



## *Project Summary*

# **A Water Vapor Monitor Using Differential Infrared Absorption**

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A water vapor monitor has been developed with adequate sensitivity and versatility for a variety of applications. The instrument has been designed for the continuous monitoring of ambient air and the measuring of the mass of  $H_2O$  desorbed from aerosol filters. The sample gas may be held static, or it may flow continuously through the 56  $cm^3$  sample cell, which is temperature controlled at 45°C. Infrared energy from a tungsten-iodide bulb passes through a rotating filter wheel and the sample cell to a PbS detector. The infrared beam passes through the sample gas twice to produce a total optical path of 40 cm. As the filter wheel rotates at 1800 rpm, the infrared beam passes alternately through two semicircular narrow bandpass filters; one is centered in a spectral region of strong absorption and the other is centered nearby in a region of weak absorption. Absorption by the water vapor in the sample produces a 30-Hz modulation of the detector signal that is proportional to the  $H_2O$  concentration. The zero-setting of the monitor is stabilized by controlling the temperatures of the detector and the filters. The r.m.s. noise level corresponds to  $\approx 3$  ppm of  $H_2O$ . The maximum concentration that can be measured accurately is  $\approx 5\%$ ; higher concentrations could be measured by shortening the sample cell.

*This Project Summary was developed by EPA's Environmental Sciences*

*Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).*

### **Introduction**

The U.S. Environmental Protection Agency (EPA) would like to obtain the mass of  $H_2O$  associated with ambient air particulate matter that has been collected on Teflon filters. This measurement is needed to estimate the contribution of  $H_2O$  to the deficit in mass between the total measured aerosol mass and the mass that can be attributed to currently measurable particulate components. This deficit is as much as 30% in some cases.

A positive and quantitative identification of  $H_2O$  poses an analytical problem for several reasons: (1) the amount of  $H_2O$  is small — i.e., 30% of a typical loading of 500 mg of aerosol per filter is only 150 mg; (2) the  $H_2O$  associated with the particulate matter is not accessible; (3) volatilization of  $H_2O$  from the filter by heating also volatilizes other aerosol components so that a simple measurement of weight loss is not acceptable as an indication of  $H_2O$  on the filter. However, volatilization of the  $H_2O$  coupled with a sensitive  $H_2O$  monitor capable of a real-time output was conceived as a tenable approach provided that the  $H_2O$  vapor concentration was sufficiently high (parts-per-thousand range) to achieve a

reasonable signal to noise as an output signal.

Previous research for the EPA concerned with the design and fabrication of prototype instruments for the detection of CO and CH<sub>4</sub> at ambient air concentrations resulted in highly successful procedures for using infrared absorption as the basis for sensitive and specific ambient air monitors. Considerations based on this analogous work indicated that the H<sub>2</sub>O could be detected if thermal desorption over a period of one to two minutes occurred into a carrier gas volume of 50-100 cc. In other work, a prototype unit capable of effecting the thermal desorption of volatile aerosols into a sulfur detector (for H<sub>2</sub>SO<sub>4</sub> detection) was developed. This prototype was to be used for the detection of aerosol-associated H<sub>2</sub>O by replacing the sulfur detector with an H<sub>2</sub>O monitor.

## Materials and Methods

The monitor consists of a radiation source (tungsten-iodide lamp), an optical absorption cell, a PbS detector and associated optical and electronic components. The unit is analogous in many ways to the family of so-called gas filter correlation (GFC) monitors that have been previously designed and fabricated at Ford Aerospace and Communications Corp.

The concentration of H<sub>2</sub>O vapor in the sample cell of the monitor is determined by electronically comparing the transmittance of the sample in two narrow infrared spectral intervals. One interval occurs near 2.59  $\mu\text{m}$  where H<sub>2</sub>O vapor absorbs much more than in the other interval centered near 2.51  $\mu\text{m}$ . Samples of gas containing H<sub>2</sub>O vapor may be introduced into the 20-cm long sample cell and kept static during the measurement, or they may flow continuously through the cell. Good stability of the zero-setting and the sensitivity is achieved by controlling the temperatures of the sample cell, spectral filters and detector. Water vapor concentrations as high as 5% can be measured with good accuracy. The minimum detectable concentration in air samples at one atm total pressure is less than 10 ppm. Discrimination against interference by other gases, particularly those in the normal atmosphere, is excellent due to the spectral position and width of the spectral filters.

A calibration curve is provided as part of the main report text. Based on the

performance of the monitor during calibration, the monitor appears to be an excellent ambient air monitor, giving a real-time output proportional to the ambient H<sub>2</sub>O content. Combined with the temperature and pressure sensors that are included in the instrument, the absolute and relative humidities can be obtained. This type of system may offer significant advantages over other currently available H<sub>2</sub>O monitors.

## Recommendations

Variations of the monitor are recommended for consideration for many applications in which the concentration of H<sub>2</sub>O vapor is to be measured. The required complexity of a monitor of this type depends on the sensitivity, stability, accuracy and time response involved. Therefore, it is not practical to design a single H<sub>2</sub>O monitor for all applications. Some of the design features that should be considered for a given application are as follows:

1. The two spectral intervals ( $\lambda = 2.59$  and  $2.51 \mu\text{m}$ ) passed by the two filters are appropriate for many applications. If a gas species in the samples absorbs strongly within one of these intervals, a different set of intervals should be selected. It may be advisable to select another spectral interval to replace the  $2.59 \mu\text{m}$  interval if the absorption is too great. A different interval is recommended if pL is greater than  $\sim 2 \text{ atm cm}$  (p is the H<sub>2</sub>O partial pressure and L is the optical path length through the sample cell).
2. A PbS detector designed for long wavelength sensitivity is inexpensive, durable, convenient, and adequate for most applications. However, a cryogenically cooled PbS, PbSe, or InSb detector could provide higher sensitivity and possibly better stability when improved performance is required. Good stability of the zero-setting can be achieved with a PbS detector near room temperature only if the detector is temperature controlled.
3. Controlling the temperature of the filters improves the stability of the zero-setting and the span calibration. However, this is not required for many monitoring applications.
4. The electronics that process the detector signal should automatically account for small variations in source radiance, detector sensitivity, window transmittance, etc.
5. The optical path in air outside of the sample cell should be kept short, and if very good stability is required, should be enclosed for convenient purging or drying with desiccant.
6. Gas lines leading to the sample cell should be heated to reduce adsorption or condensation of H<sub>2</sub>O on the walls.
7. The same basic design may be used to monitor gases without drawing them into a sample cell. For example, the monitoring beam may traverse an open volume such as an atmospheric path or an exhaust vent.

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***The complete report, entitled "A Water Vapor Monitor Using Differential Infrared Absorption," (Order No. PB 82-114 422; Cost: \$7.50, subject to change) will be available only from:***

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