

Air Flow Calibrations

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I. Introduction

- A. Evaluation of exposures
- B. Direct measurement
- C. Collection and analysis of samples for TWA

A. Evaluation of Exposures

- Measure a concentration of contaminant in air
 - Collect sample of contaminant using sampling pump or by other means
 - Measure amount of air drawn during sampling
 - Measure amount of contaminant collected
 - Calculate the concentration

B. Direct Measurement

- Device that directly quantifies the amount of contaminant in the air
 - Real time measurement
 - Series of instantaneous concentrations, or
 - Continuous indication of the concentration

C. Collection and Analysis of Samples for Time Weighted Average (TWA)

- Sampling device collects the contaminant and separates it from a volume of air
- Single, integrated measurement over a length of time allows only a time average concentration
- Later analysis of the collected contaminant(s)

More topics

- * Air flow measuring devices
- * Advantages and limitations of each type of device.
- * Proper use of each type.
- * Calibration of pumps and secondary standard devices

Steps in sampling air

- Sample with a collection device
- Draw air with an air mover
- Measure the volume of air accurately
 - The accuracy of the concentration depends on the accuracy of the measurement of the air volume.
 - The volume is measured by control of flow for a set time.

Vocabulary

- Flow--the volume of air drawn per time
- Flow (Q) = Volume (Vol) / time (t),
Usually in terms of liters per minute (LPM or L/min) or mL/min.

II. Air Movers

■ A. Pumps

- 1. Hand operated
 - » Single, fixed volume (detector tube pumps)
 - » Continuous sampling (obsolete)
- 2. Motor driven
 - » diaphragm, piston, vane
 - » adjustable flow, constant flow, pressure regulated.

B. Pumps

- Location/size: Portable (personal) vs stationary (area)
- High volume: usually too large for person to wear. Used for bulk sampling (e.g., for free silica analyses) and for collection of fine particulates.
- Low flow (10 ml/min to 1.0 L/min): typical for personal sampling of gases and vapors on activated charcoal
- Moderate flow (1.0 L/min to 2.0 L/min): typical for personal sampling of aerosols
- Line operated vs. battery operated vs. rechargeable

Pumps (Continued)

- Manual
- Adjustable flow
- Flow controlled
- Pressure controlled
- Feedback control
- Programmable

III. Measurement of Flow

- Flow is measured by the volume of air moved per unit amount of time.
 - » $Q = V / t$,
 - » Where Q = flow, V = Volume, and t is time.

Standard Levels of Flow Measurement

■ Primary

- Measurements generally involve a direct measurement of volume on the basis of the physical dimensions of an enclosed space.

■ Secondary

- Standards are reference instruments or meters which trace their calibration to primary standards and are capable of maintaining their accuracy.

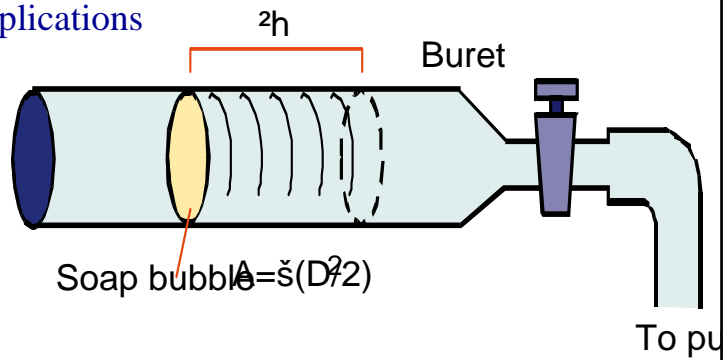
■ Intermediate

A. Primary Standard Flow Measuring Devices

1. Instruments measure volume based on measured dimensions (i.e., length)
2. Examples
 - » Soap Bubble Meters
 - » Spirometers
 - » Sealed piston Devices.

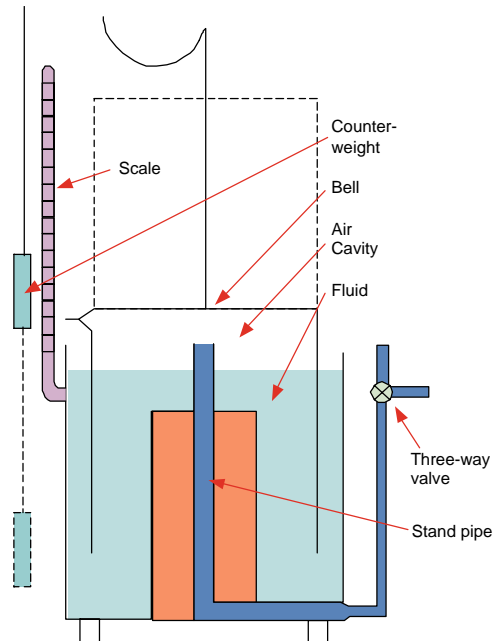
- Primary standard
- Can be directly related to measured dimensions & time
- Simple, light weight, accurate, stable
- Fragile, messy liquids for field applications

1. Soap Bubble Meters



Schematic drawing of a spirometer

- Primary standard
- Can be directly related to measured dimensions & time
- Accurate, used for medical applications
- Bulky, difficult to move, require liquid
- Not a field instrument.



Secondary Standard Devices

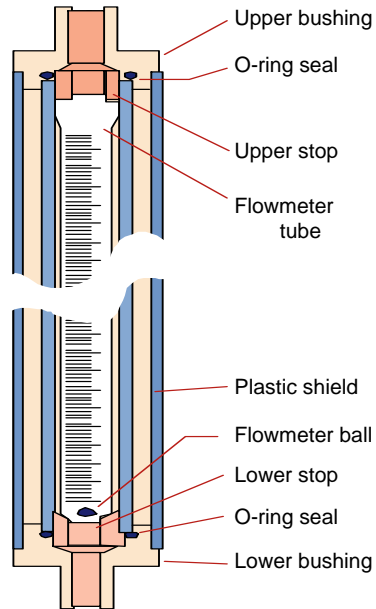
- Require calibration against a primary device
- May need repeated calibrations
- May not be as accurate as primary

B. Secondary Flow Measuring Equipment

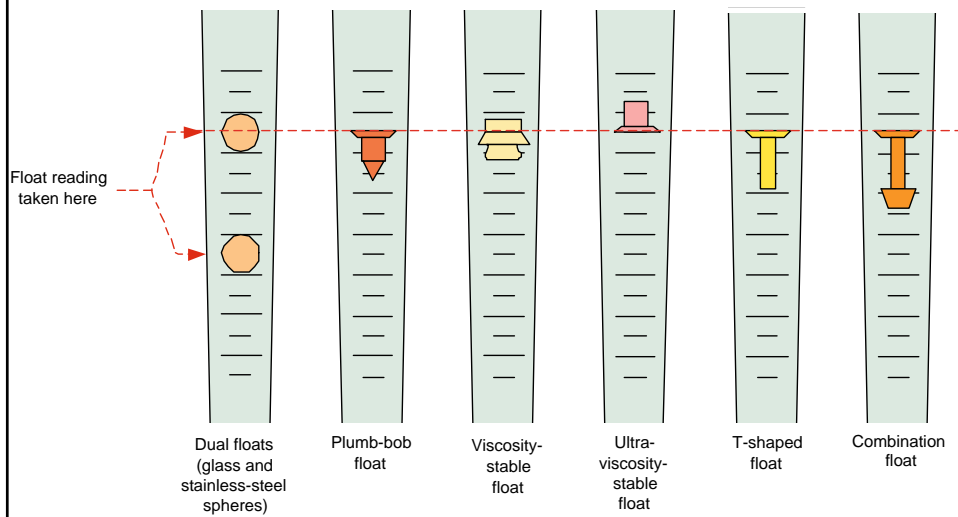
1. Rotameters
2. Wet test meters
3. Dry gas meters

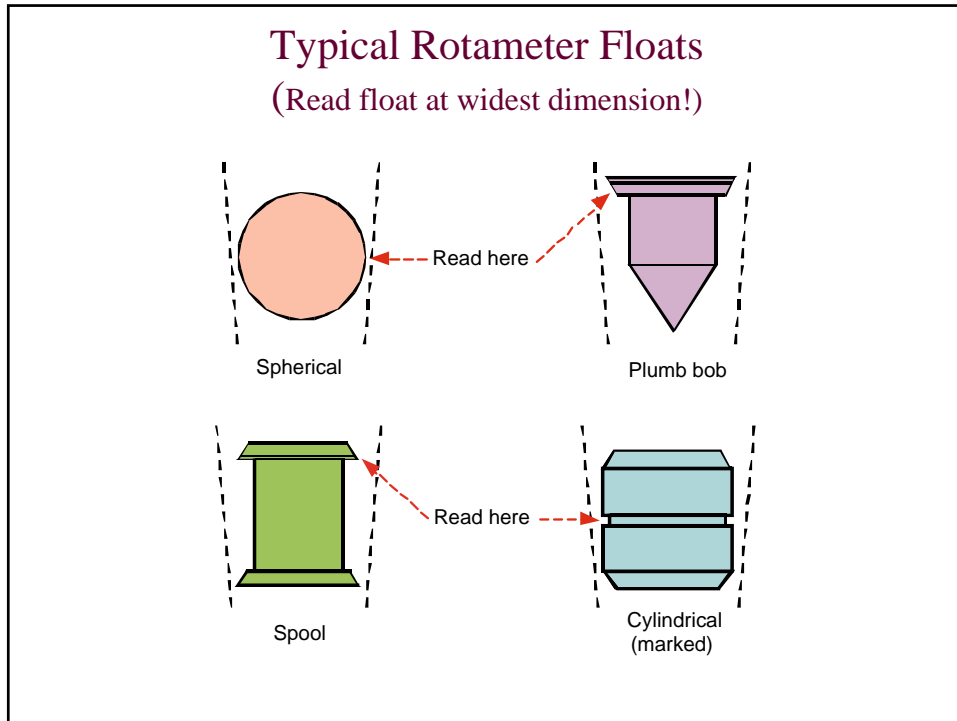
1. Rotameters

- Handy for field work.
- Need calibration.
- Accurate and precise when calibrated and maintained.
- Glass or plastic
- Measurement dependent on temperature and pressure



Six kinds of rotameter floats





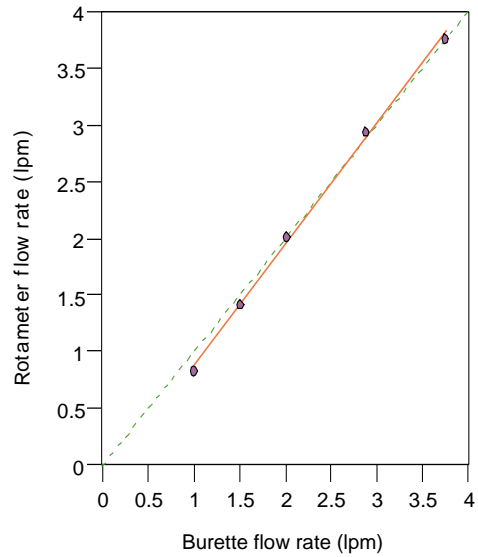
1. Rotameters (Continued)

- Measurement dependent on temperature (T) and pressure (P) of airstream passing through it

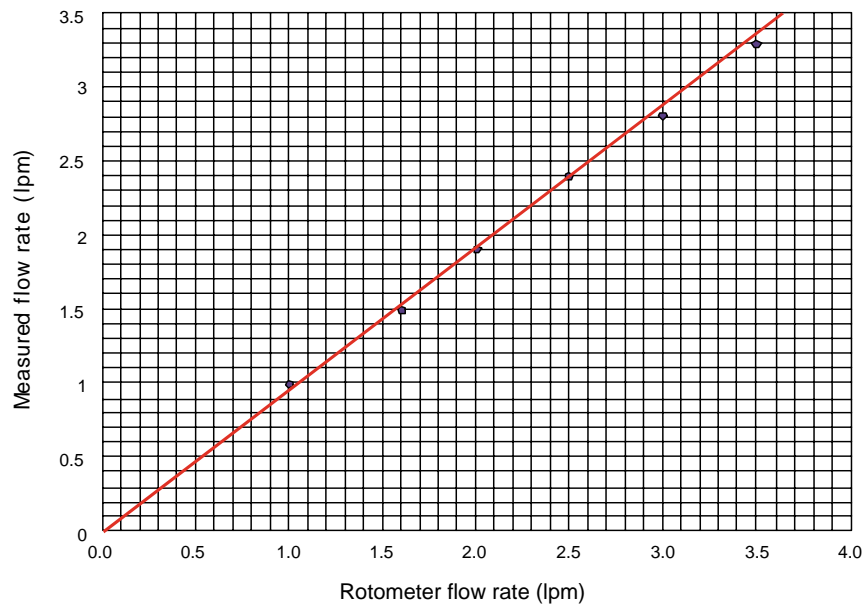
$$Q_2 = Q_1 (\text{den}_1 / \text{den}_2)^{0.5}$$
$$= Q_1 (P_1 T_2 / P_2 T_1)^{0.5}$$

Calibration of Rotameters

- Calibrate against a primary flow measuring device
- Measure the indicated flow against the actual flow
- Repeat across the working range of the meter

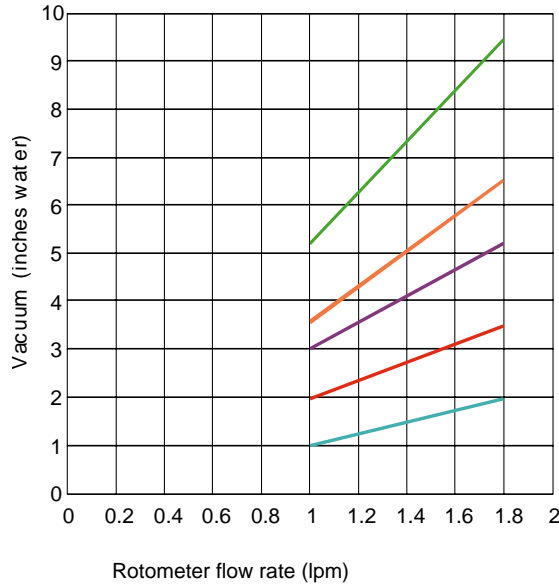
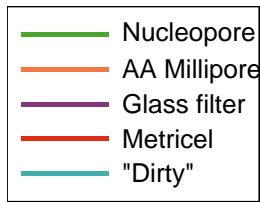


Revised calibration curve for rotameter using bubble meter



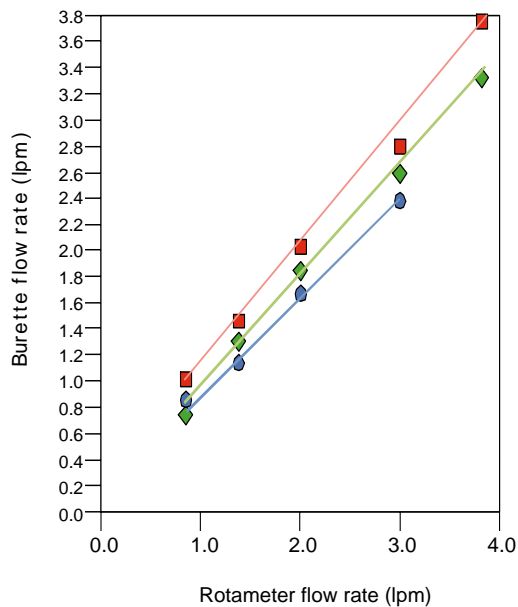
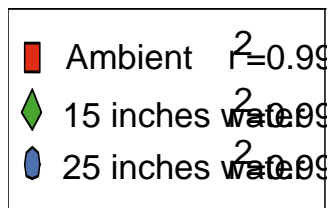
Effect of Loading and Restricted Flow on Rotameter Readings

- Comparison of changes in filter resistance for five filters



Pressure effects on pump & rotameter functioning

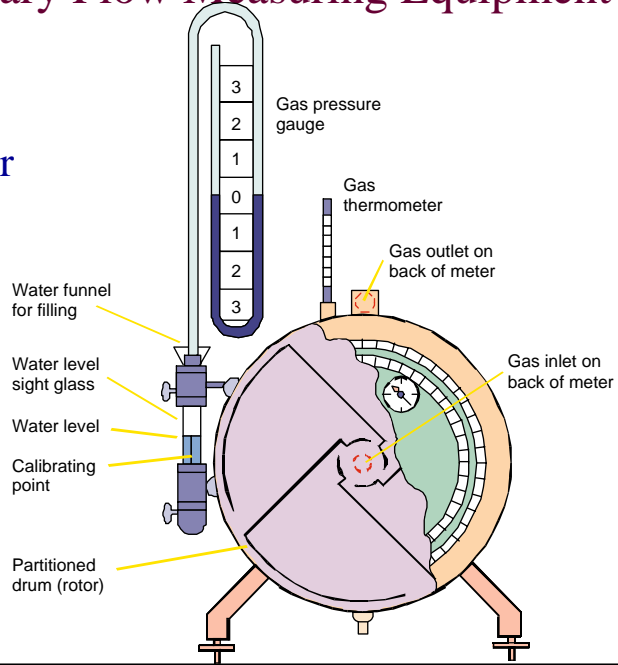
- Pump calibration vs. a standard at different pressures



B. Other Secondary Flow Measuring Equipment

■ 2. Wet test meter

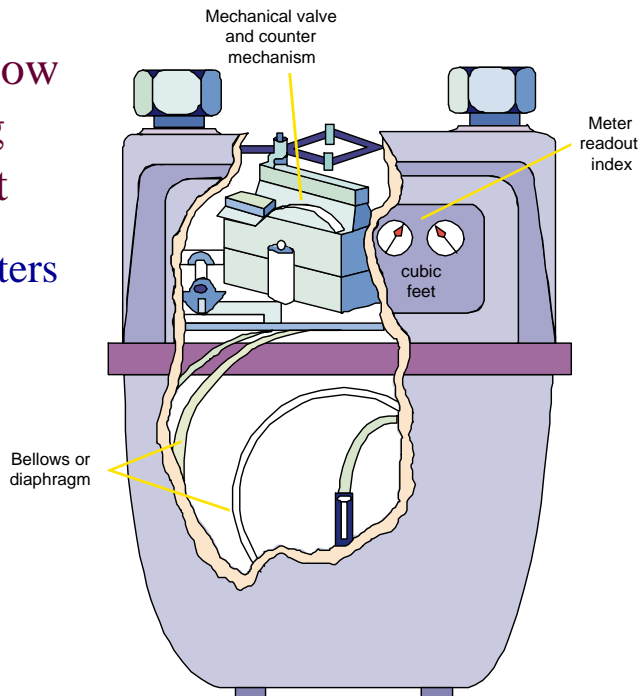
- Bulky
- Liquid filled
- Atmospheric pressure



B. Other Secondary Flow Measuring Equipment

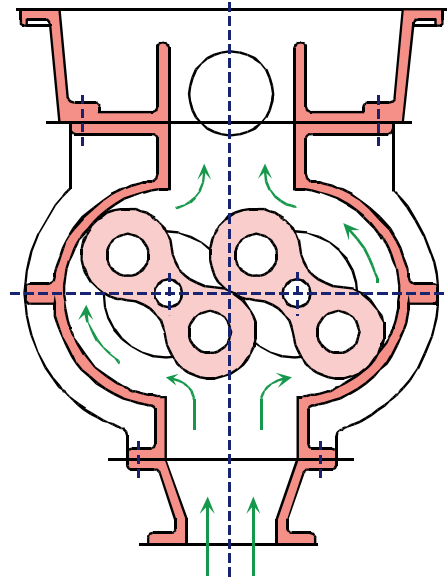
■ 3. Dry Gas Meters

- Non-portable
- Large
- Higher flow
- Stable
- Industrial applications



Dry Gas Meters

- Schematic diagram showing principle of operation of twin-lobed positive displacement meter



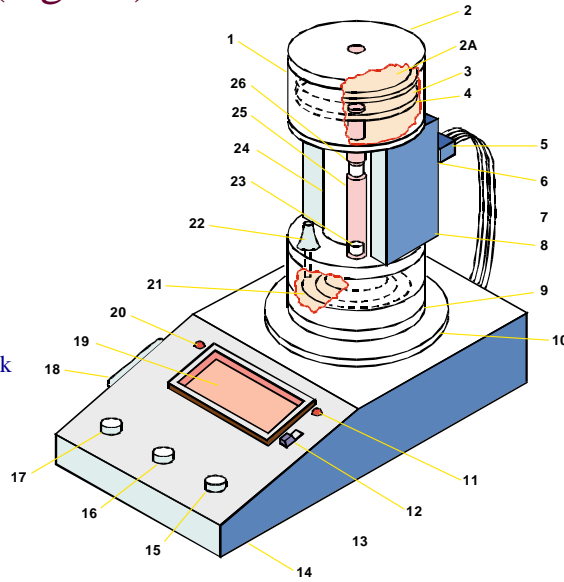
C. Other Flow measuring Devices

1. Electronic bubble meters
2. Dry cal meters
3. Mass flow meters (Perkins, Pg. 732)

The Gilibrator (legend)

■ Nomenclature:

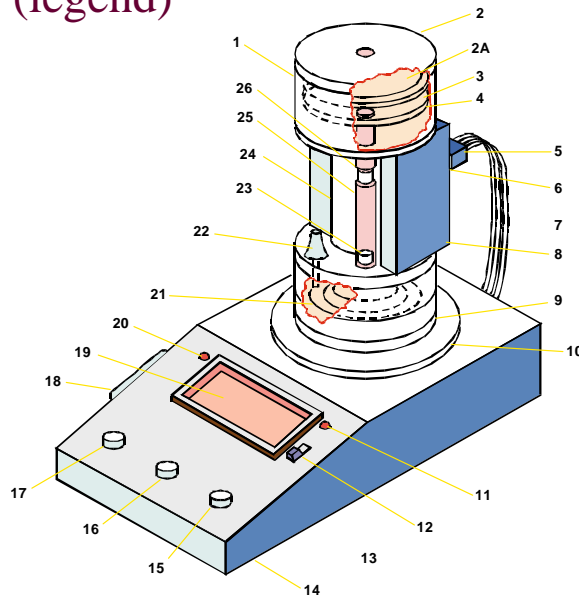
- 1. Bubble generator assembly
- 2. Damper plate
 - 2a. Pulsation damper
 - 2b. "O" ring
- 3. Spacer
- 4. Plate, bubble breaker
- 5. Cable assembly
- 6. Sensor block connecting jack
- 7. Sensor block locking screw
- 8. Sensor block
- 9. Base plate assembly
- 10. Mounting base
- 11. Charging indicator
- 12. On-off



The Gilibrator (legend)

■ Nomenclature:

- 13. Charging jack
- 14. Control unit
- 15. Average and Sample # switch
- 16. Delete switch
- 17. Reset switch
- 18. Printer jack
- 19. LCD display
- 20. Run indicator
- 21. Bubble generator ring
- 22. Bubble initiate button
- 23. Air inlet boss
- 24. Flow tube
- 25. Storage tubing
- 26. Air outlet boss

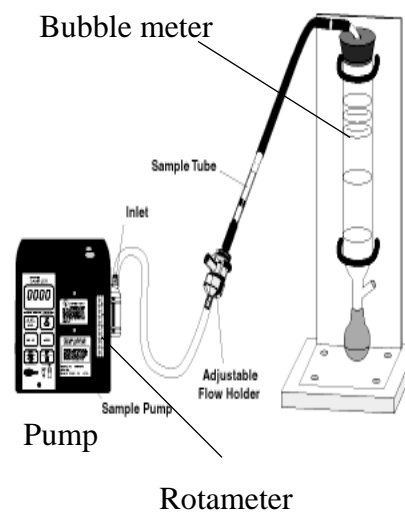


IV. Calibration of Air Flows

- Secondary devices are calibrated against primary.
- Calibration should be done under identical conditions to that of the actual sampling.
- See diagrams of calibration apparatus.
- Evaluation of pump errors.
- Calibrate before, during, and after sampling

Diagrams of Calibration Apparatus.

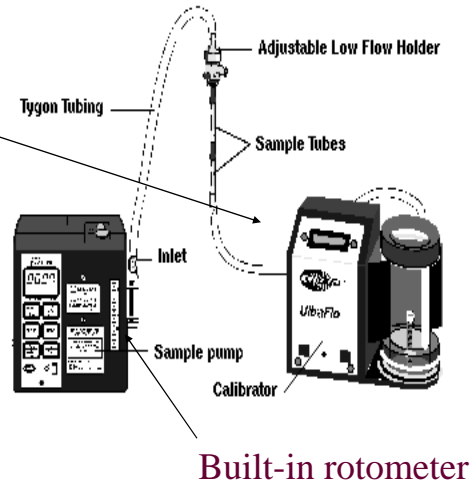
- Key to diagram
 - Soap bubble meter
 - Rotometer
 - Pump
 - Pressure gauge (not shown)



Diagrams of Calibration Apparatus.

■ Key to diagram

- Electronic soap bubble meter
- Rotometer
- Pump
- Pressure gauge (not shown)



E. Preview of Lab Experiment I.

- In this experiment we will use the different air flow measuring instruments and apply them to calibrate each other.
 - Part 1: Calibration of rotameter using bubble burette.
 - Part 2: Calibration of sampling pump using rotameter.
 - Part 3: Evaluating the effects of filters on pump performance.
 - Part 4: Evaluating the effects of atmospheric pressure on rotameter performance.
 - Part 5: Comparison of a mass flow meter and rotameter as a function of pressure.
 - Part 6: Calibration of a rotameter with a (Gilibrator) electronic flow meter.

Layout

Calibration fastest if put all devices in series

All devices except bubble meters must be corrected for density

Remember that mass flow devices may read out in L/min, but they control mass per time

Mass flow meters: $\text{Vol/time} = \text{MassFlow/density}$

Rotameters: calibrate at density will use (too confusing otherwise)

Best to calibrate at altitude will use

Density in Sealevel Lab With Resistance

- * If high resistance at needle-valve, get high SP
- * Bubble meter reads value at NTP
- * Air expanded downstream of valve
- * Electronic bubble meter reads correct *expanded* value
- * Rotameter values must be corrected for effects of density
- * Mass flow meter correct for air entering bubble meter

Density in Denver With No Resistance

The diagram illustrates a calibration setup for airflow instruments in Denver. The flow path starts with a Bubble-meter set to 1.0 Lpm, followed by a Trap, a Valve, a Pressure Gauge, an Electronic bubble or dry cell (also set to 1.0), a Mass flow meter (showing 0.88), a Rotameter, and finally a Pump set to 1.0 Lpm. The Pressure Gauge is connected to the line between the Valve and the Electronic bubble or dry cell.

- * If no resistance at needle-valve, get room pressure
- * Bubble meter reads value at Denver barometric pressure
- * Same mass of air expanded compared to Seattle
- * Electronic bubble meter reads correct value
- * Mass flow meter and rotameter values must be corrected for effects of density unless flowrates from them calibrated in Denver

REFERENCES

- PERKINS, CHAPTER 18
- AIR SAMPLING INSTRUMENTS, ACGIH, Chapter 7, 1995.