Technical/Application Article 06

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Patented Fence Electrode Eliminates Humidity Effects on Ion Science PIDs

Introduction

In the past, a major limitation to the use of PIDs was their susceptibility to ambient humidity. Humidity effects came in two forms: 1) a decrease in response to VOCs due to a quenching effect as humidity increased (false negative) and 2) a sharp rise and drifting response when subject to very high humidities of typically >90% RH (false positive). The latter response was avoided when the sensor was new or recently cleaned, but became a problem within a few to several days' use as microscopic dust accumulated on the sensor, causing a current leakage along the sensor walls. This drifting rise in readings was particularly prominent when doing soil headspace measurements, or in such areas as the U.S. Gulf Coast, where an instrument calibrated in an air conditioned building was brought outside into humid air often approaching 100% RH.

Various solutions have been proposed to minimize these humidity effects: 1) the instrument is fitted with a humidity sensor and the PID reading corrected using a compensating algorithm 2) dessicant tubes are placed in the inlet to dry the gas stream, and 3) the calibration gas is humidified by running it through a Nafion® tube to equilibrate it with the ambient air humidity. These approaches have various limitations. Humidity sensors typically have slower response than the PID sensor, causing a drifting compensation. Although newer RH sensors are faster, the humidity effect varies from sensor to sensor so that the compensation algorithm causes different units from the same manufacturer to over-or under-compensate. Dessicant tubes are an added cost, slow the PID response, and can reduce the response by adsorption, especially of heavier compounds. And humidifying the calibration gas works only for the particular humidity used, and is no longer accurate when the humidity changes. Compensation and calibration gas humidification also do nothing to solve the drifting high readings at very high humidity.

RH Effect at 100 ppm Isobutylene

Figure 1 compares the humidity effects on recent versions of the Ion Science Tiger (firmware v.4.20) and competitor device 1. Competitor device 1 can be operated with Humidity Compensation either on or off. The unit is supplied with RH Compensation in the "on" mode and requires a computer download to switch to the "off" mode. The Tiger does not have a Humidity Compensation mode because the sensor is inherently not affected by RH, as shown in Figure 1. With RH Compensation off, competitor device 1 gave decreasing readings to 100 ppm isobutylene (IBE) as humidity increased, with the response dropping to only 60 ppm near 100% RH.

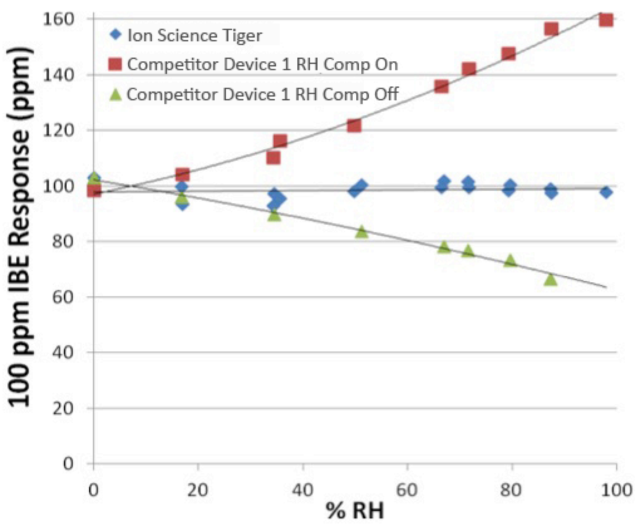

Figure 1. Effect of RH on Tiger and competitor device 1.

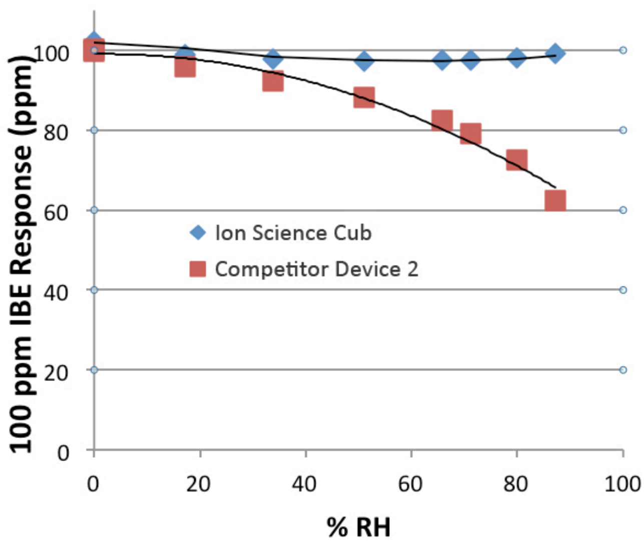

Figure 2. Effect of RH on Cub and competitor device 2.

With RH Compensation turned on, competitor device 1 overcompensated, giving readings of up to 160 ppm when testing 100 ppm IBE at near 100% RH. By contrast, the Tiger gave close to 100 ppm readings at all humidities, within a few percent experimental error.

In Figure 2, similar results are obtained comparing the two pocket-sized PIDs, the Ion Science Cub and competitor device 2 (both with 10.6 eV lamps). Again, the Cub was unaffected by humidity and gave close to 100 ppm response, whereas competitor device 2 showed decreasing response to about 60 ppm when approaching 100% RH. Competitor device 2 has no Humidity Compensation mode, and thus will always read low at high humidities.

RH Effect at Varying Concentration
Further humidity tests were conducted at isobutylene concentrations varying from 10 to 1000 ppm at 85% RH. Figure 3 shows that the Tiger gave readings within 10% of the standard at all concentrations, whereas competitor device 2 had much greater errors of up to -34% with RH Compensation off and +62% with RH Compensation on. Competitor device 1 seems to over-compensate at low concentrations below 500 ppm and under-compensate at over 700 ppm.

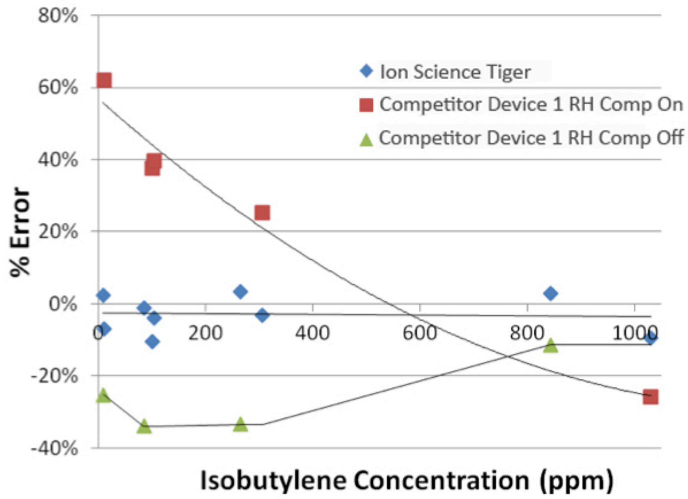

Figure 3. Measurement error at 85% RH as a function of isobutylene concentration.

Conclusions
Compensating for humidity effects is never as accurate as having a sensor that is inherently unaffected by humidity. The compensating algorithm used in competitor device 1 appears to overcompensate significantly at isobutylene concentrations below 600 ppm, and under compensate at over 800 ppm, at high RH. With compensation turned off, the unit gives a false low response at high RH, except at high isobutylene concentrations over 700 ppm. Thus, one is left with a choice of low readings, which could result in unsafe overexposures, or high readings, which could demand use of personal protective equipment when it is unnecessary. Ion Science PIDs do not exhibit such humidity effects, giving much greater confidence in reading accuracy.

Appendix: Theory of Humidity Effect Elimination
Figures 4 & 5 compare the sensor designs of a common PID vs an Ion Science PID. In most PIDs all the gas flow is drawn through the membrane, and despite the filtering, some microscopic dust particles pass into the sensor where they can accumulate and build up on the walls. In the Ion Science sensor, 99% of the gas flow passes by the sensor and only about 1% diffuses through the membrane, resulting in a much cleaner sensor. The enlargements on the left of Figures 4 & 5 show exaggerated schematics of the wall dust build-up. When this contamination is subject to high humidity, it absorbs water vapor much more than a clean Teflon® wall, and thus becomes conductive and can causes a current leakage. In the conventional PID the leakage is registered as a drifting, steadily increasing reading, whereas the fence electrode of the Ion Science PID captures the leakage current and has no false positive response. Although not diagrammed, the Ion Science sensor also has a much thinner light pathlength, thus eliminating the false negative quenching by water vapor as shown in Figures 1 & 2.

CONVENTIONAL PID

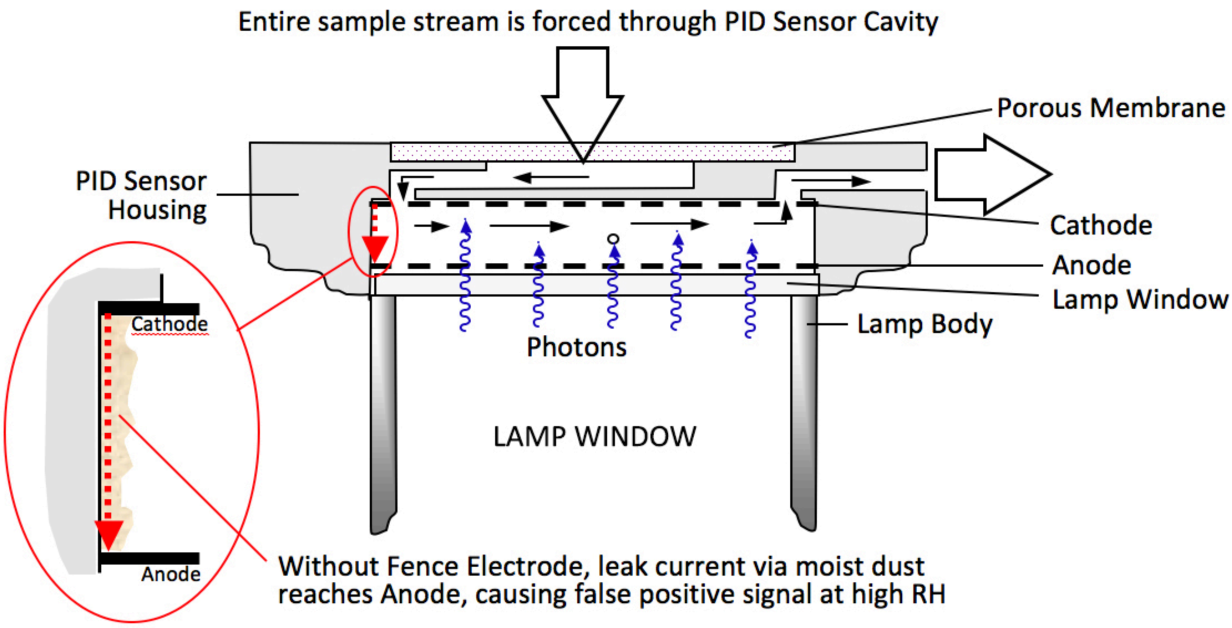

Figure 4. Common PID sensor design with entire gas flow through sensor cavity and without Fence Electrode

ION SCIENCE PID

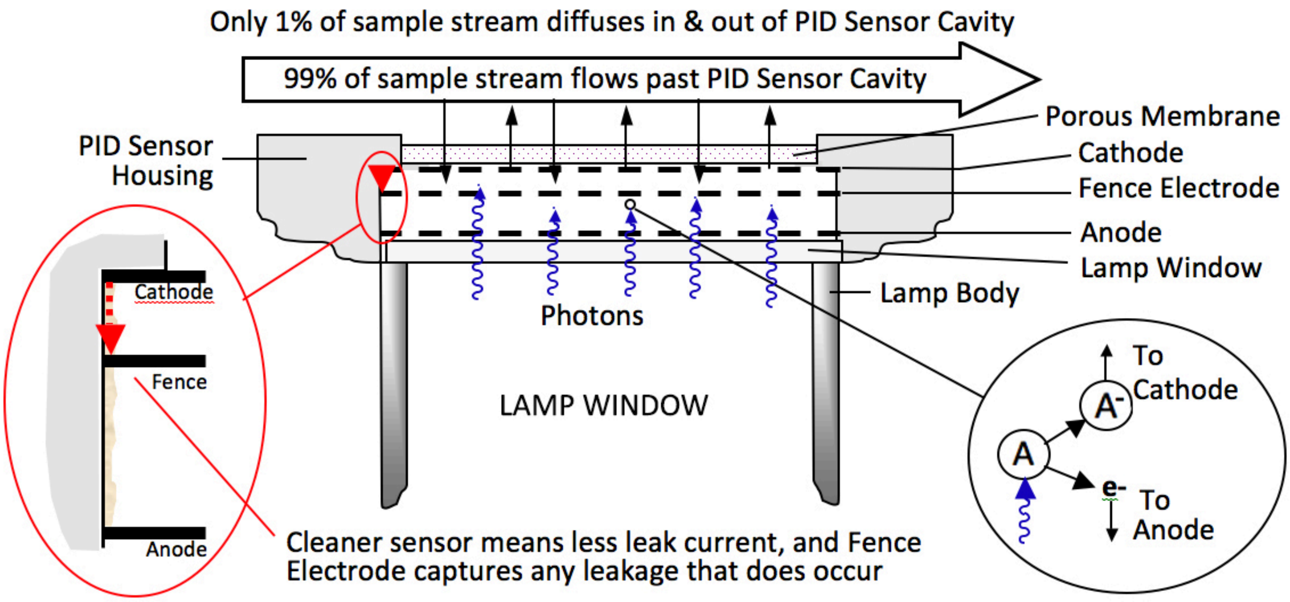

Figure 5. Ion Science PID sensor with anti-contamination design and Fence Electrode to eliminate both false positive and false negative humidity effects.

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