

## **I. PUMP OPERATION AND FLOW CALIBRATION**

### **SECTION A: PUMP OPERATION**

#### **I. Purpose:**

To become familiar with typical air sampling pumps by:

1. *adjusting and setting a sampling pump's air flow rate.*
2. *detecting pump failure.*
3. *using the pump's timing and programming mechanism.*

#### **II. Readings**

Manuals for Pumps, particularly SKC 224-PCXR7 and MSA Elf

#### **III. Outline**

This exercise has three small parts that:

Part 1: Develop familiarity with a personal sampling pump operation.

Part 2: Demonstrate setting a timed sampling sequence.

Part 3: Demonstrate setting up and wearing a sampling train.

All of these parts will be completed within one laboratory period. Complete Part 1 before proceeding to parts 2 and 3. The others can be completed in any order and you may want to work at more than one exercise at time.

#### **IV. Equipment:**

SKC model 224-PCXR7 sampling pump, and Airchek 2000

MSA Elf sampling pump and or other pumps

Low Flow Pump, such as SKC Pocket Pump or Gilian.

Rotameters

Small slotted screw driver

Small Phillips screw driver

Stop Watch

Hose Clamp, tubing, and connections.

Filter holder or charcoal tube holders (2)

## Introduction:

The sampling pump is the most commonly used industrial hygiene sampling device. It is so easy to use that the pumps are rarely used to their full technological capability. In this exercise you will work with two pumps: the SKC model 224-PCXR7, and the MSA ELF. These pumps are for air sampling in the 0.5 to 4.0 liter per minute (lpm) range. With adapters air can be sampled at lower flow rates.

For familiarization, your group should review the fundamentals of operation of each type of pump and its instruction pamphlet. As a minimum, learn how to turn the pump On and Off and how to change the flow rate. Additional electronic features, such as elapsed sampling time, timed operation, logging of data and flow fault notification, are available and useful, on most of the pumps, and are interesting to apply as time permits.

**The following sections outline necessary tasks.**

### **Part 1a: Learning Pump Basics: SKC Pump**

1. With the SKC pump, turn the sampling pump ON (Figure 1 #8).
2. Press the "Start/Hold" Key (#6) and the "Flow and Battery Check Key" (#2). The Liquid Crystal Display (LCD) should indicate "battery OK".
3. Adjust the flow from 1 up to 4 and then down to 2 on the flow indicator (#18) with the flow adjust screw (#12).
4. Connect the 1/4" tubing from the intake filter housing (#14) to the top port of a rotameter. The rotameter response depends upon pressure, temperature, and humidity, so it must be calibrated to a primary standard (you will do this in lab 2). For now, adjust the flow rate so that the rotameter reads 2.0.
5. Press the "Flow and Battery Check Key" (#2) to stop the pump. A sample has not yet been collected so the timer has not started.
6. Press "Start/Hold" (#6). Allow the pump to run for at least 2 minutes and watch the LCD display as it records sampling time.
7. After two minutes partially pinch the 1/4" tubing with the hose clamp in order to engage the constant flow mechanism (you should hear the pump speed increase). Indicated flow on the rotameter should readjust after a short period.
8. Next plug the rotameter inlet and wait for the pump to fault (stop) and "Flow Fault" appear on the LCD. **Record the elapsed time.** The pump is designed to automatically shut down if there is flow stoppage or low voltage: Sampling time remains indicated on the LCD.
9. Start the pump again and cause a pump fault again. Then record the time. **Is the time additive, or does the new sampling period start at zero?** Figure out how to reset pump to start sampling time at zero.

The pump's flow compensator is designed to maintain constant airflow as a sample substrate becomes partially obstructed. Table 1 (following page) illustrates the specifications for the SKC pump. You will be evaluating the flow compensator in the next laboratory.

**Table 1: Allowable back pressure vs flow rate for SKC 224-PCXR7**

<u>Flow Rate (L/min)</u>	<u>Back Pressure</u>
0.75	5-40 inches H <sub>2</sub> O
1.0	0-40 inches H <sub>2</sub> O
2.0	0-40 inches H <sub>2</sub> O
2.5	0-40 inches H <sub>2</sub> O
3.0	0-35 inches H <sub>2</sub> O
4.0	0-20 inches H <sub>2</sub> O
5.0	0-15 inches H <sub>2</sub> O

**Part 1b: Pump Basics for the MSA Elf Pump**

1. For the Elf pump, read the instruction book pages 2-3 and 3-3 and look-over the schematic diagram on page 2-2. Following Section 3,:
2. turn the pump on and off.
3. Adjust the flow from 2 LPM to 3 LPM. How long does it take the pump to stabilize at the new flow?
4. Set the flow back to 2 LPM. Does it take the same time to stabilize?
5. Try running the pump for 3 minutes, then turn it off and on without losing the total run time.
6. Repeat the off-on procedure, but this time erasing the run time and starting a new sampling time.

**Part 2: Set-up of timed sampling. SKC 224-PCXR7 Pump**

*(NB: Start Part 3 simultaneously!)*

In some sampling situations we would like for the pump to start at a pre-set time, or run intermittently, or shut off at the end of a specified sampling period, or any combination of these. The SKC pump has these capabilities. We will set up the pump to complete the following sampling routine:

Sample period 17 minutes (total)  
Pump period 5 minutes (total)  
Delayed start 2.0 minutes

While the pump LCD displays "hold", these time functions may be programmed.

1. Press the "Set-up" key (#7). The "Delayed Start" will display on the LCD as well as a flashing digit. The value of the flashing digit will be incremented each time the "Digit Set" (#5) is pressed.
2. The "Digit Select" (#3) is to select the flashing digit. Using these two keys, enter the desired number of minutes displayed, then press the "Mode" (#4).
3. "Sample Period" will now appear.
4. Again use the "Digit Set," "Digit Select", and "Mode" keys to program this interval. "Pump Period" will appear on the LCD.
5. Using the same keys, program pump period.
6. Press "Start/Hold" and record delay time, start and stop times, and total duration of pump sampling.

7. Prepare a bar graph of the time sequence. When would you want to use this feature?

**Part 3: Mock personal sampling**

1. Attach 1/4 inch tubing to pump inlet and at the other end of the tubing attach a filter holder or a charcoal tube holder.
2. Attach the sampling device holder to a person's clothing within their breathing zone and attach the pump to the person (usually their belt).
3. Turn on the pump and wear it for 10 minutes. Consider the following questions:  
How does it feel?  
Would you like to wear it for 8 hours?  
Can you predict instances when you, the industrial hygienist, will need to accommodate the worker by removing the pump or arranging it differently?

## **SECTION B: FLOW CALIBRATION**

The evaluation of workplace exposures requires sampling and quantitation of airborne contaminant concentrations. An essential part of any sampling is an accurate measurement of the quantity of air that was sampled. Before going on a survey of a worksite, the flow rates of the pumps and the flow measuring devices must be calibrated. The different parts of this experiment represent examples of the calibration procedures that would be a necessary part of the preparation for a survey. Emphasis is placed on the effect of atmospheric conditions.

### I. Purpose

To become familiar with:

- a. Primary (e.g., bubble buret) and secondary (e.g., rotameter) calibration standards; and other flow devices such as the electronic and dry calibrators.
- b. Pumps and filter media used in sampling.

### II. Outline

This experiment has three required parts which you will do in the two lab periods. You will probably have enough time to also do the optional part. You will work in teams of two or three; however, individual write-ups will be required.

Part 1: Calibration of rotameter using a bubble buret.

Part 2: Calibration of sampling pump using a rotameter.

Part 3: Evaluating the effects of filters on pump performance.

Part 4: Calibration of an electronic flow (Giliblator) meter or Dry Cal vs. Bubble buret.

### III. Introduction

The mainstay of industrial hygiene air sampling is the personal sampling pump. After collecting a sample, one calculates the concentration of a contaminant in air as the amount of contaminant collected divided by the volume of air drawn through the sample media (e.g., filter, adsorption tube, etc.).

$$\text{Concentration (mg/m}^3\text{)} = \text{Weight Contaminant (mg)} / \text{Air Volume (m}^3\text{)}$$

If the amount of contaminant (solid, liquid or gas) is expressed as a mass, then the resulting concentration is given as milligrams of contaminant per cubic meter of air (mg/m<sup>3</sup>). If the amount of a gaseous contaminant is expressed as a volume, then the result is given as the volume of contaminant divided by the volume of air sampled (ppm).

$$\text{Concentration (ppm)} = \text{Volume Contaminant (L x 10}^6\text{)} / \text{Air Volume (L)}$$

In either case, the volume of air sampled is determined by multiplying the sampling pump flow rate by the total time of sampling.  $\text{Volume} = \text{Flow (L/min.)} / \text{Time (min.)}$   
For example, with a pump drawing 2 L/min, the total volume of a one hour sample would be  $2\text{L/min} \times 60\text{ min} = 120\text{L}$ . Thus in order to obtain an accurate result, it is necessary to accurately and precisely control and measure the flow rate of the sampling pump.

In this experiment you will learn to calibrate sampling pumps, and will explore how some of the conditions such as barometric pressure or temperature can cause variations in pump performance. Calibration instruments are discussed in the following paragraphs.

#### Pumps:

Perkins, pages 389-399 and Air sampling Instruments, pages 233-245.

The pumps that will be used in this experiment are portable sampling pumps with a range of flow rate from 0.5 to 4 liters per minute with a constant volume feature.

#### Rotameters:

Perkins, pages 418-422 and ASI pages 149-158.

The most common air flow calibration device used in the field (and often in the laboratory) is the rotameter. The rotameter consists of a tapered vertical tube containing a float. The float rises to a height which is dependent on the flow rate and density of air moving through the tube. Rotameters are available to measure flow rates as low as 1 ml/min and as high as 300 cfm. Any particular rotameter usually covers a range of about one order of magnitude. Their accuracy varies from  $\pm 1\%$  to  $\pm 10\%$  depending on the unit. Some rotameters have multiple floats to increase their range. The float is usually a sphere or an ellipsoid; however, there are other configurations. One always reads a rotameter at the widest part of the float as a matter of standardization and in order to minimize parallax error.

#### Bubble Burets :

Perkins, pages 412-413 and Air sampling Instruments, pages 149-151

A bubble buret operates as a frictionless piston with carefully manufactured length and diameter. The rotameter is not a primary measuring device and thus must be calibrated against a more accurate air flow measuring device such as a bubble buret and timer. The accuracy and precision of the bubble buret depend upon easily calibrated parameters such as length, diameter and time which do not vary significantly under varying conditions of temperature and pressure. Thus the bubble buret is a primary standard. The rotameter is termed a secondary standard because its more complicated construction and physics of operation make it inherently less accurate and precise, and its readings vary with temperature, pressure and the density of the gas.

Because results provided by a rotameter vary under differing conditions of temperature, pressure and density, mathematical corrections must be made if the rotameter is used under conditions which differ significantly from the conditions under which it was calibrated. It is also strongly recommended that rotameters be calibrated upon receipt from the manufacturer even if they come with the manufacturer's certificate of

calibration. In this experiment you will explore some of the conditions which can cause rotameter performance to vary, and will learn to make the necessary corrections.

Other Flow Measuring Devices: Perkins, pages 406, 416-418 and Air sampling Instruments, pages 151-161

Additional types of equipment can be used to measure air flow. Exhibited in the lab will be mass flow meters, the Dry Cal and electronic bubble meters (Giliberator). Mass Flow Meters are described on page 136 in "*Air monitoring for toxic Exposures*" (McDermott)

#### IV. Equipment

Each team should obtain the following equipment before beginning:

- |  |                                 |
|--|---------------------------------|
| a. Rotameter (1-4 l/min, w/o needle valve) | j. Vacuum gage                  |
| b. 1 personal sampling pump                | k. Stop watch                   |
| c. Bubble buret                            | l. Soap bubble solution         |
| d. Beaker                                  | m. 2 three-prong clamps         |
| e. Ring stand                              | n. 2 ring stand clamps          |
| f. 1 side arm flask                        | o. Tygon or rubber tubing       |
| g. 2 needle valves                         | p. Vacuum pump                  |
| h. Manometer or magnehelix                 | q. 37 mm sampling cassettes (6) |
| i. Dry Cal                                 | r. Gilibrator                   |

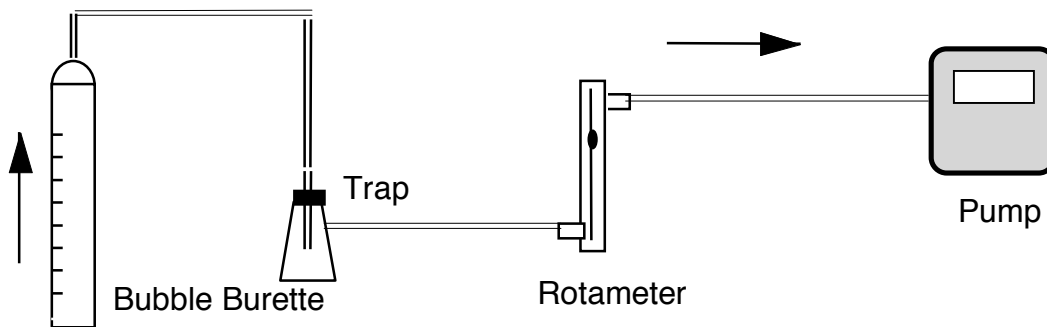
Other equipment will be provided as necessary.

Record the serial numbers of the rotameter and the sampling pumps, and label these to identify them for your team. You will use these several times during the quarter.

### Part 1: Calibration of Rotameter Using Bubble Buret

In this part you will determine the flow rate at various rotameter readings and will plot the true flow rate (as measured with the bubble buret) vs. the rotameter reading. The resulting graph will be the calibration curve for your rotameter. You will use this curve several times during the quarter when you use the rotameter to determine air flow. **Use the MSA Elf pump for this exercise.**

1. Wash the buret thoroughly and then assemble the apparatus as shown in Fig. 2.1. Put a half inch of soap bubble solution in a beaker. Have an instructor check your set-up before you continue.



**Figure 2.1**

2. Rinse and coat the inside of the buret with soap bubble solution; then drain.
3. Insure the needle valve (if present) on the rotameter is fully open. Adjust the pump air flow through its full range to determine roughly the corresponding range of rotameter settings. For example, the range might be from about 1 to about 3L/min.
4. Adjust the pump to create one a flow rate of "1.5 L/min.", as measured on the rotameter. Lift the beaker to create a soap bubble at the bottom of the buret. Time the passage of the bubble through the buret. Make at least three bubble meter measurements at this rotameter reading. Record the data and determine the average flow rate.
5. Make similar bubble meter measurements at each of four other rotameter readings. You should end up with data from at least five readings representing the full range of the pump & rotameter.
6. Plot the data to create a calibration curve (rotameter reading vs. flowrate). You can use MS Excel software on the lab computer to do this. Plot this curve during lab time as it will be used in Part 2. Repeat any points that do not fall on a smooth curve. Combine the data into a single table & graph.

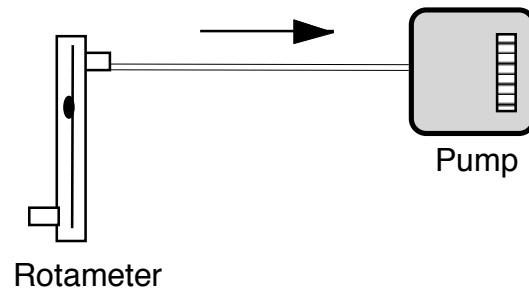
Questions: **Was a correction needed for the rotameter reading?**  
**How great is an error in a sample volume if the reading is not corrected?**  
**Is the correction constant over the range of the rotameter?**



## Part 2: Calibration of Sampling Pump Using a Rotameter

In this part you will use the rotameter which you have just calibrated to calibrate a sampling pump for flow rate. This is a common field procedure. *Use the SKC pump for this exercise.*

1. Assemble the apparatus as shown in Fig. 2.2.



**Figure 2.2**

2. Adjust the pump air flow through its full range to determine roughly the corresponding range of rotameter settings. For example, the range might be from about 1 to about 3L/min.
3. Choose four flow rates in this range and record them in your lab book. For example, you might choose 1.5, 1.7, 2.0 and 2.5 liter per minute.
4. Refer to your rotameter calibration curve and adjust the pump to create one of the corrected flow rates (as measured by the rotameter) that you have chosen. **Record the reading on the rotameter which is integral to the pump.**
5. Repeat steps 4 and 5 for all other flow rates which you have chosen. For each step record both the setting on your calibrated rotameter, and the flow reading on the rotameter that is integral to the pump.
 

**How accurate is the rotameter on the pump?**

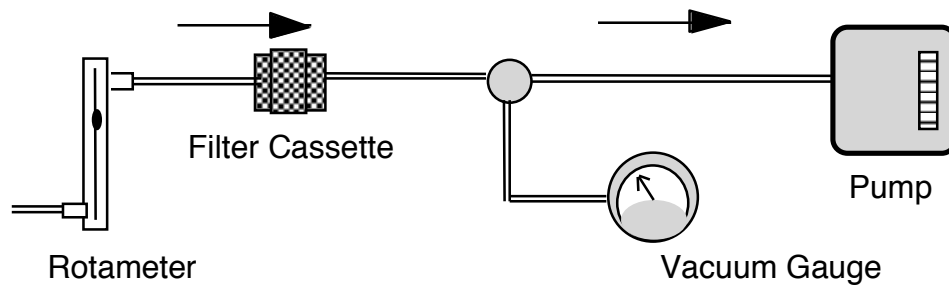
**Which is more accurate--the rotameter on the pump or the secondary standard?**

**Considering the primary standard (bubble burette) and the secondary standard (calibrated rotameter), which is best in accuracy or convenience for routine calibrations of the sampling pump?**

### **Part 3: Evaluating the Effects of Filters on Pump Performance**

In this part you will evaluate the effects of filter resistance on the pump performance **for the SKC pump**.

1. Load four 37 mm cassettes with the following filters:
  - a. Glass fiber –used for sampling/analysis of SVOCs
  - b. Metrical VM (MCE , 5.0 um pore size) –used for metals sampling.
  - c. Millipore AA (MCE, 0.8 um pore size) --used for asbestos sampling.
  - d. Nucleopore filter (polycarbonate)—used for electron microscopy samples.
2. Obtain one or two "dirty" filter cassettes from the instructors.
3. Assemble the apparatus as in Fig. 2.3 (initially without the filter cassette in line).



**Figure 2.3**

4. Without any filter cassette in line, refer to your calibration curve and adjust the pump to draw 1L/min. Record the pressure (vacuum) reading, and the rotometer readings for your calibrated rotamter and the pump rotameter.
5. Without changing the pump setting, place each of the 6 filter cassettes in line, one at a time. For each cassette note the pressure (vacuum), the (upstream) rotameter reading and the pump rotameter reading.
6. After completing Step 5 for each cassette, place each filter in line, one at a time, and adjust the pump to draw in 2.8 L/min. (Is this possible?). Note the pressure (vacuum) for each cassette.

#### **Questions:**

- a. Does a filter or a loaded filter change the flow measured on the pump?
- b. Does a filter or a loaded filter change the flow measured upstream of the filter cassette?
- c. Would the effects you note for a loaded filter alter the measured or actual sample volume for a filter sample?

#### **Part 4: Comparison of a Bubble Buret and Electronic Bubble Meter and/or DryCal**

Attach the soap bubble buret to electronic bubble meter (Gillibrator) or the DryCal and pump in series, as in Diagram 2.1. Select two flow settings with replicate readings, and compare results of the two devices. Compare the use of the electronic bubble meter with that of the soap bubble meter from Part 1 for the calibration of other flow measuring devices. **Which would you prefer for field calibration and why? Should the electronic bubble meters or the Dry Cal require calibration?** The SKC UltraFlo can be substituted for the Gilibrator.

#### **LAB WRITE UP, EXPERIMENT ONE:**

A full scale write up is not required for this experiment. Instead, please answer the questions below and include the data requested.

##### **Section 1:**

Part 1a: When the SKC pump flow-faulted and was then re-started, was the sampling time additive?

Part 2: Provide a bar graph of timed sampling sequence with time on the x-axis and air flow on the y-axis.

Are the intervals equal across the entire duration?

##### **Section 2:**

###### **Part One - Rotameter Calibration:**

Tabulate the raw data you collected in this section, and include your calibration curve of bubble burette flow vs rotameter flow. Where you have taken multiple measurements under the same conditions, use the data to calculate standard deviations and coefficients of variation and place appropriate error bars on your calibration graph.

- What error variable(s) is (are) measured?
- Was a correction needed to adjust the rotameter reading to the true flow rate as measured by the bubble buret?
- How great is an error in a sample volume if the reading is not corrected?
- Is the correction constant over the range of the rotameter?

###### **Part 2 - Pump Calibration:**

Tabulate the raw data you collected in this section.

- How accurate is the rotameter on the pump (compared to the primary standard)?
- Which is more accurate--the rotameter on the pump or the secondary standard?
- Considering the primary standard (bubble burette) and the secondary standard (calibrated rotameter), which is best in accuracy or convenience for routine calibrations of the sampling pump. Is there any difference?

###### **Part 3 - Filter Effects:**

Tabulate the raw data you collected in this section.

Besides discussing the effects of each filter, if you observe a noticeable effect for specific filters make a graph of pump flow rate (i.e., pump performance) as a function of pressure drop across the filter (i.e., filter resistance).

- a. Does a filter or a loaded filter change the flow measured on the pump?
- b. Does a filter or a loaded filter change the flow measured upstream of the filter cassette?
- c. Would the effects you note for a loaded filter alter the measured or actual sample volume for a filter sample?

Part 4- Electronic meters:

Compare the ease of use and accuracy of the Dry Cal and Gilibrator (UltraFlo) with the soap bubble buret.

- a. Which would you prefer for field calibration and why?
- b. Should the electronic bubble meters or the Dry Cal require calibration?

**References**

Air Sampling Instruments for evaluation of atmospheric contaminants. Susanne V. Herring (Tech. Ed.) 7<sup>th</sup> ed., 1989. ACGIH, Cincinnati, OH.

McDermott, H.J., Air sampling for toxic exposures, 2<sup>nd</sup> Ed. John Wiley and sons, Hoboken, NJ

Perkins, J. Modern Industrial Hygiene, Van Nostrand Reinhold, NY(1997).