# In-situ real-time, gas humidity sensing for FUEL CELLS

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## INTRODUCTION

Operating conditions for PEM fuel cells are critical for performance and durability. Some sensing technologies are mature and robust, such as temperature, flow, and pressure measurements. A significant challenge has been the measurement of water vapor in the high humidity, high temperature realm of the PEMFC. Proper reactant gas humidification ensures good fuel cell membrane hydration, which is instrumental in maintaining high ionic conductivity. Requirements would be real-time, direct-reading, in-situ measurement during fuel cell operation for the anode or cathode gas streams. Also required would be reliability and accuracy, with no drift over time, no need for dry out, and no failures from contamination, recoverable or not.

In the past, inlet gas humidity measurements have been a particular problem because of the lack of a suitable sensor. PEMFCs operate at high humidity and high temperature environments, making accurate and rapid humidity measurements difficult. The chilled mirror hygrometer and polymer and oxide sensors have been used to measure the gas moisture. However, problems with calibration drift, slow response time, contamination by other components in the gas, water condensation, and down time due to clean-up make these instruments cumbersome for fuel cell applications. Now, Tunable Diode Laser Spectroscopy (TDLAS) has been used to solve this problem. This paper describes the technology and its application to the precise measurement of fuel cell gas humidity.

## BACKGROUND

This technology was developed at the Jet Propulsion Laboratory in Pasadena, CA. The task was to measure the water vapor concentration in the atmosphere of the planet Mars, since water is generally assumed to be a necessity for life. The technology needed to be small, robust, and run with no human interaction. VIASPACE has now taken this proven technology and adapted it to the high humidity, high temperature realm of PEM fuel cells.

## THE TECHNOLOGY

The VIASPACE HS-1000 VIASENSOR incorporates a patent pending miniature laser sensor technology to provide rapid, accurate, and reliable measurements of the water vapor content in fuel cell gas streams.

A tunable diode laser is tuned to an absorption wavelength of water vapor. The laser beam passes through a heated chamber through which a humidified gas stream passes. This gas stream may be either the anode or the cathode gas. The amount of laser light absorbed is related to the number of water vapor molecules within the beam path, as defined by Beer's Law. Therefore, this technique is a direct and quantitative measurement of the fuel cell gas moisture. Molecular density is proportional to partial pressure and may be expressed in units of pressure. These measurements are readily convertible to dew point in degrees Celsius.

Figure 1 is a representation of the in-situ operation of the HS-1000 humidity sensor in line between the inlet gas humidification system and the fuel cell. Figure 2 shows a basic view of the sensor, with laser and detector, along with the humidified gas flow of interest for analysis.

## COMPARISON DATA

Figures 3 and 4 show that the stability of the humidification systems used in fuel cell systems can be challenging. Figure 3 shows 40°C to 70°C dew points obtained by passing air through a "bad" humidifier. The dew point measured is not stable because the humidification system is not stable. Figure 4 shows very stable dew point measurements with a "good" humidifier.

Figure 5 compares the transient response of the laser-based humidity sensor with that of a chilled mirror hygrometer. The two sensors were connected in series

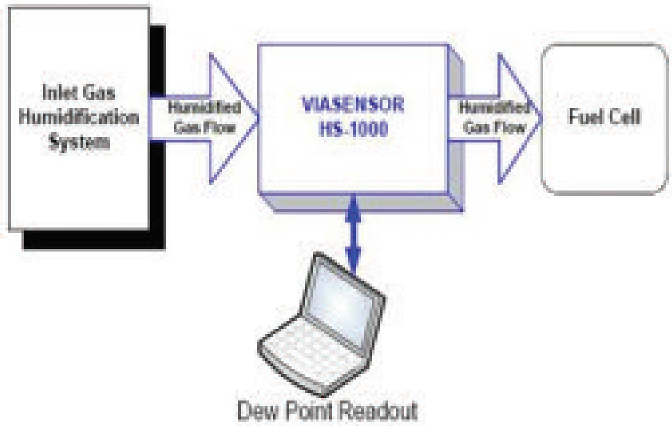


*Figure 1: Typical in-situ placement of the HS-1000 humidity sensor in a fuel cell set-up.*

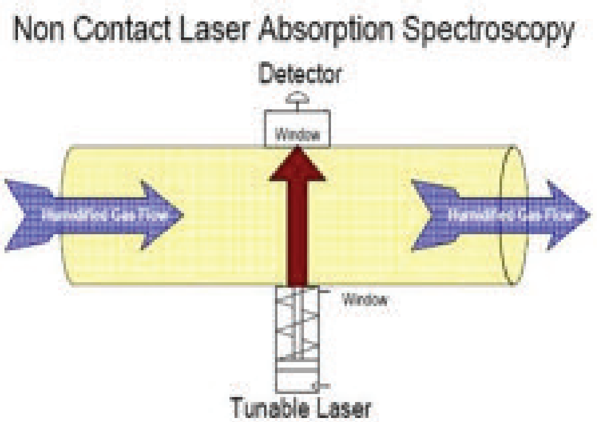


*Figure 2: Basic view of the laser-based sensor optics and the sample gas stream.*

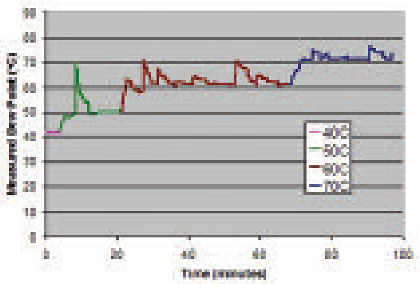


*Figure 3: Dew Point measurements of a "bad" humidifier.*

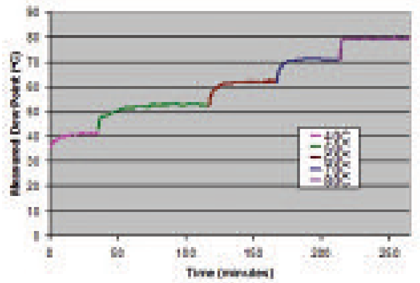


*Figure 4: Dew Point measurements of a "good" humidifier.*

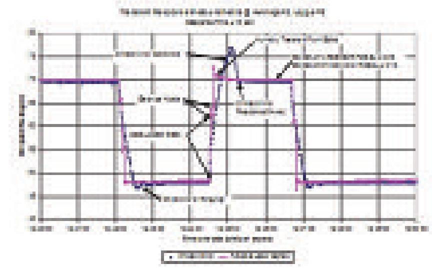

*Figure 5: Transient response comparison between laser-based sensor and chilled mirror.*

after a humidification system, which was switched between two humidity levels (by adding or stopping dry bypass gas). The sensors were then allowed to stabilize before the next switch between dew points. Note that if the data smoothing functions are reduced, the laser-based sensor has a response time of approximately 1.5 seconds. There is virtually no overshoot in the laser sensor, much faster response time, and less noise than in the chilled mirror unit.

Figure 6 is the VIASENSOR HS-1000 humidity sensor. The smaller gold-colored box on the right is the sensor head, and measures approximately 6"x6"x2" (15 cm x 15 cm x 5 cm). Gas connections are ¼" tubing. The larger box is the control box, and measures approximately 8.75"x10"x3.5" (22 cm x 25 cm x 9 cm).

## SUMMARY

Accurate measurement of fuel cell operating conditions is critical to the proper design and performance characterization of PEMFCs. Careful control and measurements of operating conditions such as temperature, pressure and moisture content of the hydrogen and air inlet gases are important to the performance and durability of PEMFCs. Low moisture and low ionic conductivity leads to decreased fuel cell performance, and even physical damage. High moisture leads to flooding of the membrane and decreased fuel cell performance.

Technology has made major advances in water vapor measurement. Accurate, reliable, and rapid measurements of high densities of water vapor are now available using Tunable Diode Laser Absorption Spectroscopy (TDLAS). This laser-based sensor is a real-time, direct-reading, in-situ measurement device with high reliability.

This will allow the fuel cell scientist to experiment confidently over a range of typical fuel cell conditions, such as humidity, temperature, and flow rates. This, in turn, may help simplify the balance of plant, resulting in cost and time savings, and possibly weight and volume savings.

VIASPACE Energy, a division of VIASPACE Inc., is focused on bringing innovative state-of-the-art products to market within the energy sector, with primary attention in the PEM fuel cell industry. For more information, visit www.viaspace.com or call (626) 768-3360.

## BENEFITS

**Benefits of TDLAS humidity sensing:**

- There is no interference from entrained liquid droplets. Liquid and gaseous water have different absorption bands.
- There is no gas composition or pressure dependence. The laser wavelength is selected such that there are no nearby absorption bands of other typical fuel cell gases. Non-water gas molecules will not absorb the laser's tuned wavelength regardless of their densities.
- There is no interference from typical fuel cell gas stream background components.
- There is no dependency upon flow rate for measurement accuracy or reliability. The molecular density of water vapor is flow rate independent. (Note: in the case of high flows, there may be a pressure drop across the sensor, and a bypass/slipstream line may be used.)
- It reacts quickly (as fast as 1.5 seconds) to slight or drastic moisture changes.

**Non-contact optical measurement:**

- The HS-1000 humidity sensor may be installed directly in line with the fuel cell process gas, and works with either the anode or the cathode gases. This allows in-situ real-time measurements of humidity. The gas flow path is heated within the sensor head to prevent condensation. Condensation or water droplets that enter the sensor head evaporate quickly, in seconds.
- Gas contaminants will not damage the sensor or cause drift in the readings. The surfaces in contact with the gas flow are nickel-plated aluminum, sapphire and epoxy. Likewise, the sensor will not contaminate the gas stream.
- The sensor is extremely stable. There is no drift in calibration. The laser remains tuned by controlling its temperature and current. Tunable diode lasers are widely used in telecommunications fiber optics networks, and have a large installed base that have been proven stable.

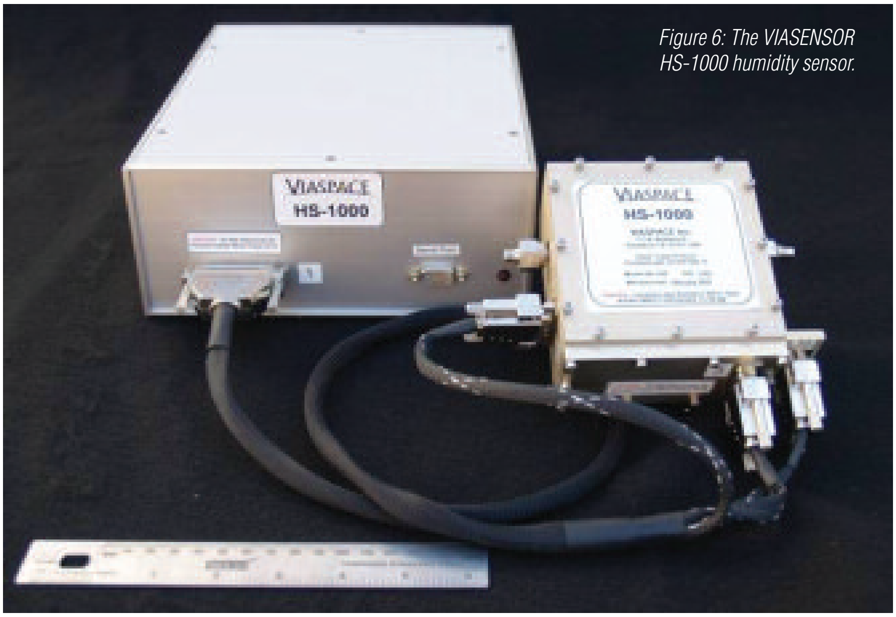


*Figure 6: The VIASENSOR HS-1000 humidity sensor.*