 30 8 24 1 0 0 130 7 211 180 0 81 133 0
N_, 299 92 0

3.5. RS232 Interface

RS232 communications with the GRIMM operate with a baud rate of 9600 bps, 8 data bits, one stop bit and no parity. A null modem cable or straight cable with a null modem fitting can be used to connect the GRIMM to a PC or data logger. It is best to communicate with the GRIMM using a terminal program; HyperTerminal is readily available and works well with the analyzer. Once a HyperTerminal session has been established, typing the '?' key on the PC keyboard while in Stand By mode will show the GRIMM RS232 Help window, identifying the available commands (see Figure). Additional explanation of the commands and their purpose can be found in the GRIMM EDM 180 Operating Manual.

4.0 SITE INSPECTIONS

4.1. Weekly Inspection

Note current conditions on the field form and verify continued proper sampler installation (e.g. check for presence of water in the shelter and moisture trap). Note the value the Status and Dryer LEDs. If the Status LED is lit then while the instrument is running press the 'Alarm' key on the front panel, note the value of the Status Code on the form and notify the appropriate APCD personnel.

4.2. Two-Week Inspection

Perform the Weekly Inspection. Additionally perform ambient temperature and pressure verifications. Perform a flow verification after a successful leak check. See Section 5.6 for detailed instructions, below.

4.3. Six-Month Inspection

Perform a two-week inspection. Additionally clean the sample air duct (see Section 5.2) and inspect the dust filter (see Section 5.4) and replace if necessary.

4.4. Annual Inspection/Calibration

A periodic factory inspection/calibration is required to ensure the GRIMM is operating well. Trained service personnel will replace the on-board batteries, inspect and replace the internal rinsing air filter and will calibrate the detector. A detailed description of the detector calibration procedure can be found in the GRIMM EDM 180 Operating Manual.

5.0 MAINTENANCE/VERIFICATION/CALIBRATION PROCEDURES

5.1. Verification Procedures	**Interval**
Batteries	Internal batteries should only be changed by trained service personnel.
Inlet Bug Shield	Inspect and clean if necessary every two weeks
Sample Air Duct	Inspect and clean every six months
Dust Filter	Replace every six months
Leak check	Perform a leak check prior to every two-week verification procedure, every time any part of the flow system is interrupted or broken, and once per year prior to Mass flow controller hardware calibration.
Ambient Temperature	Verify the ambient temperature measurement once every two weeks.
Ambient Pressure	Verify the ambient pressure measurement once every two weeks. Calibrate the sensor once per year or as needed.
Flow audit	Perform flow verification once every two weeks and after every calibration.

5.2. Sample Inlet Bug Screen

Periodically the insect screen should be examined and cleaned if there are any obstructions. Place the instrument in StandBy mode and using clean, compressed air remove any obstructions from the bug screen. Return the instrument to operating mode.

5.3. Sample Air Duct Inside the Optical Chamber

Put the GRIMM in StandBy mode and turn it off using the power switch on the front panel. Remove the sample downtube from the top of the unit and the glass bottle from the front compartment. Blow the sample air duct with clean, oil-free compressed air with a maximum pressure of ~42 psi from the top down, never from the bottom up. After cleaning install the glass bottle and remount the sample downtube. Take care while remounting the bottle as an incorrectly mounted bottle will cause the instrument to leak. Turn the instrument back on and return it to normal operation

5.4. Dust Filter (BQ Filter)

Periodically the dust filter (see flow schematic, above) which collects all of the sampled particulate matter should be changed. Put the instrument in Standby mode and power off using the power button on the front panel. Remove the top cover, the BQ filter can be simply removed from its seat, located near the centerline of the analyzer towards the front. Note the direction of the arrow on the filter as placed prior to removal. Remove the BQ filter and replace as the original was oriented. Replace the top cover and return the instrument to Operating mode. This is also performed at the annual inspection by trained personnel (see Figure).

5.5. Internal rinsing air filter

In order to protect the laser optics from contamination and also to ensure the instrument can perform its self-test routine, particle-free air is generated by an internal fine filter. The life expectancy of this filter is several years; consequently this filter should only be changed by trained service staff. The message, "CHECK NOZZLE AND AIR INLET", may be a sign that the rinsing air supply is not adequate and that the filter must be replaced. Please contact the manufacturer or local sales representative.

5.6. Leak Check Procedure

Using the GRIMM EDM 186 leak check/verification kit (or custom APCD leak check/verification kit) line the face of the silicon stopper with vacuum grease. With the instrument operating place the stopper around the sample down tube immediately beneath the bug shield, the smaller side oriented upwards. Compress the cap (or APCD FTS) around the silicon stopper. Insert the zero test filter onto the cap (and block the manometer port if using an APCD FTS). Wait for one minute and verify that the GRIMM reports a mass concentration of 0 $\mu g/m^3$ for all particulate readings. This results indicates the instrument is pneumatically tight. If a reading other than 0 μ/m^3 is observed the operator should check all the connections and reseat the cap on the silicon stopper. Once a mass concentration of 0 $\mu g/m^3$ is observed the operator can perform the rest of the verification procedures or return the instrument to normal operation. Note the leak check results on the GRIMM field form.

5.7. Ambient Air Temperature Verification

Perform the weekly activities and leak check verifying the ambient temperature.
Follow these steps to verify the ambient air temperature:

1. The instrument's ambient temperature can be viewed on the data logger. If this isn't the case then on the front panel press the **Temp./r.H.** key, temperature is displayed in ^{o}C.
2. Determine the current temperature (°C) at the ambient temperature sensor using an external thermometer, [°C = 5/9 x (°F - 32)].
3. Verify that the reported value of the current ambient temperature is within ± 2° C of the measured temperature. If this is not the case there may be a problem with the external temperature sensor, notify the appropriate APCD personnel.
4. Note the results on the GRIMM log sheet.

5.8. Ambient Pressure Verification

Perform the weekly checks, leak check, and ambient air temperature verification before verifying the ambient pressure

Follow these steps to verify the ambient pressure:

1. The instrument's ambient pressure can usually be viewed on the data logger. If this isn't the case then on the front panel press while the instrument is running press the '+' key to enable the cyclic display of the sensor values. Ambient pressure is displayed in hPa.
2. Determine the current ambient pressure in hPa.
3. Verify the monitor's ambient pressure by measuring the current ambient station pressure with an independent barometer.
   - To convert from hPa to atm divide by 1013.25.
   - To convert from hPa to mm Hg multiply by 0.75012.
5. Verify that the reported value field is within ±10 mm Hg or 0.013 atm of the measured ambient pressure. If this is not the case there may be a problem with the internal pressure sensor, notify the appropriate APCD personnel.
4. Note the results on the GRIMM log sheet

5.9. Flow Verification Procedure

If using an EDM 186 kit then connect one end of the red tubing to a flow audit adaptor. Insert an adapted piece of 1.25" OD downtube into the open end of the flow audit adaptor and a flow transfer standard onto the open end of the adapted downtube. Connect a manometer using appropriate tubing to the flow transfer standard and record the manometer reading (inH_2O) on the form. If using an APCD FTS then simply connect a manometer to the manometer port and record the manometer reading (inH_2O) on the form.

Calculate the flow rate according to the following equation (note the results on the field form):

$Q_{ltp} = ((T_a/P_a)*\Delta H_2O)^{1/2} *m + b$ where

Q_{ltp} = flow rate, actual conditions, liters per minute
Ta = ambient temperature, degrees Kelvin
Pa = ambient pressure, atmospheres
ΔH_2O = manometer reading, inches water
m = flow transfer standard slope
b = flow transfer standard intercept

The acceptable range for a successful flow verification is from 1.08 lpm to 1.32 lpm. However, any flow greater than 1.26 lpm or less than 1.14 lpm should be a possible reason for recalibrating the instrument.

If using an APCD FTS then simply connect a manometer to the manometer port and record the manometer reading (inH_2O) on the form. Calculate the flow rate as above, note the value on the GRIMM log.

6.0 CALIBRATION PROCEDURES

All calibration procedures must be done in the following order.

6.1. Hardware setup Prior to Flow Calibration

Follow these steps to set up the hardware prior to performing any calibration procedure. The operator must first perform a successful leak check, a flow verification and confirmatory flow verification with a different flow transfer standard prior to performing a flow calibration:

1. Place the GRIMM in Standby mode using the front panel or RS232 and turn the power off.
2. Remove the top panel.

Find the pot that controls the flow rate, the pot is located on a blue block with a screw and red polish on it. Turn the power back on; take care to not cause a short in the motherboard by touching it with a metal tool. With a flow

transfer standard in place and after having calculated what the manometer reading should be for a flow rate of 1.2 liters per minute adjust the pot until the desired manometer reading is achieved. Turn the pot clockwise to increase the flow rate and counter clockwise to decrease the flow rate. Make any change incrementally (i.e. small adjustments) until the desired manometer reading is achieved. Verify the flow after calibration with a separate flow transfer standard.

6.1.1. Factory Calibration/Certification

Periodically each EDM 180 needs to be factory recertified to verify each unit is working properly, see the manufacturer's operating manual for full details.

7.0 FIGURES

Figure 2 GRIMM EDM 180 Sample Chamber Configuration

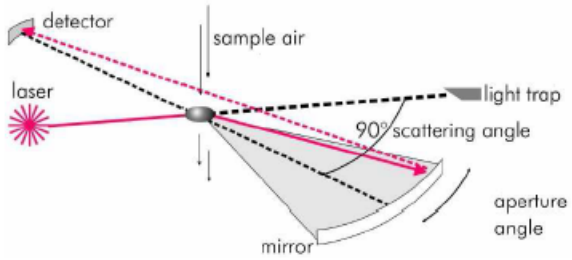

Figure 3 GRIMM EDM 180 Flow Diagram

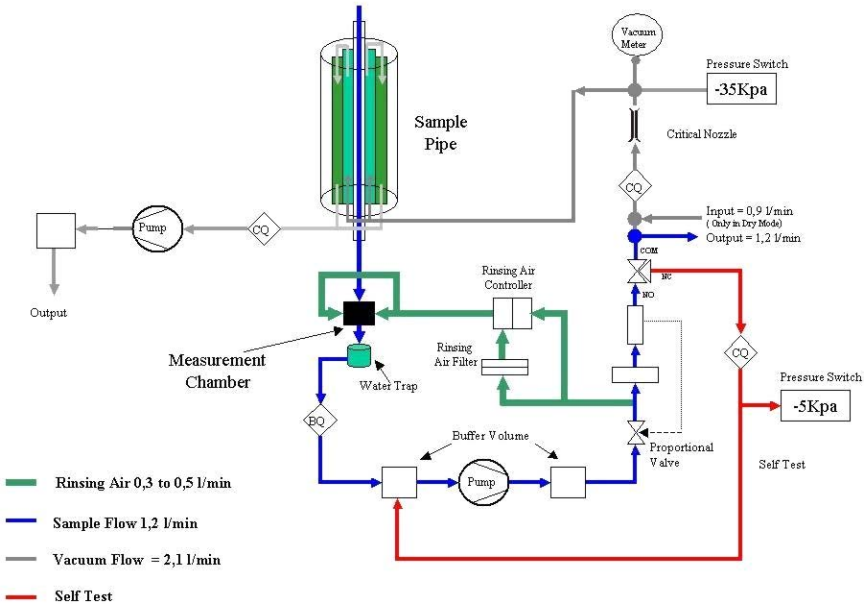

Figure 3 GRIMM EDM 180 RS232 Command List

Figure 5 GRIMM EDM 180 Field Form