TI 226H Calibration of Flow Check Devices using Positive Displacement Flow Meter

TABLE OF CONTENTS

LIST OF FIGURES

1. PURPOSE AND APPLICABILITY

This technical instruction document describes the procedures for calibrating the flow check devices necessary for performing flow rate measurements on an IMPROVE aerosol samplers. The calibration of the flow check device is done by Air Quality Group personnel prior to and subsequent to flow rate measurements at an IMPROVE sampling site. Each flow check device is labeled so that its calibration can be tracked through time. All calibrations are stored on the computer network and in the field specialist's flow check device files. The most current calibration equation for each flow check device is written on a sticker which is pasted on the flow check device gauge following the calibration procedure.

2. RESPONSIBILITIES

2.1 Field Specialist

The field specialist shall:

- Train field technicians in the use of flow check device calibration equipment.
- Approve and file the flow check device calibration equation.
- Maintain an accurate database of flow check device calibrations.

2.2 Field Technician

The field technician shall:

- Perform the calibration of the flow check device.
- Submit the derived calibration equation to the field specialist for approval.

3. REQUIRED EQUIPMENT AND MATERIALS

The equipment required to calibrate a flow check device includes the following:

a. Definer 220, Mesa Labs, http://drycal.mesalabs.com/definer-series/, accuracy 1%.

- 3/8" I.D. hose, 2'
- ¼ NPT brass nipple for 3/8" I.D. hose
- Stack inlet plug for top of IMPROVE $PM_{2.5}$ module tee inlet
- 3/8" O.D. stainless steel tube, 2"
- IMPROVE $PM_{2.5}$ module tee plug tapped for ¼ NPT fitting

b. 1 flow check device (orifice meter) and calibration form.
C. 1 leak checked IMPROVE $PM_{2.5}$ module.
d. 1 IMPROVE controller.

e. 1 IMPROVE rocker piston pump with corresponding vacuum line.
f. 1 IMPROVE pump relay box
g. 1 leak checked calibration filter cartridge

4. METHODS

This technical note covers the methods for calibrating orifice meters using a Definer 220 as a standard. Section 4.1 covers the theory describing the behavior of orifice meters, while section 4.2 describes the procedures used to calibrate orifice meters against a Definer 220.

4.1 Orifice Meter Theory

An orifice meter consists of a restriction in the air path and a device to measure the pressure drop across the restriction. Orifice meters in the IMPROVE network use magnehelics to measure the pressure drop. The flow check devices consists of a magnehelic, tubing, and a probe that fits into the base of the inlet tee of the $PM_{2.5}$ (fine) sampling modules and at the base of the inlet stack in the PM_{10} (coarse) module. For the fine modules, the probe blocks the normal flow through the inlet, forcing all air entering the system to pass through the probe orifice. The probe and magnehelic, hereafter called the flow check device, are calibrated at Davis using a Definer 220.

The flow rate through an orifice meter, Q, depends on the pressure drop across the restriction, δP, and the square root of the density of the air:

$$Q = Q_1 \, (\delta P)^{\beta} \sqrt{\frac{P_\circ}{P}} \sqrt{\frac{T+273}{293}} \qquad \text{(TI226-1)}$$

Where P is atmospheric pressure, T is temperature in °C, and Q_1, β, and $P_\circ$ are constants. For laminar flow, $\beta = 0.5$. We express Equation TI226-1 in parameterized form using the magnehelic reading, M, for the pressure drop:

$$Q = 10^{a} \, M^{b} \sqrt{\frac{P(sea\ level)}{P(site)}} \sqrt{\frac{T+273}{293}} \qquad \text{(TI226-2)}$$

We have arbitrarily defined all pressures relative to the standard pressure at sea level and all temperatures relative to 20°C. Thus, the parameters, a and b, are always calculated relative to 20°C and Davis. The value of b should be similar to that of β, around 0.5. The advantage in expressing the parameters relative to sea level is that all modules should have parameters with similar values independent of the site elevation.

Because of the difficulties in measuring the ambient pressure at each sample change, we have chosen to use an average pressure based on the elevation of the site. The pressure- elevation function is discussed in SOP201-3.

The reference flow rate is provided by a Definer 220 located in the sampler laboratory at UCD. Taking the logs of Equation TI226-2, the flow rate equation for the flow check device is

$$\log(Q) = a_\circ + log\sqrt{\left(\frac{29.92}{P}\right)\left(\frac{T+273}{293}\right)} + b_\circ * \log(M_\circ) \qquad \text{(TI226-3)}$$

The log of the meter reading, M_O, is regressed against the log of the flow rate for a set of four flow rates covering the normal range of the device. The constants relative to the nominal sea level pressure (29.92) and 20�C are calculated using

$$a_c = intercept - log\sqrt{\left(\frac{29.92}{P}\right)\left(\frac{T+273}{293}\right)} \qquad b_\circ = slope \qquad \text{(TI226-4)}$$

4.2 Calibration of an Orifice Meter Using a Definer 220

The flow check device, or orifice meter, is used as the standard against which each module in the field is calibrated. The flow check device is calibrated against a primary flow device, a Definer 220, at the Air Quality Group Lab both prior to and following calibration at a site. The calibration equation for the orifice meter is printed on a sticker on the magnehelic side, along with the date of calibration and name of the technician responsible for the equation. A flow restricting device and a filter cartridge with 4 filters with distinct pressure drops, is used to change the flow rate to develop the equation. Finally, a spreadsheet for doing logs and linear regressions is required.

1. Install the calibration cartridge shown in Figure 1. in the module. This cartridge is set up with four cassettes that produce a range of flow rates.

Figure 1. Calibration Cartridge

2. Insert Definer 220 probe at bottom of tee and tee plug on top of tee as shown in Figure 2. Ensure that both probe and plug are inserted fully.

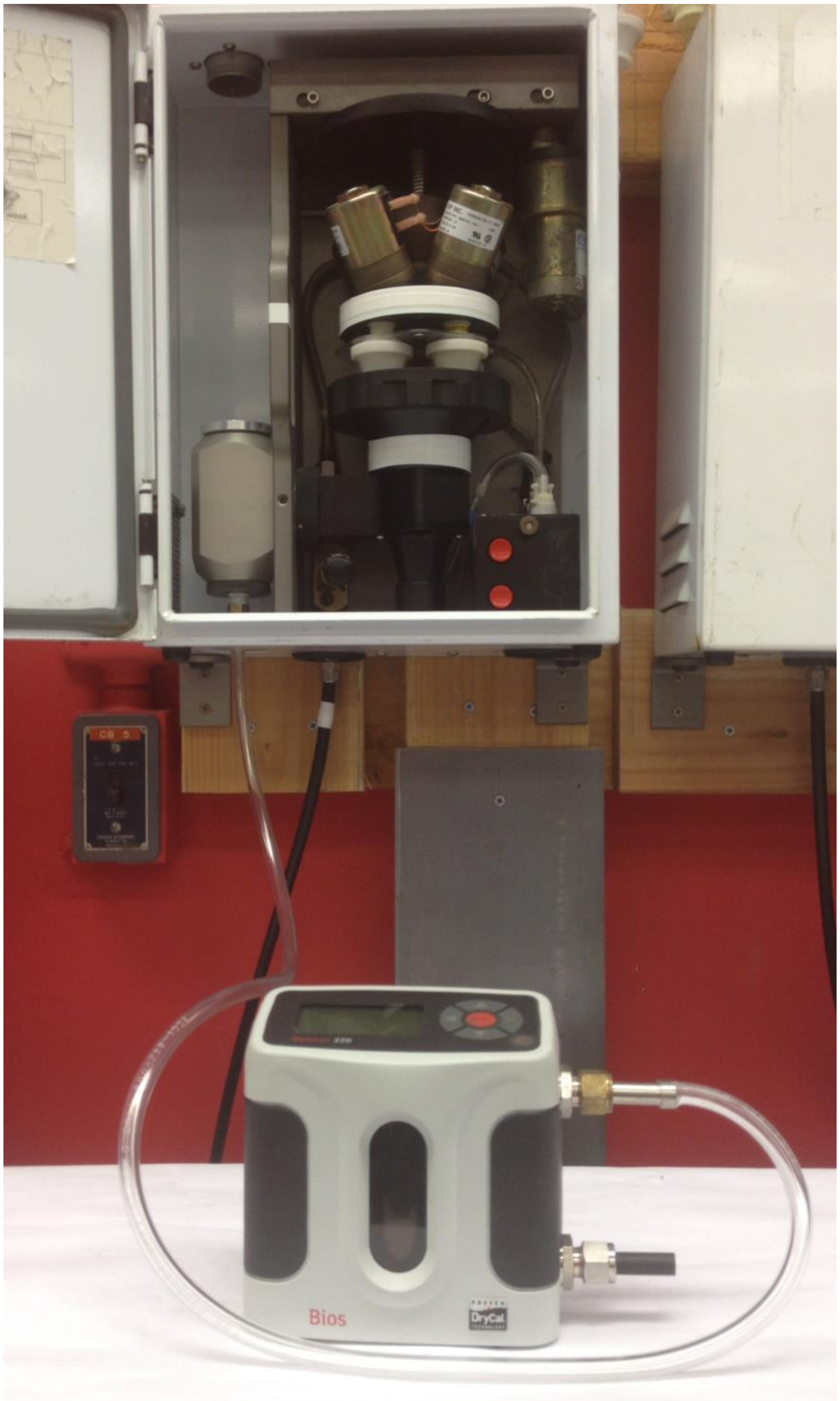

Figure 2. Calibration System with Definer 220

3. At the controller access the main menu and press F-3 for "Advanced Menu".
4. From the "Advanced Menu" press F-1 for "Calibration". This will turn on the pump and open solenoid one on module A.

5. Turn on the Definer 220 by pressing the red power button in the bottom of the right corner for 2 seconds.
6. When the Definer has been turned on press the red "Enter" button while "Measure" is selected as in Figure 3.

Figure 3. Setting up the Definer 220

7. Select "Burst" mode and take flow reading for filter position 1 of the calibration cartridge. Ensure that the Definer is set to the standard temperature of 20°C for determining SLPM. This is indicated by "Std. Temp:20" shown on the definer screen during readings as shown in Figure 4.

Figure 4. Operating the Definer 220

8. Record the average flow rate for each filter position in cell B7 of the calibration spreadsheet shown in Figure 5.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Device:**	F-6											
2	Year:	2015											
3													
4	**Calib. Date:**		**Calib. By:**										
5	ΔP_{mag}	Q_{bios} Savg	Q_{eqn}	% Error from prev. calib	LOG ΔP_{mag}	LOG Q_{bios}	R^2	a	b	23 lpm	16.9 lpm	Temp	BP
6	"H_2O	lpm	lpm							STP	STP	°C	"Hg
7			#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!		
8			#NUM!	#NUM!	#NUM!	#NUM!	**Comments:**						
9			#NUM!	#NUM!	#NUM!	#NUM!							
10			#NUM!	#NUM!	#NUM!	#NUM!							

Figure 5. Flow Check Device Calibration Spreadsheet

9. Repeat steps 7 and 8 for the remaining filter positions.
10. Remove the Definer plug and tee inlet plug from the module.
11. Insert the flow check device probe into the bottom end of the inlet tee. Ensure that the probe is fully inserted. Attach the magnehelic gauge on a vertical metallic surface as shown in Figure 6. The back end of the gauge base is magnetic.

Figure 6. Calibration System with Magnehelic Flow Meter

12. Press F-3 on the controller key pad to return to filter position one for module A.
13. Record the magnehelic reading for each filter position on cells A7-10 of the calibration spreadsheet.
14. Record the calibration date, technician name, ambient temperature, and pressure on the spreadsheet.
15. The spreadsheet will generate values for R2, intercept, slope, nominal magnehelic value for a flow rate of 23 LPM, and 16.9 LPM at standard temperature and pressure.
16. If the r^2 is not better than 0.990, the calibration is invalid. Repeat the orifice meter calibration procedure, beginning with step 2.
17. If the r^2 is better than 0.990, write out the equation, the date, technician initials, temperature, and r^2 value on a 3 7/16" x 9/16" file folder label, and paste it to the side of the orifice meter magnehelic.
18. Save the calibration spreadsheet.
19. Share the results of calibration spreadsheet with the field manager for approval.