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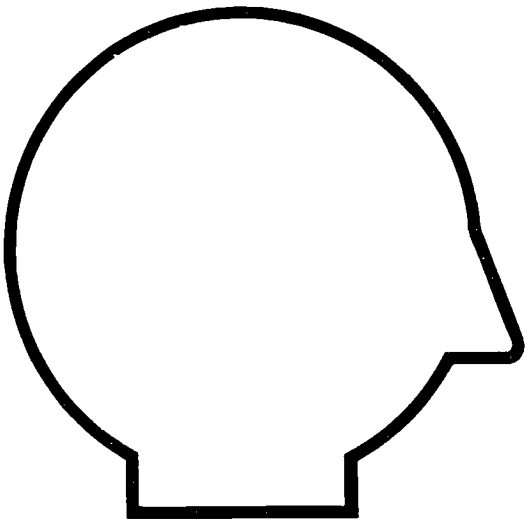
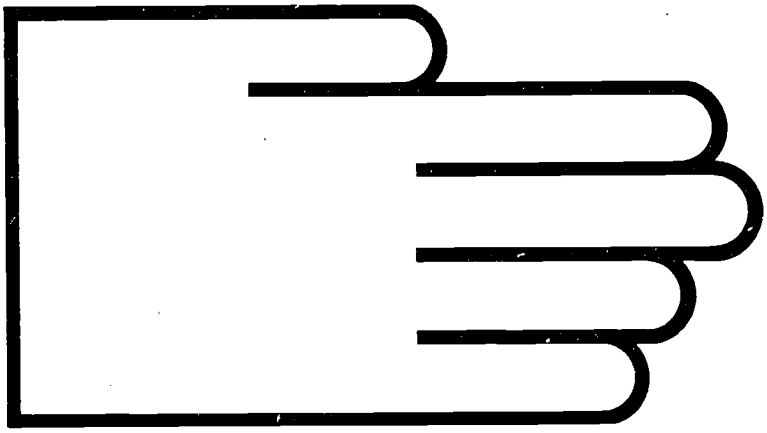
ABSTRACT

This module, one of 25 on vocational education training for careers in environmental health occupations, contains self-instructional materials on using precision rotameters. Following guidelines for students and instructors and an introduction that explains what the student will learn are three lessons: (1) naming the parts of a low-flow precision rotameter and describing how each part functions: (2) disassembling, cleaning, and reassembling a low-flow precision rotameter: and (3) calibrating a precision rotameter, using a soapbubble meter. Each lesson contains objectives, recommended methods and locations for practice, performance criteria, equipment and supplies to perform a task, detailed step-by-step instructions for learning a task, and performance exercises. Two performance tests cover cleaning a precision rotameter and calibrating a precision rotameter. (CT)



# Using Precision Rotameters



## Module 6



U.S. DEPARTMENT OF EDUCATION, Office of Vocational and Adult Education

## FOREWORD

The Curriculum and Instruction Branch of the Office of Vocational and Adult Education, U.S. Department of Education, identified a need to improve the training opportunities for vocational education students interested in pursuing careers in environmental health. To fulfill that need, Consumer Dynamics, Inc., a Rockville, Maryland, based company, was awarded the contract to develop performance-oriented, competency-based modules in the environmental health sciences.

USING PRECISION ROTAMETERS is one of the modules in the series, "Vocational Education Training in Environmental Health Sciences." The module content is based on selected materials in the environmental health field. The module is intended to supplement existing course materials.

CONTENTS

## USING THESE SELF-INSTRUCTION MATERIALS

... self-instruction learning package or module is designed to ...w both students and instructors flexibility of use. Although ...marily intended for use in existing training programs, the ...le can be used by anyone interested in learning new skills or ...ng up old ones. Therefore, two sets of guidelines are ...ted--one set addressed to students and the other set ...sed to instructors. First, find out how you, the student, ... use the materials in this book.

## GUIDELINES FOR STUDENTS

**Take the Performance Test as a pretest.**

When you pick up this book and work through it, your goal will not be a letter grade or a high score on an exam. Instead, you will work to develop skills that you can measure. You will not have to worry about how well someone else is doing. Before you start work on this module, you should, first, find out if you have sufficient skills to start training by reading through the section called PERFORMANCE TEST. If you think you can do all or most of the items in this test, ask your instructor to obtain the necessary equipment and supplies. Before entering the training in this module, you should have gained skills in calibration, operation, and use of portable sampling pumps.

**Work on parts you need to practice.**

If you do everything well, according to the criteria in the Performance Test guidelines, you will not need to spend time working on this module. If after taking the Performance Test you discover there are parts you need to practice, follow the key to each item in FOR FURTHER STUDY.

**Work straight through each lesson in the order presented.**

Should you decide to completely work through this module, begin with the INTRODUCTION and go straight through each of the three lessons. The lesson begins with the OBJECTIVE of the training. Follow the instruction for each part in the order presented. Practice each step in a lesson until you can do it according to the criteria stated for the step. At the end of a lesson, do the EXERCISES. When there are audiovisuals listed at the end of a lesson, ask your instructor for help in obtaining them.

| | |
|---|---|
| Take the Performance Test as a posttest. | Finally, after you have mastered all of the exercises in each lesson, ask your instructor to watch you do each item in the Performance Test. The items in the Performance Test are intended for use as a posttest to evaluate the quality of your performance. Turn now to the Performance Test. |

## GUIDELINES FOR INSTRUCTORS

| | |
|---|---|
| Approach | The approach of these materials is to provide the student with the opportunity to learn skills for cleaning and calibrating a precision rotameter for use as a secondary calibration standard. The equipment you have available may be somewhat different from that presented in the lessons. If such is the case, you may need to write supplementary instructions to point out the equipment differences. The skills tested on the Performance Test are designed for use with any make and model of instrumentation. |
| Independent Study | Students can work independently and at their own pace. Depending on the time frame you set for completing each lesson, you may want to start a group off in each lesson with a demonstration and informal presentation. |
| As a Laboratory Workbook | Alternatively, you may choose to use this module as a laboratory workbook in a structured laboratory session. With this option, you may allow students greater access to your assistance, especially in watching them perform the pre- and posttest portions of the training. |
| General Instructions | Read through each lesson to anticipate what equipment and supplies you will need to make available for students to use. Also, order any audio-visuals or reading materials you think may present a complementary perspective to the training in this module. Use the items in the Performance Test as the minimum requirements for gauging successful completion of the training. |

## BACKGROUND

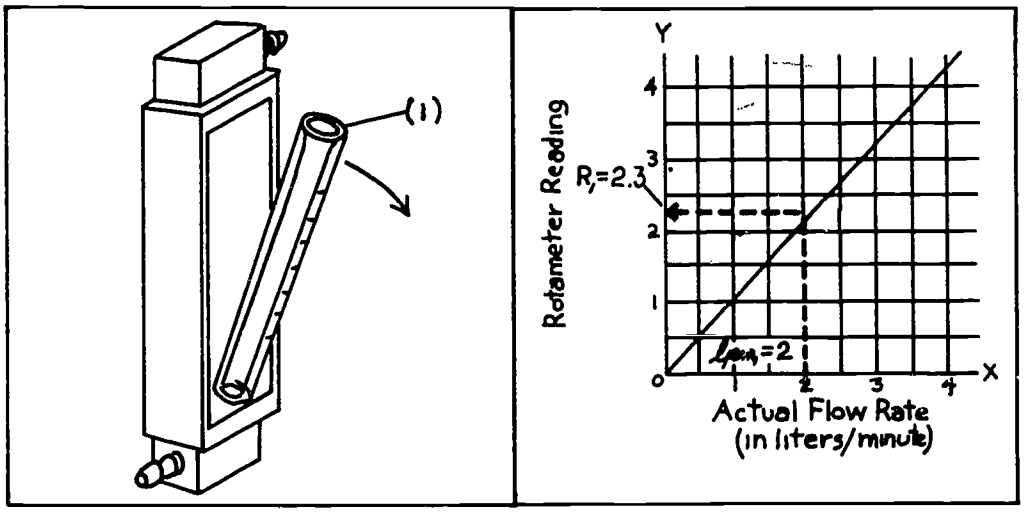
Precision rotameters are used to measure quantitatively and accurately the flow of air or fluid. A rotameter that is built to measure the flow rate of air or fluid under great pressure is constructed out of a specially made glass and metal body. Consequently, such an instrument is usually large and bulky. The type of rotameter you will use in this lesson, however, measures air at low flow--5 liters per minute (lpm) or less. It is constructed of lightweight materials and is only 6-8 inches in length.

Precision rotameters are widely used with environmental monitoring and testing equipment. They offer a convenient method for calibrating portable air sampling equipment used for collecting either environmental or workplace air samples. Such equipment must be calibrated before and after use to ensure accuracy in the collection of samples. Another advantage to using a precision rotameter is that if the flow rate drops off during the sampling period and cannot be adjusted back to the desired flow rate, the instrument can be used to determine the reduced flow rate. The result is that the sample may be salvageable.

The rotameter must be recalibrated after cleaning, and at least quarterly, or more frequently if a change in flow rate characteristics is noted. Once the rotameter is calibrated against the bubble meter, it is unnecessary to recalibrate it for each pump you use. For example, if you calibrate the rotameter with a pump in the laboratory, you can check the flow rate of another pump just before and just after you use it to collect a sample. The validity of calibrations is based on the assumption that tests are made at standard conditions of temperature (20° C) and pressure (760 mmHg) or corrected to standard conditions.

## WHAT YOU WILL LEARN

When you finish working through the steps and exercises in this module, you will be able to clean and calibrate a low-flow precision rotameter for use as a secondary calibration standard; as such, the rotameter can be used instead of the soapbubble meter to calibrate a personal sampling pump just before and after use.




You will learn how to clean and calibrate a precision rotameter in three lessons:

- Lesson One

  You will be able to name the parts of a low-flow precision rotameter and to describe how each part functions.

- Lesson Two

  You will be able to disassemble, clean, and reassemble a low-flow precision rotameter.

- Lesson Three

  You will be able to calibrate a precision rotameter, using a soapbubble meter.

## LESSON ONE

### OBJECTIVE

You will be able to name the parts of a low-flow precision rotameter and to describe how each part functions.

### WHERE AND HOW TO PRACTICE

You should practice this lesson on a table or desk where there is room to spread out parts and also this module. Ideally, you should work in the equipment breakout area or laboratory at your school or place of employment. Read through each step before attempting to do it, and make sure you can perform the step as well as described in "How Well You Must Do." Practice labeling parts by using the diagrams in "Exercises."

### HOW WELL YOU MUST DO

You must be able to name all parts of the precision rotameter, and describe in your own words how the rotameter and its parts function.

### THINGS YOU NEED

To work through the steps and exercises in this lesson, you will need:

- a precision rotameter, such as the "Sho-Rate 50"* designed for measuring gas flow
- an 8-inch piece of clear plastic tubing, such as Tygon* tubing
- an instruction manual for the rotameter.

Instructions: Now turn to the next page and begin work on Lesson One, "Getting There--Steps."

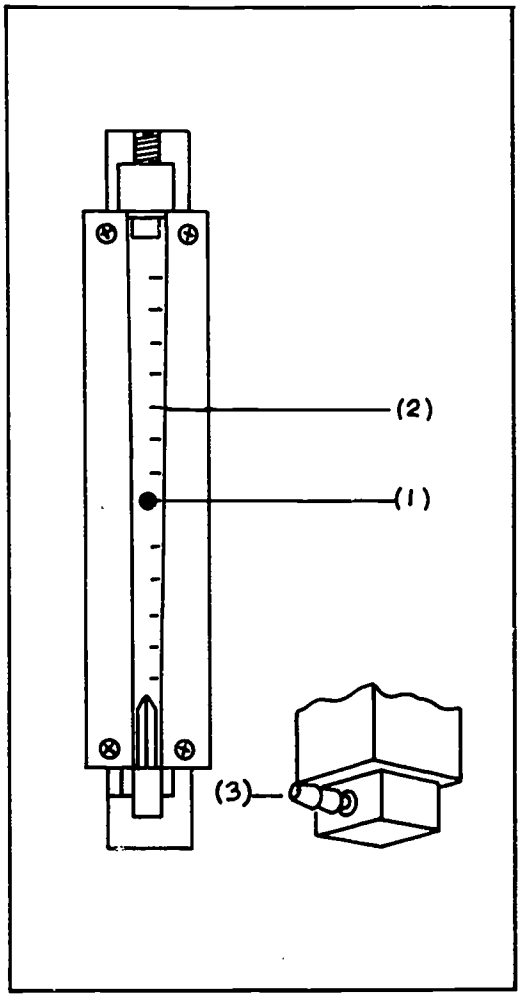
*Presentation of information in this module on any specific type or model of equipment should not be construed as an endorsement of the equipment by the U.S. Department of Education. The equipment used in this module is simply typical of rotameters that are commonly used in laboratories and in the field.

## GETTING THERE--STEPS

### STEP 1

Pick up the rotameter and compare it with the diagram in Key Point 1. Tip the rotameter so the float (1) moves from one end of the vertical tapered tube (2) to the other. Notice that the tube is wider at the top than it is at the bottom. When air enters the rotameter through the inlet (3), it pushes the float up.

### KEY POINT 1

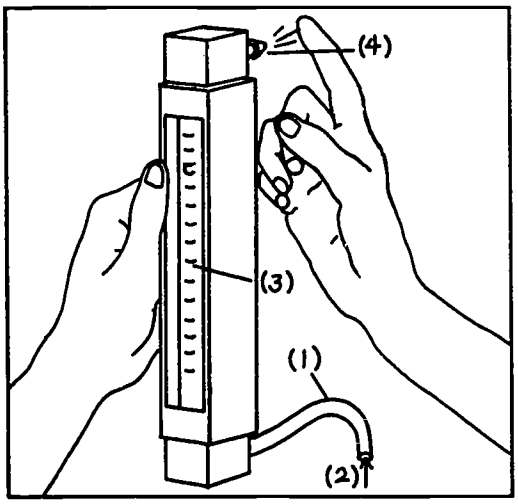



The float travels through a tapered tube.

STEP 2

Demonstrate how air causes an upward force on the float. Attach a short length of clean Tygon tubing (1) to the inlet and blow (2) softly at first and then harder to make the float rise to the top of the metering scale (3). Feel the force of the air coming out of the outlet (4) of the rotameter as you blow. To get the float to the top of the scale, you must blow 10 times harder to get the float to rise to the first mark. The tapered construction of the tube makes it possible to keep the rotameter small while allowing it to operate within an accuracy range of ±5 percent when calibrated.

KEY POINT 2

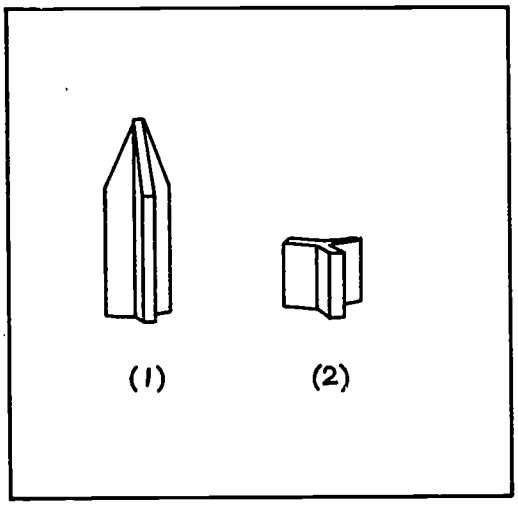



Feel the pressure of air escaping through the outlet. To push the float up to the top of the scale, the air pressure must be 10 times greater than when it is at the bottom.

STEP 3

Find the inlet (1) and outlet (2) float stops. These are located at the bottom and top of the metering tube. Their function is to keep the float from bumping the bottom and top of the tube.

KEY POINT 3

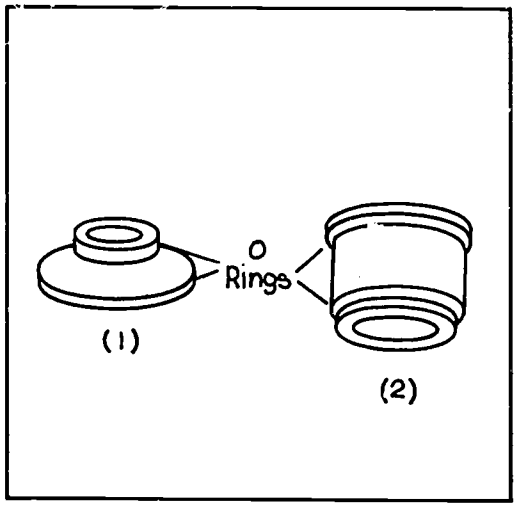



The float stops keep the float from hitting the bottom and top of the tube.

STEP 4

Look at the examples of packing in the Key Point. You cannot see the packing from the outside, but you will find it when you clean the rotameter in Lesson Two. The function of the rubber O-ring packing is to provide a seal at the top and bottom of the rotameter, between the inlet (1) and outlet (2) fittings and the metering tube.

KEY POINT 4

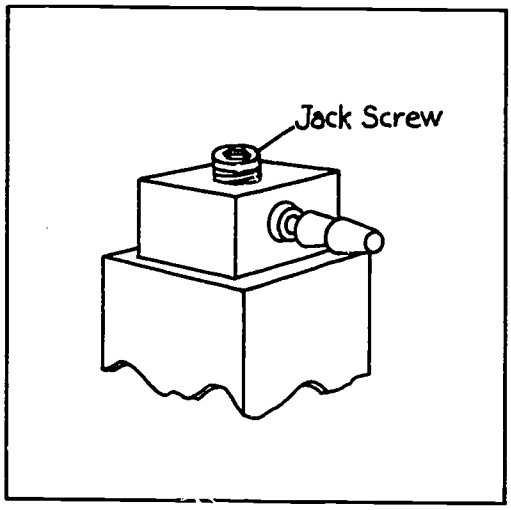



The packing usually consists of rubber O-rings.

STEP 5

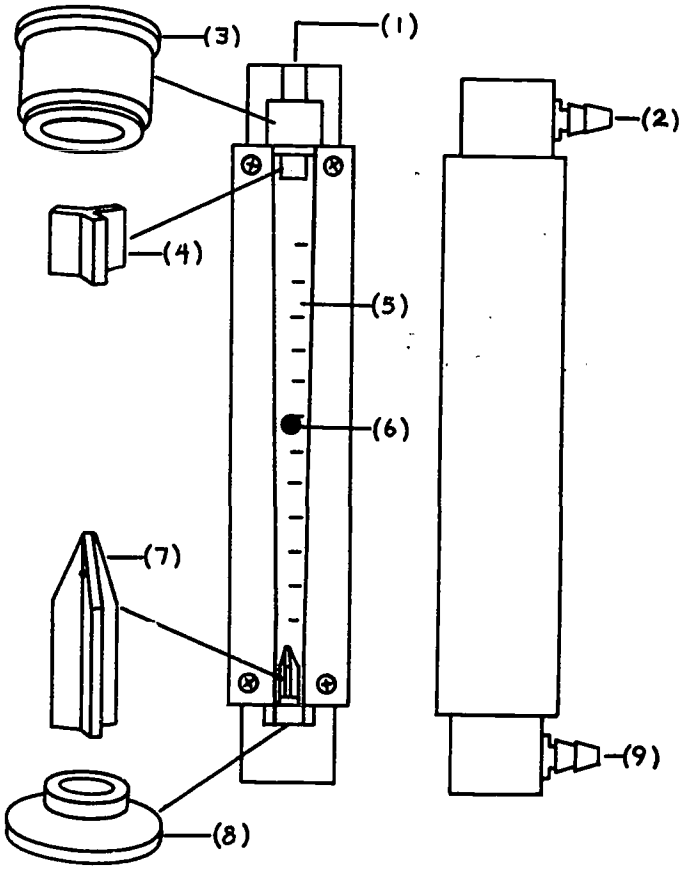
Locate the jack screw at the top of the rotameter. The jack screw holds the tapered tube in place.

KEY POINT 5



## EXERCISES

Instruction 1: With the rotameter in front of you, practice naming each part. Then label the following drawing to test your knowledge. You should be able to identify all of the parts and give the function of each within 5 minutes.




1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____

Instruction 2: If you are using a rotameter that is different from the one illustrated, compare and contrast your model with the illustration. Point out similarities and differences in each part. If there are great differences, look at the manufacturer's operating manual for a description of the part and how it is used.

## LESSON TWO

### OBJECTIVE

You will be able to disassemble, clean, and reassemble a low-flow precision rotameter.

### WHERE AND HOW TO PRACTICE

Continue using the area you selected for practicing Lesson One. Before doing any actual disassembling and cleaning of the instrument, carefully read each step. If you have any questions about how to perform any step in this lesson, request help from your instructor.

### HOW WELL YOU MUST DO

You must be able to determine when a rotameter needs to be cleaned, and to disassemble, clean, and reassemble it so that all parts are free from particulates and organic residues and can function properly. You must be able to perform these procedures within 15 minutes.

### THINGS YOU NEED

- rotameter from Lesson One
- glassware cleaner (ammonia solution) or ultrasonic cleaner
- pipe cleaners
- Phillips screwdriver
- 5/32" hex wrench
- small piece of wire bent into a hook
- spare packing.

Instructions: Now turn to the next page and begin work on Lesson Two, "Getting There--Steps."

## GETTING THERE--STEPS

STEP 1

The rotameter should be periodically inspected for cleanliness. Dirt and foreign materials can adhere to the tube and float, which could cause the float to stick. Dirt also can accumulate in the inlet and outlet fittings. When the rotameter is regularly used at a particular flow rate, it will be possible to tell when it should be cleaned because the rotameter readings will change.

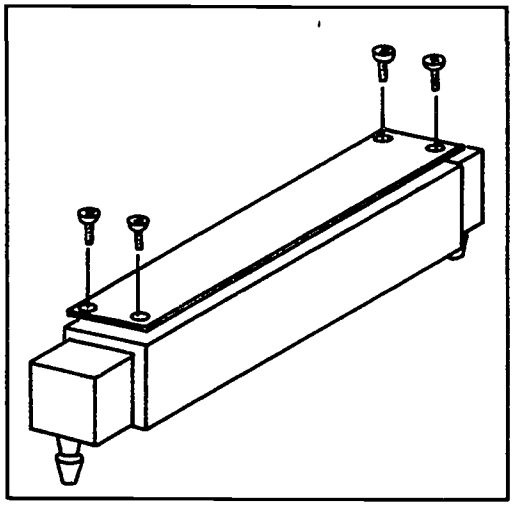
KEY POINT 1

Particulates and organic residues adhering to the tube can lower the accuracy of the instrument.

STEP 2

Disassemble the low-flow rotameter by first removing the plastic or glass safety shield (bezel) by unscrewing the four Phillips screws.

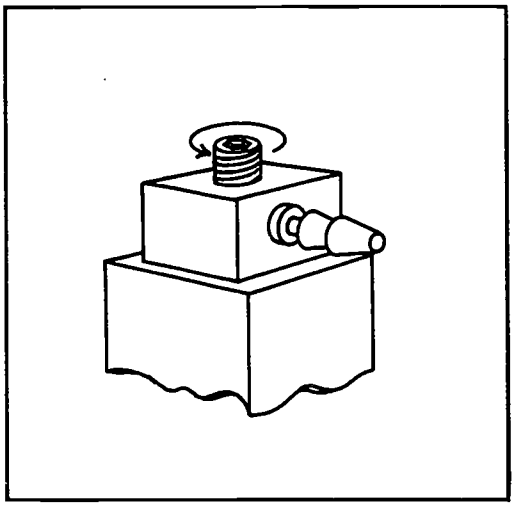
KEY POINT 2



STEP 3

Loosen the jack screw by turning it counterclockwise with a 5/32" hex wrench. You do not need to remove the jack screw. Loosen it until the metering tube is loose.

KEY POINT 3

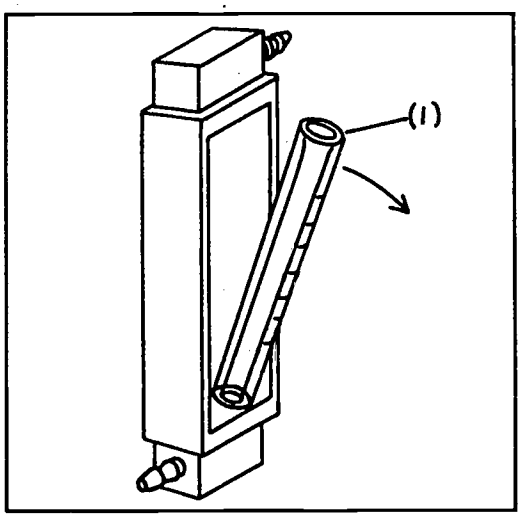


Do not remove the jack screw completely.

STEP 4

Tip the tube (1) as shown in the Key Point to remove it from the rotameter body. Using a small wire hook, remove the float stop from the outlet end of the tube. Invert the tube and allow the float to fall out into your hand. Place the float on a paper towel off to one side. Remove the float stop from the inlet end.

KEY POINT 4




Tilt the tube forward to remove it; remove the stops and float.

STEP 5

If available, place the tube, float stops, and float in an ultrasonic cleaner. Otherwise, clean the parts in the following way: Moisten a pipe cleaner with ammonia solution and slide it back and forth through the tube and the inlet and outlet fittings. Rinse the tube with tapwater. If water beads on the walls, reclean the tube. Dry these parts with dry pipe cleaners. Clean the float by rubbing it on an ammonia-moistened towel. Place all dried parts on a clean paper towel.

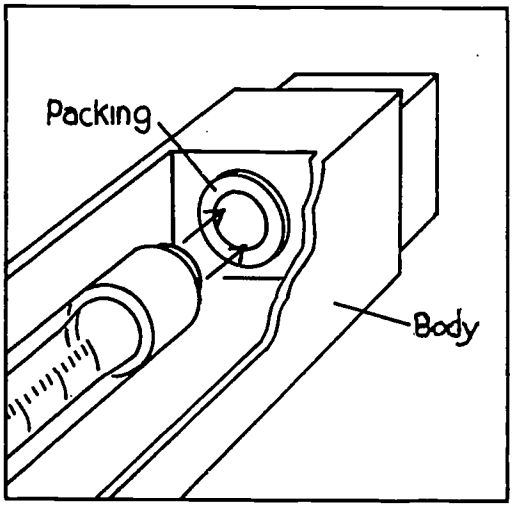
KEY POINT 5

To clean rotameter parts manually, use ammonia-moistened pipe cleaners.

STEP 6

Pick up the body of the rotameter and check the packing. This flexible rubber gasket (O-ring) protects the metering tube and prevents air loss. It is visible at the top and bottom of the body, at the points where the tube fits into each end of the body. The packing should be free of cracks and perfectly flat where it meets the face of the tube. Replace the packing if it is cracked, has irregularly shaped surfaces, or is excessively hard.

KEY POINT 6




Check the O-rings and replace if necessary.

STEP 7

Reassemble the rotameter in this order:

- o place float in tube
- o place float stops in tube
- o place bottom of tube against bottom packing and tip tube into place in the body
- o turn jack screw clockwise, tightening the top packing against the tube (do not overtighten--firm pressure is all that is required)
- o replace front plate using the four Phillips screws
- o tip the rotameter upside down and back to make sure the float moves freely.

KEY POINT 7

Make sure the tube rests smoothly on the packing, and that there are no leaks.

## EXERCISES

Instruction 1: Practice disassembling, cleaning, inspecting, and reassembling the rotameter with which you have been working. You should be able to perform these procedures within 15 minutes.

Instruction 2: Repeat Instruction 1 using a rotameter from a different manufacturer.

## LESSON THREE

### OBJECTIVE

You will be able to calibrate a precision rotameter, using a soapbubble meter.

### WHERE AND HOW TO PRACTICE

Work through the steps and exercises in this lesson at the same location where you worked on the previous lessons. Read through all of the steps before starting work on the first one. If you have any questions on any of the steps, ask your instructor for assistance.

### HOW WELL YOU MUST DO

You must be able to put the sampling train and soapbubble meter together so that all components needing support are firmly attached to prevent any air leaks from occurring where tubing joins components together into a system, and to prevent kinking of tubing. (You should be able to calibrate a rotameter within 20 minutes, using the equipment required in the lesson.) You must be able to time consecutively the rise of three bubbles in a soapbubble meter so that each timing is within $\pm$1.0 second of the average of all three.

### THINGS YOU NEED

In addition to the precision rotameter you used in the previous lessons, you also will need the following equipment and supplies:

- Personal air monitoring pumps with battery chargers

  -high flow such as the MSA Model G
  -low flow such as the MSA Model C-200
  -full flow range such as the Bendix BDX44 and Sipin pump

- Sampling devices and accessories

  -filter cassette, filters, and support pads, 37-mm diameter
  -cyclone
  -charcoal tube and holder
  -midget impinger and holder

THINGS YOU NEED (cont'd)

o Soapbubble meter

-buret stand
-buret clamps (2)
-buret, 1,000-ml with hose connection
-beaker, wide-mouthed or flat-bottomed shallow dish (petri)
-buret, 100-ml with hose connection
-soap solution, 50-ml liquid detergent in 500 ml of water
-Tygon tubing, 1/4-inch inside diameter, 30-inch and 8-inch piece.

Instructions: Now turn to the next page and begin work on Lesson Three, "Getting There--Steps."

## GETTING THERE--STEPS

STEP 1

The day before you use any portable pump, recharge the pump's batteries. Follow the manufacturer's instructions for battery recharging time and for operating the charging unit. Many pumps need 16 hours for recharging. When recharging is complete, run the pump for 5 minutes to let it warm up just before calibrating.

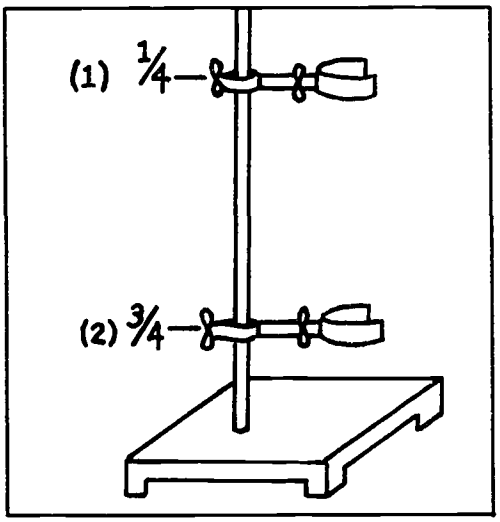
KEY POINT 1

Fully recharge the batteries of a portable pump before calibration.

STEP 2

Assemble the soapbubble meter. Tighten the buret stand shaft by turning it into the base. Fasten two buret clamps on the shaft--one at a point one-fourth of the way down the shaft (1) and the other at a point three-fourths of the way down the shaft (2).

KEY POINT 2

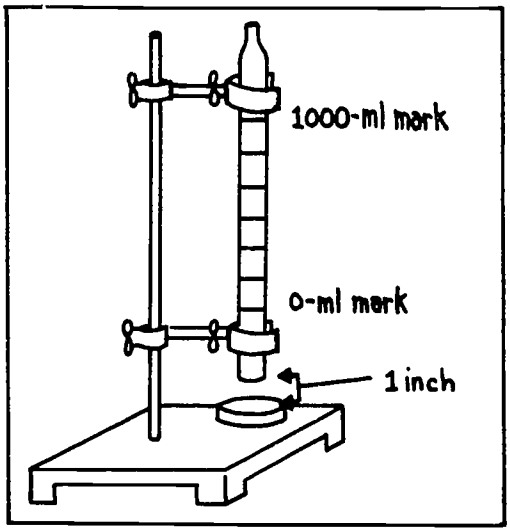



Fasten the support equipment tightly.

STEP 3

Prepare the buret for calibration. Completely rinse the inside of the buret with soap solution. Immediately turn it upside down. Note that in the inverted position the 0-ml mark will be the zeroing line, and the 1,000-ml mark will be the finish line. Position the buret in the buret clamps so the mouth is about an inch above the soap solution. Adjust the clamps to keep the buret from falling, but not too tightly to cause it to crack.

KEY POINT 3

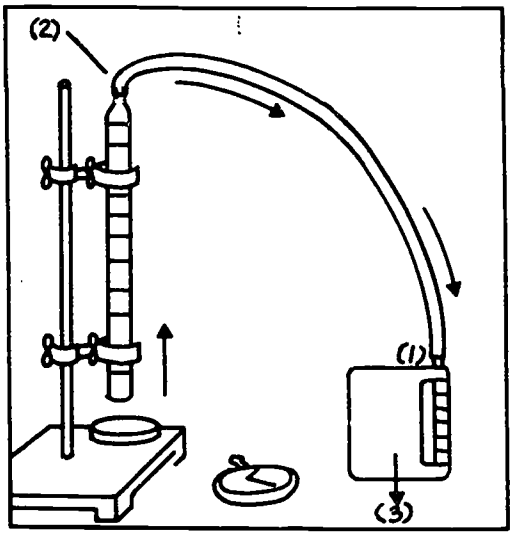



Rinse the buret and place it upside down.

STEP 4

Connect one end of a 30-inch piece of Tygon tubing to the inlet of the pump (1). Connect the other end to the stopcock end (2) of the buret. The pump draws air up through the buret and exhausts it through an outlet on the bottom of the pump (3).

KEY POINT 4

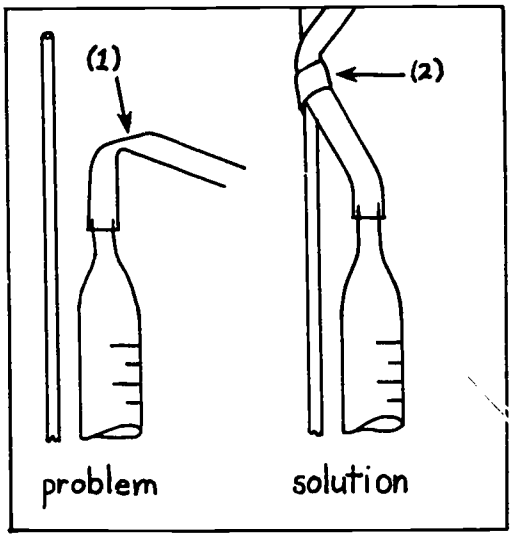



Connect the tubing so that air flows into the sampling device through the tubing and into the pump.

STEP 5

Test for air leaks between fittings and tubing on the bubble meter, the filter cassette, and the pump. Turn on the pump. Check the tubing size and push the tubing further onto the fittings. Check the tubing to make sure it is not kinked (1). Kinking could occur particularly at the joint where the tubing connects the sampling pump with the buret. If tubing is kinked at this point, tape it (2) to the buret stand shaft to keep the air line open.

KEY POINT 5

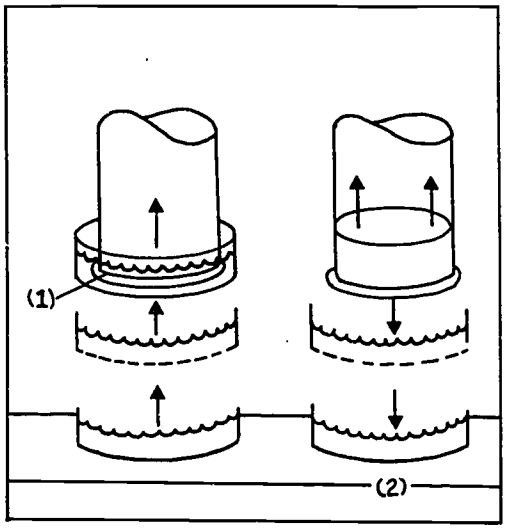



Remove the kink by supporting the tubing on the buret stand shaft.

STEP 6

Turn on the pump and adjust the pump valve as far as possible so that maximum flow is obtained. Make sure the soap solution container is filled. Form a bubble in the buret by raising the soap solution dish until the buret mouth is just below the surface of the solution (1). Quickly lower the dish (2). A bubble should have formed and begun to rise in the buret through the sucking action of the pump. Draw two or three bubbles up the buret to make sure that at least one bubble makes it to the 1,000-ml mark. Make sure the soapbubble solution is not drawn into any component of the calibration train. Do not use a trap, however, since this adds air resistance during calibration that is not present during sampling.

KEY POINT 6




Submerge the buret mouth only briefly in the soap solution.

STEP 7

If you cannot get a bubble to rise to the 1,000-ml mark, wet the buret walls with soap solution. A stronger soap solution may also be needed. If these remedies do not work, clean the buret. Then repeat Step 5 until you can get two or three bubbles to rise to the 1,000-ml mark each time you try.

KEY POINT 7

If the bubbles do not rise, wet the buret with soap solution and/or make the solution stronger.

STEP 8

Practice timing the bubble's travel. Adjust the pump for maximum flow. Time three trial runs (TR). Record each here:

$TR_1$ _____ sec

$TR_2$ _____ sec

$TR_3$ _____ sec

Average time _____ sec

The difference of any one of these from the average of all three must be within $\pm$1.0 second.

KEY POINT 8

Your timing accuracy on any one trial run must be $\pm$1.0 second of the average of three trials.

STEP 9

Form a bubble in the buret, and start timing the bubble's travel up the length of the buret after it is lined up on the 0-ml mark. Stop timing when the bubble reaches the 1,000-ml mark. Record the time for the bubble to travel 1 liter here:

($T_1$)_____ sec

While the pump is still running, disconnect the tubing from the bubble meter and attach it to the outlet end of the rotameter. Keep the inlet of the rotameter off the table or working surface and position the rotameter vertically. You may have to use a ringstand and clamp to support the rotameter in this position. When the float settles down, take a reading by matching the index mark on the scale that is directly across from the center of the float (ball). Record the rotameter reading here:

($R_1$)_____

KEY POINT 9

Record the time the bubble takes to travel the length of the buret, and then replace the bubble meter with the rotameter to obtain a reading in liters.

STEP 10

Turn the pump flow adjustment valve approximately one-fifth of the way in to obtain the first of four more readings that you will need to develop a calibration curve. Reconnect the bubble meter and make a second timing, $T_2$. Record $T_2$ here:

($T_2$)_____ sec

Disconnect the bubble meter and connect the rotameter and record the reading here:

($R_2$) _____

KEY POINT 10

To obtain another reading, turn the pump adjustment valve another one-fifth of the way in; the pump flow will decrease each time.

STEP 11

For each of the remaining three trials, turn the pump flow adjustment another fifth of the way in. Record each trial here:

($T_3$) _____ sec

($R_3$) _____

($T_4$) _____ sec

($R_4$) _____

($T_5$) _____ sec

($R_5$) _____

KEY POINT 11

Repeat Steps 8 and 9 three more times.

STEP 12

Calculate the flow rate of the sampling pump using the timing data you collected in Steps 9 through 11. Use the formula shown in the Key Point. For example, if $T_1$ = 30 seconds, the flow rate would be:

1 liter X 60 sec/30 sec
= 2 lpm.

Calculate liters per minute for trial run. If:

$T_1$ _____,
$lpm_1$ = _____
and $R_1$ = _____

$T_2$ _____,
$lpm_2$ = _____
and $R_2$ = _____

$T_3$ _____,
$lpm_3$ = _____
and $R_3$ = _____

$T_4$ _____,
$lpm_4$ = _____
and $R_4$ = _____

$T_5$ _____,
$lpm_5$ = _____
and $R_5$ = _____

KEY POINT 12

To find the pump flow rate in liters per minute (lpm), use this formula:

$$\frac{\text{Volume}}{\text{Time}} = \text{volumetric flow rate}$$

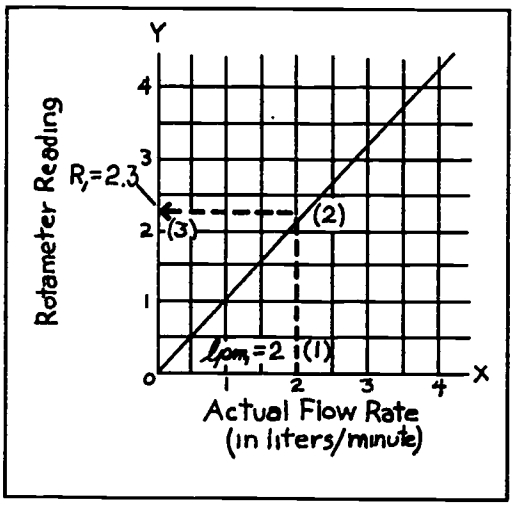
Use this working formula:

$$\frac{1 \text{ liter} \times 60 \text{ sec}}{T \text{ sec}} = \text{lpm}$$

STEP 13

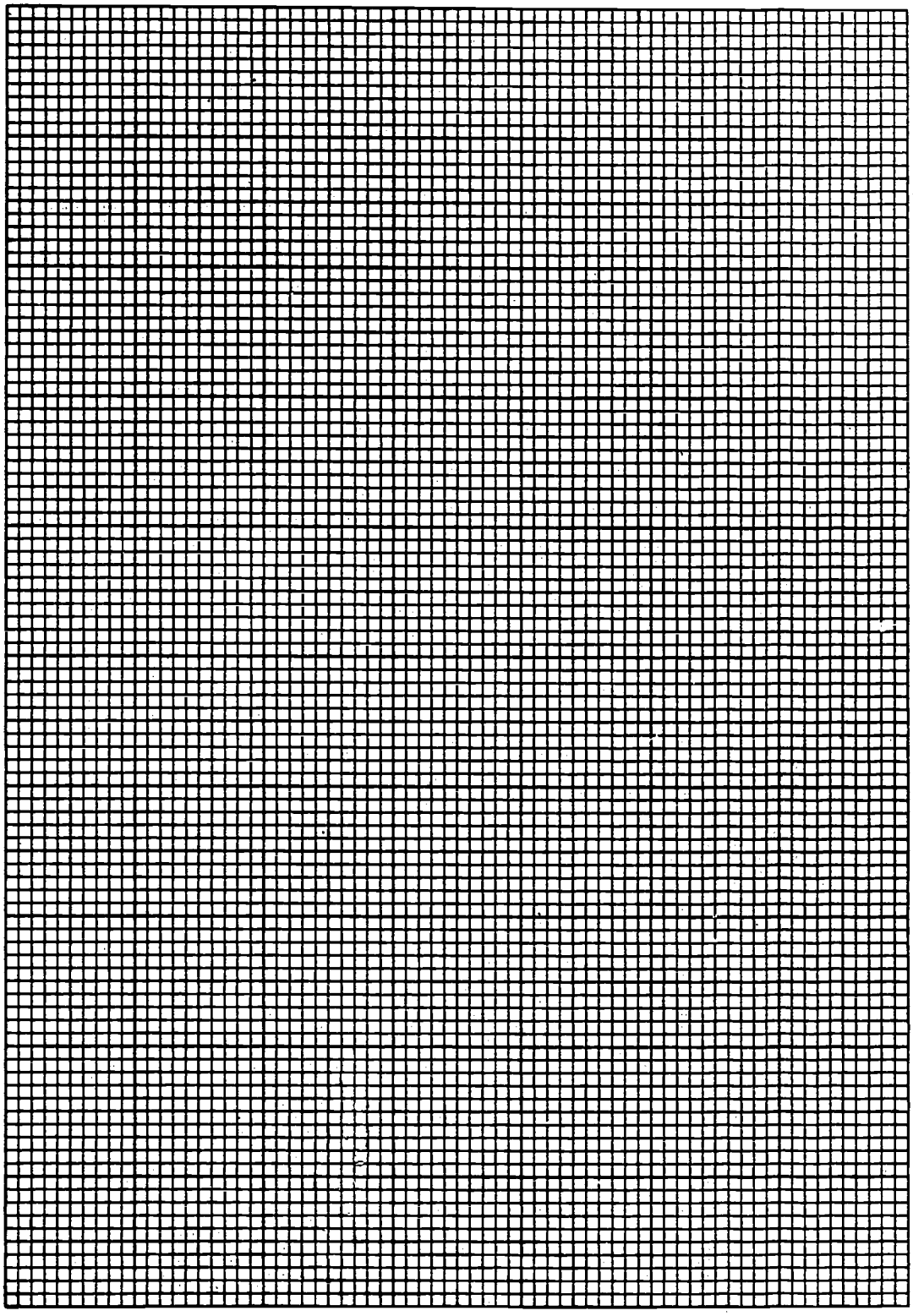
Use the graph paper provided at the end of this lesson and plot a graph like the one shown in the Key Point. Using the values you calculated in Step 12, locate 1pm on the x-axis, and $R_1$ on the y-axis. Find and mark the point where these values meet at (2). Repeat this process for the other four pairs of values. To find the rotameter reading for a desired flow rate after you draw the curve, first find the desired flow on the x-axis (1). Follow the line at this point up to the graph curve (2). Follow the horizontal line at this point to where it touches the y-axis (3). In the example, you must adjust the pump until the rotameter reads 2.3 in order to have an actual flow rate of 2.0 lpm.

KEY POINT 13




Plot each "1" against each corresponding "R" to find the relationship between an actual flow rate value and the corresponding rotameter reading.

## EXERCISES



## EXERCISES

Instruction 1: Calibrate a precision rotameter using a 100-ml buret bubble meter. Follow each step in the lesson as you did to calibrate the rotameter the first time.

Instruction 2: Compare the calibration curve using the 1,000-ml buret with the calibration curve. Are there any differences in the relationships between actual flow rates and rotameter readings between the two curves? Explain your findings.

Instruction 3: Calibrate the following portable sampling trains using the rotameter instead of the bubble meter:

(a) charcoal tube for organic vapors
(b) membrane filter for particulates
(c) cyclone for respirable particulates
(d) midget impinger for readily oxidized airborne mists, gases, or vapors.

Calibrate the appropriate sampling train at the NIOSH-recommended sampling rates for sampling each of the following substances: molybdenum, chloroform, nitric acid, and respirable coal dust.

Instruction 4: Some industrial hygienists prefer to perform a calibration of a precision rotameter with the rotameter included in the calibration train instead of connecting and disconnecting it as recommended by OSHA (IHFOM). The primary advantage to this other method is that the rotameter float can be adjusted to a desired reading, thus making it easier to construct a calibration curve.

To observe the difference between the two methods, repeat Lesson Three and include the precision rotameter between the bubble meter and the sampling pump.

Adjust the sampling pump so that the readings on the rotameter are evenly distributed up the scale. Obtain the pump flow rates as you did in Steps 9 through 13.

## OTHER READING

U.S. Department of Health, Education, and Welfare, NIOSH. NIOSH Manual of Sampling Data Sheets, 1977.

## PERFORMANCE TEST

Instructions: Check your skill level or progress by working through each of the items in this test. If you can perform each item as well as required, place a check in the space provided. When all of the items are checked, you are ready to demonstrate your skills to your instructor. You may use the following list if needed. You will be considered trained in a skill after your instructor approves your performance on each of the following items.

### CLEANING A PRECISION ROTAMETER

You must be able to perform the following in 15 minutes or less:

No. 1 _____ Remove the tube from the rotameter.

No. 2 _____ Remove the float and float stops from the tube.

No. 3 _____ Clean the tube manually with pipe cleaners and ammonia solution so that no water beads on the walls of the tube, and clean the float and float stops so that all surfaces are free of accumulated dirt and organic residue.

No. 4 _____ Check the condition of the packing; O-rings must be flat and undamaged, round, and flexible.

FOR FURTHER STUDY

If you could not perform one or more of the four items above, review and practice the following lesson steps:

No. 1
Lesson Two, Steps 1 through 4

No. 2
Lesson Two, Step 4

No. 3
Lesson Two, Step 5

No. 4
Lesson Two, Step 6

## PERFORMANCE TEST

### CALIBRATING A PRECISION ROTAMETER

You must be able to perform the following in 20 minutes or less:

No. 1 _____ Allow a 5-minute warmup for the portable sampling pump.

No. 2 _____ Prepare a 1,000-ml capacity soapbubble meter for calibration of a sampling pump.

No. 3 _____ Time the travel of three consecutive bubbles so that the difference of any one from the average of all three must be within ±1.0 second.

No. 4 _____ Set the pump for the highest flow rate, and record the time it takes a bubble to travel the entire length of the bubble meter. Replace the bubble meter with the precision rotameter and record the reading. Repeat this process at four other consecutively lower flow rate settings.

No. 5 _____ Construct a calibration curve that can be used to find the rotameter reading corresponding to an actual flow rate.

### FOR FURTHER STUDY

If you could not perform one or more of the five items above, review and practice the following lesson steps:

No. 1
Lesson Three, Step 1

No. 2
Lesson Three, Steps 3 through 5

No. 3
Lesson Three, Steps 6 through 8

No. 4
Lesson Three, Steps 9 through 11

No. 5
Lesson Three, Steps 12 and 13

## REFERENCES


Installation and Operating Instructions for the Sho-Rate "50." Emerson Electric Company, Hatfield, PA, 1979.

The Rotameter Sheds Its Limitations. Harold Mangin, Fischer & Porter Company, Hatboro, PA. (no date)

U.S. Department of Health, Education, and Welfare, NIOSH. The Industrial Environment--Its Evaluation & Control, U.S. Government Printing Office, Washington, DC, 1973.

U.S. Department of Labor, OSHA. OSHA Instruction CPL 2-2.20, Field Operations Manual, April 1979.

Variable Area Flowmeter Handbook, Volumes 1, 2, and 3, Fischer & Porter Company, Hatboro, PA. (no date)