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STANDARD OPERATING PROCEDURE
Instructions for Use of ALICAT Flow Meter (MB Series)

KEY WORDS

air sampling, ALICAT flow meter

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1.0 INTRODUCTION

1.1 Purpose

This Standard Operating Procedure (SOP) discusses the use of the ALICAT flow meter (MB Series) for collection of ambient air samples.

1.2 Scope

This document provides specific instructions for the use of ALICAT flow meters: MB-100SCCM (Low), MB-2SLPM (Medium), and MB-20SLPM (High) in measuring volumetric flow rates when collecting air samples using various sampling devices (e.g., regulators, Met-One, SKC Pumps and AirChek Pumps).

2.0 MATERIALS

2.1 ALICAT flow meters

- 2.1.1 MB-100SCCM (Low)
- 2.1.2 MB-2SLPM (Medium)
- 2.1.3 MB-20SLPM (High)

2.2 Calibration Tubing

2.3 Calibration Tubing Adaptor (for regulators)

3.0 PROCEDURES

3.1 General

The ALICAT standard battery-powered volumetric/mass flow meter (MB series) can simultaneously measure mass flow, volumetric flow, gas pressure, and gas temperature for 98+ gases. <u>Please note that volumetric flow rate is used for the collection of ambient air samples (Appendix 2).</u>

3.1.1 Connectors and Buttons

The drawings below (Figure 1) represent typical configurations of a standard ALICAT flow meter.

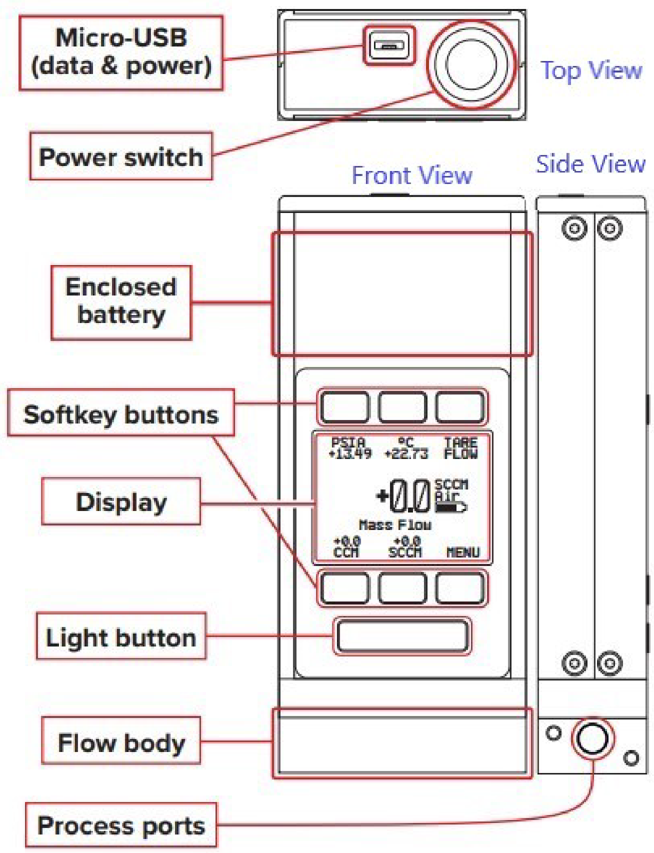

Figure 1. Flow meter Connectors and Buttons

3.1.2 Backlight

The ALICAT monochrome display comes equipped with a backlight. To activate, turn on the device by pressing the power switch on top and press the center of the ALICAT logo on the front of the device (Figure 1). To turn the backlight off press the button again.

3.1.3 Main Display

The main display has two primary functions:

- Collecting real time temperature, pressure, and flow data (Figure 2)
- Changing engineering units (Appendix 1) for temperature, pressure, and flow.

This screen displays real time data for all flow parameters simultaneously. Flow parameters are:

- PSIA - pounds per square inch absolute for pressure
- Temperature in Celsius
- SLPM/SCCM - standard liter per minute or standard cubic centimeters per minute is used for measuring mass flow rate
- LPM/CCM - liters per minute or cubic centimeters per minute is a volumetric flow rate of a gas

Please note that volumetric flow rate is used for the collection of ambient air samples (Appendix 2).

By pressing the button next to any of the four flow parameters, you can highlight its value in the center of the screen. For example, if you press the button next to LPM, the LPM value will be displayed in the center of the screen.

The main display is slightly different in the older (2021) and newer (2022) versions of the ALICAT flow meter. The differences in other screens will be explained in the relative sections.

Figure 2. Main Display

The 6 buttons on the main display have the following functions (Figure3):

1. Highlights *pressure* in the center of the meter.
2. Highlights *temperature* in the center of the device.
3. *Tares* the device's flow measurement (section 3.6.2).
4. Highlights *volumetric flow* rate in the center of the device (default).
5. Highlights standard *mass flow* rate in the center of the device.
6. "Next" enters the optional *flow totalizer* and the menu system (section 3.6).

Figure 3 Main Display Functions

3.2 Calibration

Calibrations are performed by the manufacturer. ALICAT recommends that the flow meter is calibrated every year to ensure the certainty of the readings.

3.3 Charging the Battery

3.3.1 Typical battery life of a fully charged battery is 18 hours with a monochrome display when the backlight is set to full brightness. Dimming the backlight will increase battery life.

3.3.2 The battery indicator on the right side of the main display reflects the relative battery level (Figure 4). When the battery indicator is completely empty, approximately 15 minutes of battery life remains. Please charge the flow meter as soon as possible to maintain full device performance.

3.3.3 Charge the flow meter using the supplied USB cable or any micro-USB cable. You may charge the flow meter using any USB outlet on a computer or portable power supply, but charging will be fastest (approximately 3.5 hours) when connected to the supplied 2.0A power supply. The red indicator LED on top of the device lights up red to indicate that the unit is charging. The red LED turns off when the battery is charged. The flow meter may be used while it is charging. A small lightning bolt symbol (⚡) will appear to the right of the battery symbol while the device is charging. If the battery has been fully depleted, you may need to charge the flow meter for a full minute before the device can be turned on. <u>The device can also be used while plugged to the charger.</u>

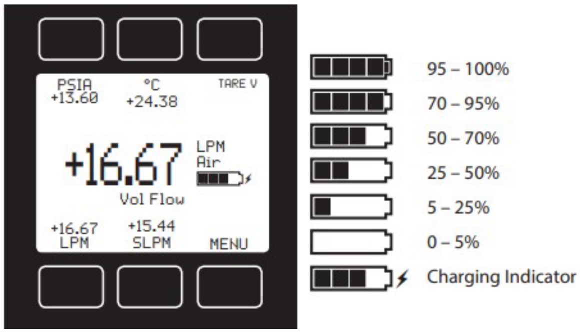

Figure 4. Battery Indicator

3.4 Mounting

You can mount or hold the meter in any position, because the flow meter internally compensates for any changes to its orientation during use. Since the flow meter uses media-isolated sensors, it must be tared (section 3.6.2) after changing the orientation. The flow meter is also minimally affected by vibrations, so it can be rested on top of a vibrating instrument with little impact to measurement accuracy.

3.5 Totalized Flow Data

The optional flow totalizer displays the total amount of mass or volume that has flowed through the instrument since its last reset (Figure 5) You can access the totalizer screen by pressing Next on the main display.

1. V AVG (volume average) shows totalizer averaging, which displays average volumetric flow rate since last reset.
2. LPM or CCM displays the real time volumetric flow rate.
3. V PEAK (volume peak) displays the maximum volumetric flow rate since last reset.
4. TOTAL/TIMER displays totalized flow and elapsed time since last reset.
5. RESET clears all totalized data and immediately resets the timer to 0.
6. MENU enters the main menu.

Figure 5. Totalized flow data

Please note the screen above is from the newer version (2022) of the ALICAT flow meter. The flow totalizer display in the older version (2021) is slightly different. The displays are compared below (Figure 6).

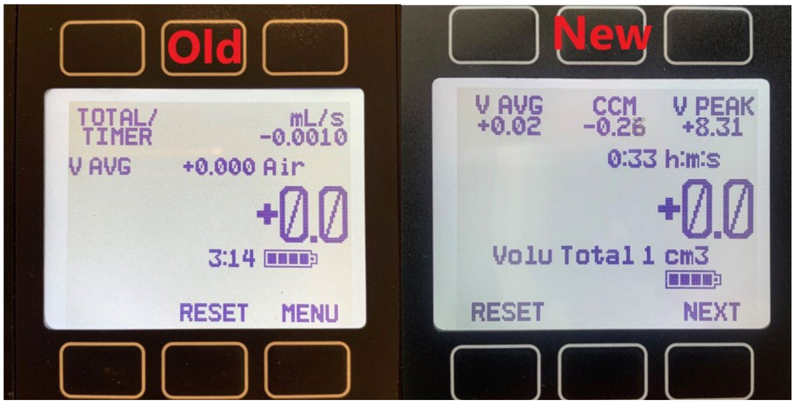

Figure 6. The Flow Totalizer Display in the new and old Version

3.6 Menu

By pressing the **NEXT – MENU** button from the main display, you can enter the MENU system (Figure 7).

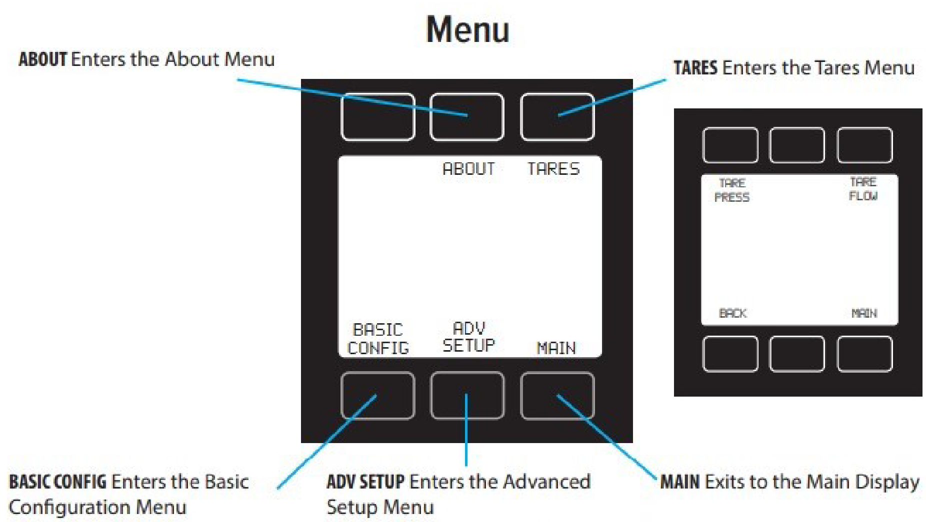

Figure 7. Menu

3.6.1 About

About contains useful information for setup, configuration, and troubleshooting (Figure 8). For more information and instructions on "About" functions please refer to the ALICAT MB Series User Manual.

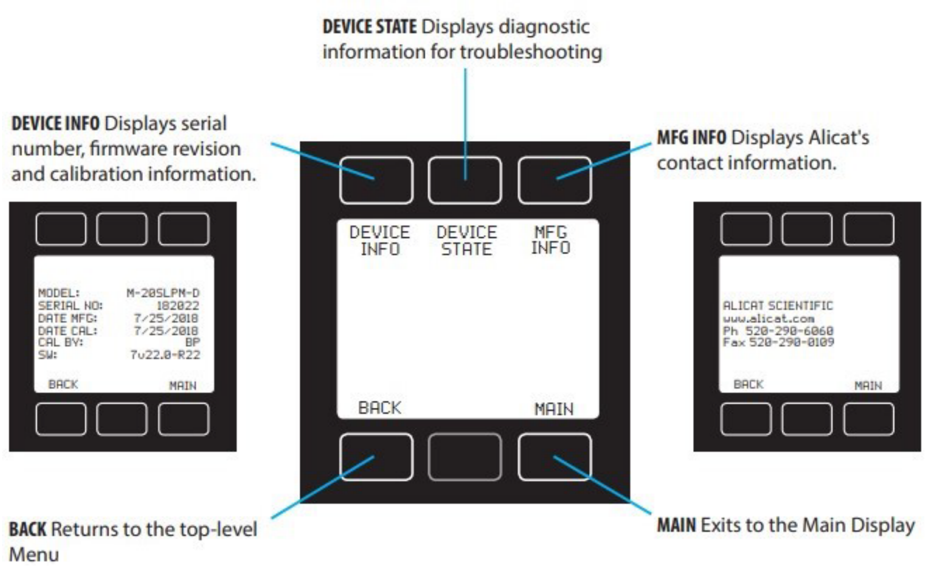

Figure 8. About Menu

3.6.2 Tares

Taring ensures the flow meter provides its most accurate measurements. This function gives the flow meter a zero reference for flow measurements. The flow can be tared from the main display (recommended) by clicking the button next to "TARE FLOW".

3.6.2.1 How to Tare

Ensure that nothing is flowing through the device. Plastic plugs can be used to cover the flow ports, or the flow ports can be simply covered by fingers to stop the flow.

3.6.2.2 When to Tare

- Before every new flow measurement cycle
- After dropping or bumping the flow meter
- After changing the device's orientation

3.6.3 Basic Configuration

The basic configuration menu contains options for choosing the gas calibration, device engineering units and STP/NTP flow references (Figure 9).

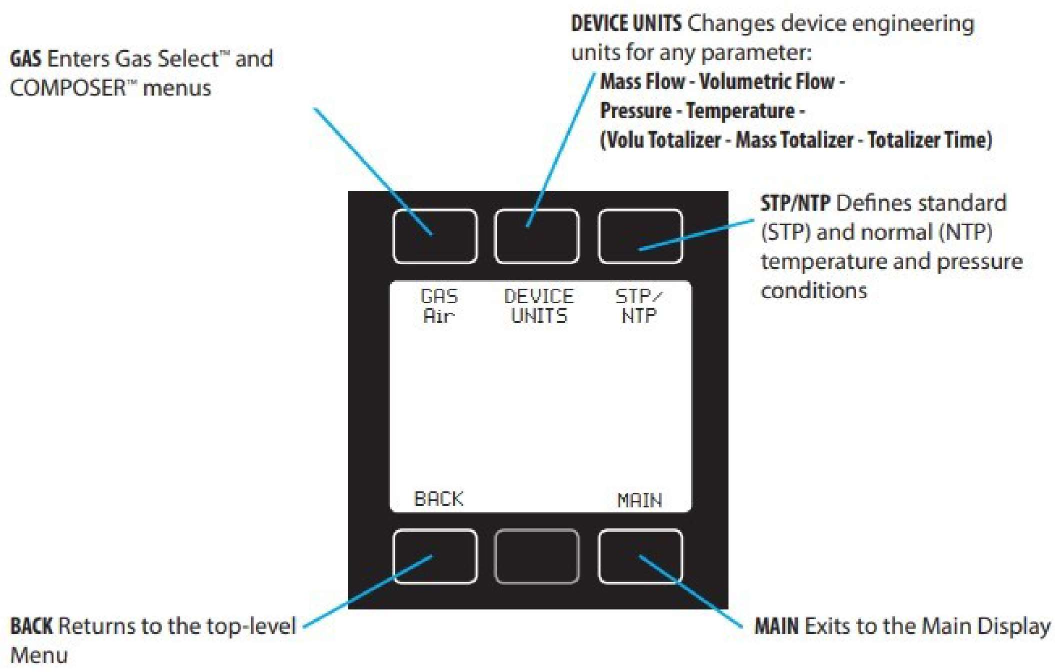

Figure 9. Basic Configuration

For more information and instructions on basic configuration and changing these parameters please refer the ALICAT MB Series User Manual.

3.6.4 Advance Setup

The advanced setup menu lets you configure the display, zero band, averaging (for flow and pressure) and serial communications (Figure 10).

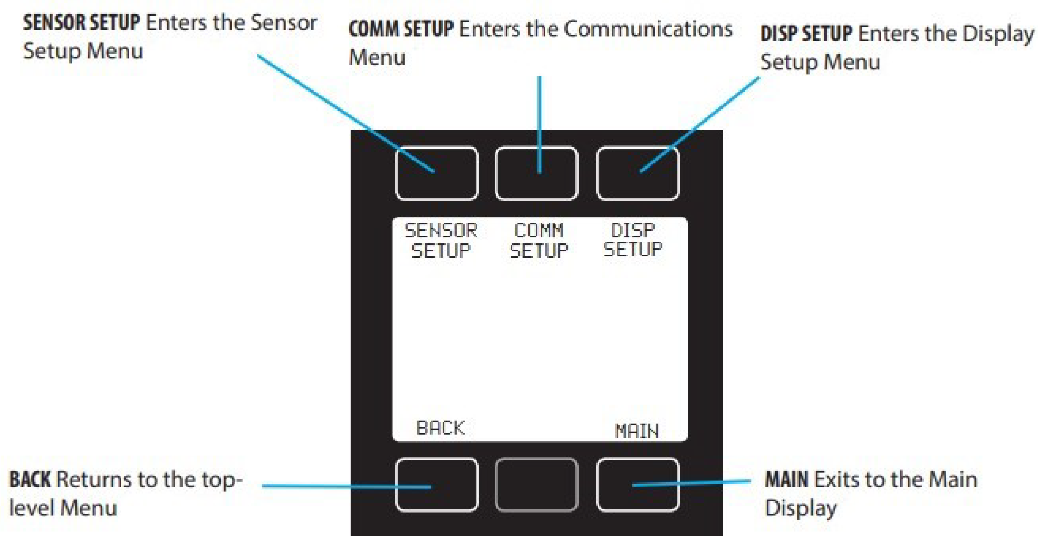

Figure 10. Advance Set up Menu

For more information and instructions on advance set up and changing these parameters please refer to the ALICAT MB Series User Manual.

4.0 Air Sampling

4.1 General

Air sampling studies are usually conducted for the purpose of determining the flux rate of a chemical following an application or estimating ambient air concentrations from off-site movement. The chemical being monitored will determine the sample media and tube type.

4.2 Met One

The Met One 3-Channel Pesticide Sampler, which is based on a Speciation Air Sampling System (P-SASS) sampler, is a portable integrated ambient particulate sampling system designed to collect ambient air samples on three separate sampling media

4.2.1 Initial Sampler Set Up

For detailed information on Sampler set up please refer to "**Instructions for Calibration and Use of a Met-One 3-Channel Pesticide Sampler",** SOP Number EQAI006.01.

4.2.2 Flow Measurement and Calibration

The Met-One 3-channel pesticide sampler has three sampling channels, each at different flow rates. The first channel is designed to operate at 15 liters per minute (LPM), the second channel is designed to operate at 1.5 LPM, and the third channel is designed to operate at 50 cubic centimeters per minute (ccm). The sampler's flow must be calibrated if initial flow reading falls outside of acceptable flow range. If flow calibration is required, the calibration procedure described in Met One SOP should be performed.

4.2.2.1 Attach Calibration Tubing to the sampling media (Figure 11)

Figure 11. Calibration Tubing

4.2.2.2 Turn on the flow meters and while ensuring there is no Flow, "Tare" the flow meters (Section 3.6.2). If the flow meter's orientation is changed during the process, the flow meter needs to be tared again.

4.2.2.3 Connect ALICAT "High" flow meter (MB- 20SLPM) to channel 1 (multi-residue cartridge).

4.2.2.4 Connect ALICAT "High" flow meter (MB-20SLPM) to channel 2 (MITC sorbent tube).

4.2.2.5 Connect ALICAT "Low" flow meter (MB-100SCCM) to channel 3 (chloropicrin sorbent tube).

4.2.2.6 From the main system display, press "Calibrate".

4.2.2.7 Press "F1" to reach the "System Test" window.

4.2.2.8 Press "Pump" then "Continue" to start the pump.

4.2.2.9 After waiting 5 minutes for the flow to stabilize, then read the ALICAT flow meters for the flow on all 3 channels on the sampler.

4.2.2.10 Compare measured flows to the acceptable starting flow criteria.

4.2.2.11 Press "Exit" twice to leave "System Test" display and get to the main system display.

4.2.2.12 If all measured flows are within acceptable starting flow range, procced to schedule sampling event and if any of the measured flows are out of the acceptable starting flow ranges, conduct the calibration procedure (Met-One SOP).

4.3 AirChek/SKC PUMPS

The SKC / AirChek HV30 pump and the SKC Personal Sampler Pumps are used to collect ambient air samples on multi-residue cartridges, MITC sorbent tube and chloropicrin sorbent tube.

4.3.1 Initial Sampler Set Up

For detailed information on Sampler set up please refer to "**Instructions for Calibration and Use of an SKC AirChek HV30 Environmental Air Sampler**" SOP Number EQAI004.00 and "**Instructions for Calibration and Use of SKC Inc. Personal Sample Pumps**" SOP Number EQAI001.00.

4.3.2 Flow Measurement and Calibration

After following the above instruction, attach the multi-residue cartridge to the AirChek pump, the MITC sorbent tube to the High Flow SKC pump and the chloropicrin sorbent tube to the Low Flow SKC Pump.

4.3.2.1 Attach calibration tubing to the sampling media

4.3.2.2 Turn on the flow meters and while ensuring there is no flow, "Tare" the Flow Meters (Section 3.6.2). If the flow meter's orientation is changed during the process, the flow meter needs to be tared again.

4.3.2.3 Connect ALICAT "High" flow meter (MB-20SLPM) to the multi-residue cartridge.

4.3.2.4 Connect ALICAT "High" flow meter (MB-20SLPM) MITC sorbent tube.

4.3.2.5 Connect ALICAT "Low" flow meter (MB-100SCCM) to the chloropicrin sorbent tube.

4.3.2.6 From the ALICAT flow meters record the flow on all 3 samplers.

4.3.2.7 Compare measured flows to the acceptable starting flow criteria.

4.3.2.8 If the flow on AirChek Pump needs to be adjusted, use the small flat head screwdriver located in the toolbox. Flow can be adjusted by placing the screwdriver in the small valve directly above the word "flow" on the top of the sampler (Figure 12). Make small adjustments until the flow has hit the desired range.

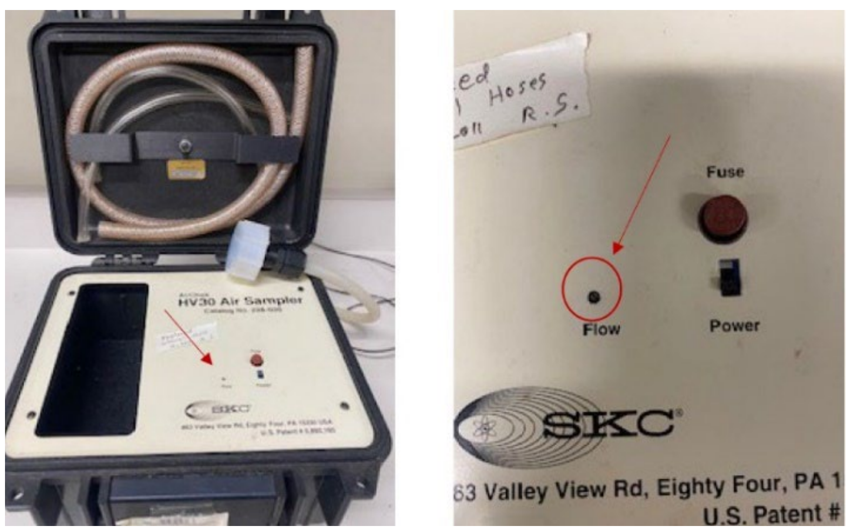

Figure 12. AirChek Pump

4.3.2.9 To adjust flow on MITC sampler, place the screwdriver in the valve directly below the word "flow" (Figure 13). Make small turns until the flow has hit its desired range.

Figure 13. High Flow SKC Pump

4.3.2.10 Adjusting flow on the chloropicrin sampler is done on the tubing directly above where the sorbent tube is placed. Place the screwdriver in the location shown below (Figure 14) and adjust flow. Make small turns with the screwdriver until flow has reached its desired range.

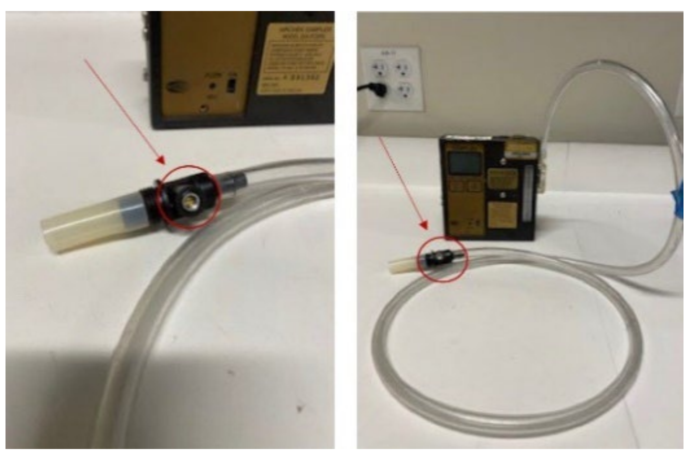

Figure 14. Low Flow SKC Pump

4.4 Regulator

Passive sampling refers to air pulled through a flow controller (regulator) into an evacuated canister over a given time interval ranging from five minutes to 24 hours. Regulator samples are set up for 24 hours by the Air Program.

4.4.1 Initial Sampler Set Up

For detailed information on the regulator set up please refer to "**Instructions for Calibration and Use of a SilcoCan® Canister",** SOP Number EQAI005.00.

4.4.2 Flow Measurement and Calibration

4.4.2.1 Turn on the "Low" ALICAT flow meter (MB-100SCCM) and while ensuring there is no flow, "Tare" the flow meters (Section 3.6.2). If the flow meter's orientation is changed during the process, the flow meter needs to be tared again.

4.4.2.2 Attach the calibration tubing adaptor to the sampling inlet.

4.4.2.3 Connect the flow meter. Once the flow has stabilized, record the initial flow on the field data sheet (FDS).

4.4.2.4 If the flow is not within this range, the flow needs to be adjusted, to do this you will need to look on the back side of the regulator. Take the cap off with an Allen wrench. Once the cap is removed you can adjust the flow with the same Allen wrench you used to take the cap off. If you turn the Allen wrench clockwise you will decrease the flow (Figure 15).

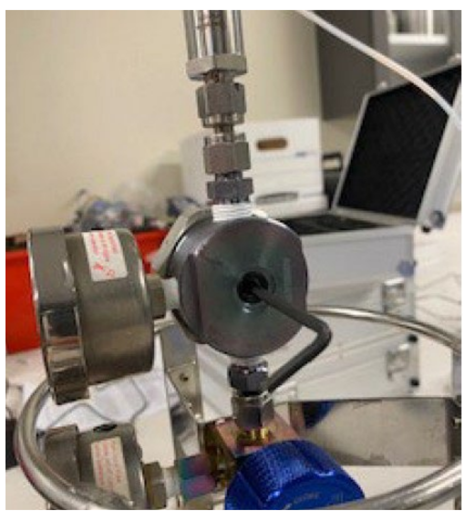

Figure 15. Adjusting the Flow on a Regulator

4.4.2.4 Prior to the sample being collected, flow must be measured again to assure it is within the acceptable range.

5.0 Troubleshooting

If you have any issues with operating the flow meter, please refer to the ALICAT MB Series User Manual.

STANDARD OPERATING PROCEDURE
Instructions for Use of ALICAT Flow Meter (MB Series)

Appendix 1

Engineering Units

Pressure Units

Absolute or Barometric	Gauge	Notes
PaA	PaG	Pascal
hPaA	hPaG	Hectopascal
kPaA	kPaG	Kilopascal
MPaA	MPaG	Megapascal
mbarA	mbarG	Millibar
barA	barG	Bar
g/cm^{2}A	g/cm^{2}G	Gram force per square centimeter†
kg/cm^{2}A	kg/cm^{2}G	Kilogram force per square centimeter*
PSIA	PSIG	Pound force per square inch
PSFA	PSFG	Pound force per square foot
mTorrA	mTorrG	Millitorr
torrA	torrG	Torr
mmHgA	mmHgG	Millimeter of mercury at 0°C
inHgA	inHgG	Inch of mercury at 0°C
mmH$_2$OA	mmH$_2$OG	Millimeter of water at 4°C (NIST conventional)†
mmH$_2$OA	mmH$_2$OG	Millimeter of water at 60°C†
cmH$_2$OA	cmH$_2$OG	Centimeter of water at 4°C (NIST conventional)†
cmH$_2$OA	cmH$_2$OG	Centimeter of water at 60°C†
inH$_2$OA	inH$_2$OG	Inch of water at 4°C (NIST conventional)†
inH$_2$OA	inH$_2$OG	Inch of water at 60°C†
atm		Atmosphere
m asl		Meter above sea level
ft asl		Foot above sea level
V		Volt
count	count	Setpoint count, 0–64000
%	%	Percent of full scale

Temperature Units

Label	Notes
°C	Degrees Celsius
°F	Degrees Farenheit
K	Kelvin
°R	Degrees Rankine

** Displayed as kg/cmA and kg/cmG.*

† Superscript and subscript numerals are displayed as lining (normal) numerals.

‡ Instances of µ are displayed as a lower-case u.

Flow Units

Volumetric	Standard	Normal	Notes
µL/m	SµL/m	NµL/m	Microliter per minute‡
mL/s	SmL/s	NmL/s	Milliliter per second
mL/m	SmL/m	NmL/m	Milliliter per minute
mL/h	SmL/h	NmL/h	Milliliter per hour
L/s	SL/s	NL/s	Liter per second
LPM	SLPM	NLPM	Liter per minute
L/h	SL/h	NL/h	Liter per hour
US GPM			US gallon per minute
US GPH			US gallon per hour
CCS	SCCS	NCCS	Cubic centimeter per second
CCM	SCCM	NCCM	Cubic centimeter per minute
cm^3/h	Scm^3/h	Ncm^3/h	Cubic centimeter per hour†
m^3/m	Sm^3/m	Nm^3/m	Cubic meter per minute†
m^3/h	Sm^3/h	Nm^3/h	Cubic meter per hour†
m^3/d	Sm^3/d	Nm^3/d	Cubic meter per day†
in^3/m	Sin^3/m		Cubic inch per minute†
CFM	SCFM		Cubic foot per minute
CFH	SCFH		Cubic foot per hour
CFD	SCFD		Cubic foot per day
	kSCFM		1000 cubic feet per minute
count	count	count	Setpoint count, 0–64000
%	%	%	Percent of full scale

True Mass Flow Units

Label	Notes
mg/s	Milligram per second
mg/m	Milligram per minute
g/s	Gram per second
g/m	Gram per minute
g/h	Gram per hour
kg/m	Kilogram per minute
kg/h	Kilogram per hour
oz/s	Ounce per second
oz/m	Ounce per minute
lb/m	Pound per minute
lb/h	Pound per hour

Total Units

Label	Notes
µL	MicroLiter‡
mL	MilliLiter
L	Liter
US GAL	US gallon
cm^3	Cubic centimeter†
m^3	Cubic meter†
in^3	Cubic inch†
ft^3	Cubic foot†
µP	Micropoise, a measure of viscosity‡
mg	Milligrams
g	Grams
kg	Kilograms
oz	US ounces
lb	US pounds

Time Units

Label	Notes
h:m:s	Hours:Minutes:Seconds
ms	Milliseconds
s	Seconds
m	Minutes
hour	Hours
day	Days

Appendix 2

Department of Pesticide Regulation

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MEMORANDUM

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DATE: October 5, 2022

SUBJECT: INVESTIGATION OF FLOW RATE UNIT DURING FLOW RATE VERIFICATION AND CALIBRATION.

In 2011, the California Department of Pesticide Regulation (DPR) established a long-term statewide Air Monitoring Network (AMN) to monitor ambient air concentrations of 35 pesticides and 5 pesticide breakdown products. The four operational AMN monitoring sites were in the communities of Oxnard (Ventura County), Santa Maria (Santa Barbara County), Shafter (Kern County), and Watsonville (Monterey County). DPR also established a targeted study to monitor 1,3-dichloropropene (1,3-D) air concentrations at two sites in the Central Valley agricultural communities of Delhi (Merced County) and Parlier (Fresno County) as study 309.

The operation of the AMN and Study 309 sites requires the use of specialized equipment and supplies for field operations. Basic considerations for sampler selection include flow control and measurement systems, maintenance requirements, reliability, and ease of operation (US EPA, 2016). DPR uses different types of samplers from various manufacturers to accommodate its air sampling needs.

One of the most important goals for air sampling is to maintain the specified (or target) ambient air flow rates through the sampling inlet. To ensure maintenance of the target flow rate, air samplers require staff to regularly perform a quality control procedure to verify that target flow rates fall within a sampler’s calibration tolerances. These tolerances are typically ±10% of the target flow rate. If the procedure indicates that the target flow rate is out of range, a calibration procedure should be followed. The calibration involves adjusting the instrument based on a standard (i.e., a calibrated reference flow meter). However, there is a lot of confusing information in the literature on which flow rate units should be used to verify or calibrate the flow rate of the instruments. These standards vary by industry, application, and what is being monitored.

This document aims to clarify and establish a standard flow rate unit for use in the verification and calibration of air sampling instruments used in the AMN, Study 309, and future ambient air studies.

Current Air Samplers

Current air samplers used in DPR’s AMN and 1,3-D sites by manufacturers and their target flow rates are given in Table 1. These instruments are actively in use in DPR’s ambient air monitoring studies. The equipment indicated as a legacy is the first generation of instruments procured for air sampling projects. They are simple and contain basic operational capabilities. The other instruments are more complex and possess digital and multi-parameter operational capabilities with software. Parameters may include 5-minute flow rate averaging, flow rate averages, total volume, temperature, and pressure readings.

Table 1. Air samplers used in AMN and 1,3-D monitoring with their target flow rates.

Air Sampler	Target Flow Rates	Manufacturer
AirChek HV30 Air Sampler - Legacy	15 L/min	C Inc
AIRCHEK sampler - Legacy	1.5 L/min	SKC Inc
AIRCHEK sampler - Legacy	50 mL/min	SKC Inc
Flite4	15 L/min	SKC Inc
AirCheck CONNECT	1.5 L/min	SKC Inc
AirCheck CONNECT	50 mL/min	SKC Inc
Xonteck model 901	7.5 mL/min	Xonteck, Inc.
Passive Air Sampler (Regulator) - Legacy	3.1 mL/min	Restek Corporation
Nutech 2703 Automatic Air Sampler	3.1 mL/min	Nutech Instruments, Inc
MetOne SASS	50 mL/min 1.5 L/min 15 L/min	Met One Instruments, Inc.

Which flow rate unit should be used?

There are two main types of flow rate units: mass flow rate and volumetric flow rate. The mass flow rate is the measure of the number of molecules in a flowing gas, whereas the volumetric flow rate is a measure of space that those molecules occupy without any consideration given to the number of molecules within that space. As gases are compressible and widely affected by temperature, mass flow rates can change depending on pressure and/or temperature changes. Mass flow is sometimes converted to a type of unit that may be referred to as “standard volumetric flow”, which uses the ideal gas law to adjust flow rate volume under one set of temperature and pressure conditions to those of a “standard” set of temperature and pressure conditions (e.g., 25^{o} C and 760 mmHg pressure), thereby scaling the target volumetric flow rate up or down in an effort to sample an equivalent mass of air as would be obtained by the target volumetric rate under standard temperature and pressure. This distinction between “actual” and “standard” volumetric flow rates is one of the main points of confusion regarding the calibration of sampling instruments, as calibration tools will require the user to select one of these two units.

All instruments include a sample flow rate control system which controls the air velocity passing through the system. These velocities are determined by the actual volumetric flow rate through the sampler’s inlet and sampling media. The actual flow rate must be maintained at a constant value that is as close as possible to the target flow rate specified for the air sampler. The flow units on the verification and calibration flow meter need to be selected based on the requirements of the equipment being verified or calibrated. According to the Met-One SASS, Xonteck 901, SKC AirConnect instrument manuals, the verification and calibration of flow rates require the use of actual volumetric units. Use of “standard” volumetric flow (i.e., mass flow) would therefore be inappropriate because, as shown by the ideal gas law, the actual flow rate volume would then vary in response to the ambient temperature and pressure at the time of calibration and would not correlate well with the fixed volumetric flow rates expected by the sampling instruments.

US EPA (2016) also indicates that the verification and calibration of the air sampler's flow rate measurement system must be performed in terms of actual volumetric units. However, US EPA (2016) pointed out that the standard volume flow rate should not be confused with the actual volumetric flow rate. The standard volumetric flow rates which have been adjusted to EPA-standard conditions of temperature and pressure (25 ^{o}C or 298 K and 760 mmHg or 101 kPa), are often used by engineers and scientists because they represent mass flow rates.

In conclusion, a volumetric flow rate is more appropriate for use in the calibration of DPR's ambient air monitoring equipment. The typical units of volumetric flow are mL/min, L/min (LPM), or cm^3/min (CCM), and program staff should use these units in our Alicat flow meters in verification and calibration procedures. Units prefaced with an "S" in the Alicat interface (i.e., SCCM, SLPM) are in the form of "standard" volumetric flow and should not be used. The use of "actual" volumetric flow conforms to the needs of the sampling instrumentation, and the units are more consistent with the project goal of quantifying the mass of pesticides in a volume of air under ambient temperature and pressure conditions.

References

USEPA. 2016. Quality Assurance Guidance Document 2.12. Monitoring PM2.5 in Ambient Air Using Designated Reference or Class I Equivalent Methods. U.S. Environmental protection Agency Office of Air Quality Planning and Standards Air Quality Assessment Division, RTP, NC.