TELEDYNE INSTRUMENTS
Hastings Instruments
A Teledyne Technologies Company

APPLICATION NOTE

HASTINGS

Improve Air Sampling by Measuring Mass Flow

How can contaminant concentration be stated unless the sample mass is known?

The answer: it can't. Without an accurate measure of the mass of air collected as a sample, the relative concentration of a contaminant—whether it be chemical or particulate—cannot be stated as a part per million, billion, or trillion. Even for sampling applications where the contamination is expressed as a time integrated volumetric measure, ensuring that a constant sample flow has occurred requires accurate flow metering. Often air sampling systems have used passive flow methods based on orifices, needle valves, venturi meters, or rotameters to monitor the sampling rate. However, these passive devices are highly susceptible to errors due to temperature or pressure fluctuations which often occur in real-world situations due to weather or altitude. Even the best of these passive flow meters can vary by over 10% between typical daytime and nighttime temperatures—significantly distorting the sample weighting. Further, the measurement principle for all of these devices relies on critical dimensions in very small passageways that can easily become contaminated by the sample itself. Alternatively, a mass flow meter provides for accurate flow monitoring which is independent of pressure and temperature. These instruments also provide an electronic output. The output can be used for various purposes including regulatory documentation, event tracking, and flow totalizing. For applications where flow control is useful, a mass flow controller can be used to automatically maintain the sample flow at a constant rate throughout the sample period.

Objectives

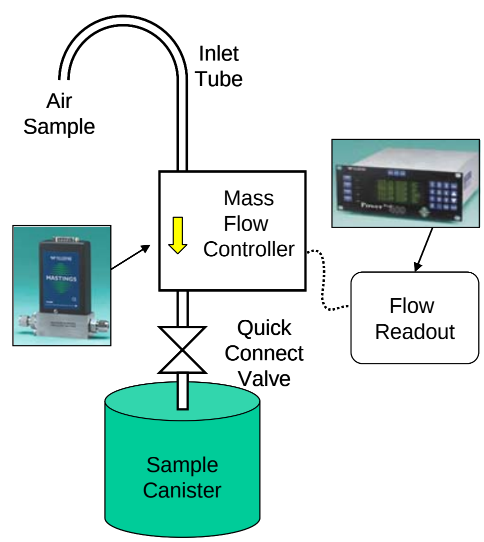
- ✓ To ensure accurate air sample flow for collection or continuous analysis
- ✓ To provide a flow signal for documentation, event tracking, or flow totalizing
- ✓ To control the sample flow despite changes in temperature and pressure

Methods

With a variety of techniques and regulated methods, the systems that accomplish air sampling take many forms. This note will focus on two of the common forms, time integrated collection and continuous analysis, with possible extension to others.

Time Integrated Collection

In the figure to the right, the components of a time integrated collection system using a mass flow controller are shown. In this case, the canister is under vacuum to begin the sampling process, thereby allowing the air sample flow to be driven by the negative differential pressure. Regulating the flow at a constant rate is accomplished by a mass flow controller (MFC) throughout the sampling process. The MFC is an active closed-loop control system. It measures mass flow and actuates an internal control valve to automatically and continuously maintain the flow at the desired rate, regardless of the atmospheric pressure, the canister pressure, and the temperature. So as the canister fills and its pressure rises, the MFC's internal controller opens the control valve to maintain the mass flow through its sensor and into the canister. This continues until the sample collection is completed or until the pressure in the canister has risen near enough to atmospheric pressure that the flow cannot be driven at the desired rate. Should this condition occur, it would be indicated by the output of the MFC.



A suitable flow set point can be estimated by knowing the canister volume and sample time. As a typical example, say we want to collect a 24 hour composite sampling into a 6 liter canister. First, to ensure proper differential pressure throughout the sample period, it is advised to allow the canister to fill up to 90% of the ambient pressure. If sampling at altitudes close to sea level it's reasonable to target a final canister pressure of 0.9 atmospheres. Now we can calculate the amount of accumulated gas as a standard condition (0°C and 1 atm) volume. If the temperature is assumed to be 20°C, we have: 6 liters × 0.9 atm × 273K/293k = 5.03 standard liters. (Incidentally, these assumptions and calculations are not critical to the contamination measurement, they only allow us to pick an appropriate set point flow for the sampling.) So we need to collect 5 standard liters or 5000 standard cc's in 24 hours or 1440 minutes. By dividing these we see that about 3.5 sccm (standard cc per minute) is the proper set point flow for this case.

In addition to the control advantages that an MFC provides to the sampling process, the electrical output from the MFC can be useful in detecting problems or ensuring that a sample has been successfully collected. The readout unit displays the real-time flow and may also have functions that provide flow totalizing, trip point alarms, and communication with other equipment. The flow totalizer can be particularly useful. If for example in the case above we came back to collect the canister after 24 hours and the flow totalizer did not read 5 standard liters, then we would be aware that there had been a significant flow interruption during the sampling time.

Continuous Analysis Sampling

Many applications such as stack monitoring and environmental safety require continuous sampling and analysis of air quality. These systems also benefit from the stability and accuracy of a mass flow meter to measure and/or regulate the sample flow. Unlike the time integrated collection systems, continuous analysis systems require some type of pump to move the air from the inlet to the analyzer. Although metering pumps are often used in these applications, the pump's flow is volumetrically based while the analysis technique is often an absolute measurement. This leads to problems when expressing concentration levels since the pump flow depends on the gas pressure and temperature and is influenced by restrictions in the sampling line. Even if a passive flow meter is added to the system, the same dependencies plague the concentration analysis. Measuring the mass flow of the sample removes these uncertainties from the analysis and provides an independent verification that the pump is drawing properly.

Instrument Selection

For each of the methods addressed above, flow regulation using a mass meter/controller has distinct advantages over relying on passive flow meters and volumetric metering pumps. For the time integrated collection method, the Hastings HFC 202 mass flow controller is recommended. Its 1% accuracy and relative insensitivity to temperature and pressure make it ideal for this application. Since the controller operates at a low differential pressure condition in this application, the internal control valve can be configured to optimize the performance. This can be specified when ordering the instrument. The flow range is specified by estimating the sample flow rate as shown above and then selecting the next higher range (this would be 10 sccm FS in the example).

For the continuous sampling method, a meter or controller may be required depending on the specific configuration of the system. The HFM200 (meter) or HFC202 (controller) are recommended for general purpose applications. Again, the differential pressure provided by the pump should be specified at the time of ordering an MFC to ensure proper instrument configuration. For systems where a low differential pressure pump is used, the HFM 300 flow meter may be advantageous due to its extremely low pressure drop requirement.

The selection of a power supply/readout depends on the functionality and capabilities required. If visual and analog or RS-232 interfaces are sufficient, the Hastings Power^{Pod} THPS-100 is recommended. The Power^{Pod} THPS-400 is the ideal choice for more sophisticated functionality including flow totalizing and either RS-232 or RS-485 communications.

For Information on all Teledyne Hastings Vacuum Measurement and Mass Flow Instruments, visit our website:

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