Is the Rotameter Ready for Retirement in Air Sampling/Monitoring Applications?

The variable area rotameter has been the primary tool utilized for determination of flowrates passing through the air circuitry pathway of air sampling or air monitoring systems for many years.

In air sampling applications a pollutant is captured on a collection medium (filter paper, charcoal cartridge, etc.) and taken to a laboratory for determination of the quantity of pollutant on the collection medium.

In air monitoring applications a real time detection device is continuously making measurements of the pollutant quantity being collected on the collection medium and possibly correcting for background levels of pollutants. In either case, utilization of a rotameter affects the accuracy of the air sampling and the air monitoring results in the same manner.

Rotameter Technology Basics

Rotameters have the advantages of being simple in design, very economical to manufacture, small in size and easy repair or replace.

The variable area rotameter has a float made of plastic or metal which is raised in the variable area tube of the rotameter in proportion to the mass of air entering the rotameter. The scale on the rotameter is determined by altering the flowrate of air passing through the rotameter while maintaining the absolute pressure at the outlet of the rotameter and the temperature of the air passing through the rotameter constant. An absolute pressure of 14.7 PSI (1 ATM) is usually chosen as the reference pressure. Air temperatures of 15ºC, 20ºC, 21.1ºC or 25ºC are common references dependant upon the manufacturer’s target market.

The air monitoring specialist usually reads the widest diameter of the float, or other measurement point identified by the manufacturer of the rotameter and estimates the flow value on the given rotameter scale.

The observation made by the air monitoring specialist is generally referred to as indicated flow or actual flow. It is representative of the actual conditions of air temperature and absolute pressure at the outlet of the rotameter at the time the flowrate is observed assuming a properly performed observation of the float level and interpretation and interpolation of the scale whether the ball is steady or oscillating up and down.

In order to accurately compare the current flowrate measurement with a prior, or subsequent flowrate measurement, one must (1) measure the absolute pressure at the outlet of the rotameter, (2) measure the temperature of the air passing through the rotameter and (3) correct mathematically to the reference T and P values that the manufacturer’s scale is based upon, or to any other mutually acceptable industry standard reference conditions utilizing the formula specifically applicable to variable area rotameters.

Shortcomings of the Variable Area Rotameter Technology

The most obvious shortcomings of utilizing rotameters for air sampling/monitoring applications are as follows:

(a) Rarely does anyone measure the absolute pressure at the outlet of the rotameter, or the temperature of the air flowing through the rotameter of an air sampler in order to be able to correct to a set of reference T and P conditions.

(b) Samples at a single location of long duration (24 hours or more) experience many different variations of T and P due to local variations in barometric pressure and temperature during the sampling period. Dust loading characteristics for the location may create unique changes in absolute pressure which if unmonitored are not available for correction of indicated flow.

A few observations of the flowrate on the rotameter during a long term sampling period, even if T and P are measured at the rotameter during the observation of the flowrate, are very inadequate to determine a scientifically accurate average flowrate for the entire sampling period and to make a scientifically accurate calculation of the true volume that has passed through the collection medium and from which the pollutant was obtained.

(c) Comparisons of flowrates and downstream calculations of air sample volumes and pollutant concentration values representative of the air sampling/monitoring event at one location are not comparable with other measurements performed at different locations within a province, country or other worldwide air sampling stations.

(d) The ability to universally compare reference standard data is not readily available for any air sampling/monitoring stations that utilize uncorrected flow data obtained from simple rotameter flow measurement technology. This is extremely important where accuracy is necessary to compare air sample data results against industry standards or when comparing air sampling data among industry members.

(e) Legal credibility of the data may be suspect in enforcement proceedings or legal actions because variable area rotameters (and similar devices) do not represent "Best Available Technology".

Current Air Flow Measurement Technologies that Address the Shortcomings of the Rotameter

Best Available Technology consists of smart flow measurement systems that incorporate the use of microprocessors and electronic sensors to perform continuous measurement of all necessary parameters required to determine corrected flowrates to a predetermined set of temperature and pressure conditions.

The predetermined set of temperature and pressure conditions can be any set of values the user desires. It is recommended that the user selects from one of the four most appropriate options for the T and P conditions listed below in Table I.

Table I

Typical Reference Standards for Gases	
Classical Standard Temperature and Pressure (STP)	0ºC, 760 mm Hg
Normal Temperature and Pressure (NTP)	20ºC, 760 mm Hg
Standard Ambient Temperature and Pressure (SATP)	25ºC, 760 mm Hg
Modified Normal Temperature and Pressure (MNTP)	21.1ºC, 760 mm Hg

The above standard reference conditions for T and P are utilized by scientists worldwide for comparison of physical measurements involving flows and volumes of gases such as air.

The type of smart instruments that can accomplish the job are advanced technology mechanical flow sensors coupled to smart electronics, or mass flow sensors with ability for the user to correct air flowrates to the user's desired set of reference temperature and pressure conditions.

Typical Measurement Accuracies Achievable with Advanced Technology vs. Traditional Rotameter Technology

The accuracy achievable from rotameters based on a careful observation of the flow indicated by the float position on the scale of the rotameter is generally 4-7%. This error does not include the error inherent in the measurement of the absolute pressure and air flow temperature at the rotameter which is needed to correct to a set of reference T and P conditions (assuming these measurements are performed) nor does it include the error involved in the calibration of the variable area rotameter.

If no measurement of T and P is made, the error from a conventionally true value of flow is unknown and dependant on location, time of year, sample duration, air circuitry design, the filter(s) utilized and dust loading, if any. It would not be unrealistic to have errors introduced that would be as high as 25-35% in a sampling period exceeding 24 hours. The worst part is that the actual accuracy of the measurement can not be determined if T and P measurements are not available.

Since indicated flow, at unknown T and P conditions is not comparable to a reference standard or to flow at any other sample location any volumes for the sample event and pollutant concentrations derived there from are not really comparable and for the most part of limited use from a regulatory or industry comparison perspective.

The accuracies achievable by advanced technology air flow measurement systems are generally in the range of 2 to 4% for air sampling systems and 1 to 2% for air flow calibration systems. These accuracies include all the calculations and the accuracies involved in multiple measurements necessary to correct flowrates to a reference temperature and pressure. Additionally, flowrates can be determined as frequently as once per second and corrected to whatever reference standard the user selects for his application.

Additional Bonuses for the Air Monitoring Professional from Advanced Technology Air Monitoring Instrumentations

Up to this point we have achieved, with Best Available Technology, our goal of obtaining air flowrate measurement results that have the following features:

(a) Flowrates and downstream calculations derived from the flowrates are always being reported to the same standard reference conditions of temperature and pressure.

(b) Flowrates and downstream calculations derived from flowrates are comparable with all other sampling events at the same sample station and with any other sample station in the world that corrects flowrates to the same reference T and P.

What more can we ask for?

Fortunately, the benefits of advance technology which enabled the world to go from the slow, grossly large computers in the 1970's to today's micro PCs which weigh approximately 0.5 kg. and are incredibly faster and more powerful than those behemoths of the 1970's also enables the air monitoring professional to receive any one or all of the following benefits:

(a) Automatic calculation of accumulated sample volume
(b) Determination of elapsed time
(c) Multiple on-board calculations including minimums, maximums, averages
(d) Password protection
(e) Programmable set up
(f) Multiple engineering unit selections
(g) Various options for displays
(h) Implementation of automatic flow control
(i) Pollutant concentration values (continuous air monitors)

The Corporate Strategy

As you can see, the benefits of implementing advanced technology instrumentation for air sampling or air monitoring applications are numerous.

The organization that employs the modern technology will benefit from (1) the lower manpower costs needed to support the air monitoring programs, (2) the increased technical and legal credibility of more accurate measurements, (3) lower maintenance costs and (4) lower calibration costs.

There is generally no downside to upgrading from traditional rotameter air sampling systems to advance technology systems.

The initial capital cost is greater, but in the last ten years very affordable instruments have been available that pay for themselves easily from the reduced manpower costs needed to support the air sampling systems. The larger cost is hardly noticeable in high end ambient air sampling systems.

The monetary benefits that can be derived for the organization in a legal or regulatory proceeding when it is established, if the organization has implemented the Best Available Technology can only be speculated, but they will probably be large. In today’s climate of environmental health and safety concerns it doesn’t make sense to operate air monitoring programs with instrument technology that goes back to the 1950’s and earlier. Good corporate business strategy demands otherwise. The prudent investment in advance technology instrumentation for nuclear power facility air monitoring programs is a good business strategic planning decision that the forward thinking utility executive will recognize.

From a scientific perspective it would be nice to be able to compare air flow derived data on an apple to apple basis so that industry comparisons are as realistic as possible.

The variable area rotameter and other analog flow measurement devices have reached the retirement age.