Criteria for Evaluating Photoionization Detectors

Criteria for Evaluating Photoionization Detectors

PIDs are Necessary in Many Applications

Fire departments, HazMat teams, refineries, and most recently homeland security personnel are all deeply concerned with the detection of hazardous compounds. Both gas detection and monitoring are needed at sites of spills, leaks, and other emergencies. Photoionization detectors (PIDs) are capable of effectively detecting and monitoring a vast number of hazardous gases and have become popular in recent years as sensors in hand-held multigas detection instruments. If well-engineered, a PID can offer an ideal combination of fast response, ease of use and maintenance, convenient size, the ability to detect very low levels of hazardous compounds, and affordability. What follows are basic guidelines to help you make the best choice when selecting a PID instrument.

The Basic Principle of Photoionization

PIDs rely on a process called ionization as the basis of gas detection. The energy required for a neutral molecule to be ionized (i.e. to have an electron removed) and thus change to a charged molecule (an ion) is known as its ionization potential (IP). The IP is expressed in an electron volt (eV) energy scale. In a PID, a small current of removed electrons is generated and measured, which is in proportion to the concentration of ionizable gas that is present. There are several excellent sources available to research the IPs of particular gases, such as the National Institute of Science and Technology (NIST) [http://webbook.nist.gov/chemistry/ie-ser.html] and the National Institute of Occupational Safety and Health (NIOSH) [www.cdc.gov/niosh/npg/npgd0000-all.html].

PID Lamps

The energy for ionization is provided by a special lamp designed to emit ultraviolet (UV) light. The "heart" and most critical part of the instrument is the PID lamp, which consists of a glass tube filled with low-pressure gas and sealed with a crystal window. The gas within the tube (or "bulb") is usually an inert gas such as krypton (Kr). Two basic versions of PID lamps exist: with or without internal electrodes. The basic operational principle of both versions is the same; they emit UV light by electrical breakdown (discharge) of the gas sealed in the tube. Well-sealed and cleanly processed lamps provide a UV output with a defined and repeatable energy spectrum as shown on the left, compared with that of a poorly processed lamp as shown on the right (Fig.1). Contaminated lamps like this example whose spectrum is shown on the right, will not provide consistent performance from lamp to lamp, especially if the lamp processing is contaminated and results in outgassing of extraneous compounds into the volume of the tube. Its expected lifetime can be compromised as well.

9.8 eV and 10.6 eV Lamps

The most common and easy-to-use PID lamps operate with photon energy of about 9.8 eV or 10.6 eV. A practical feature of the lower-energy lamps is the ability they provide to discriminate against higher-energy compounds that may not be of interest in a particular detection application. For example, a 9.8 eV lamp can detect benzene which has IP = 9.25 eV, but not acetaldehyde, which has IP = 10.21 eV. To make sure that the gas of interest will be ionized, the lamp energy has to be higher than that of the gas. 9.8 eV and

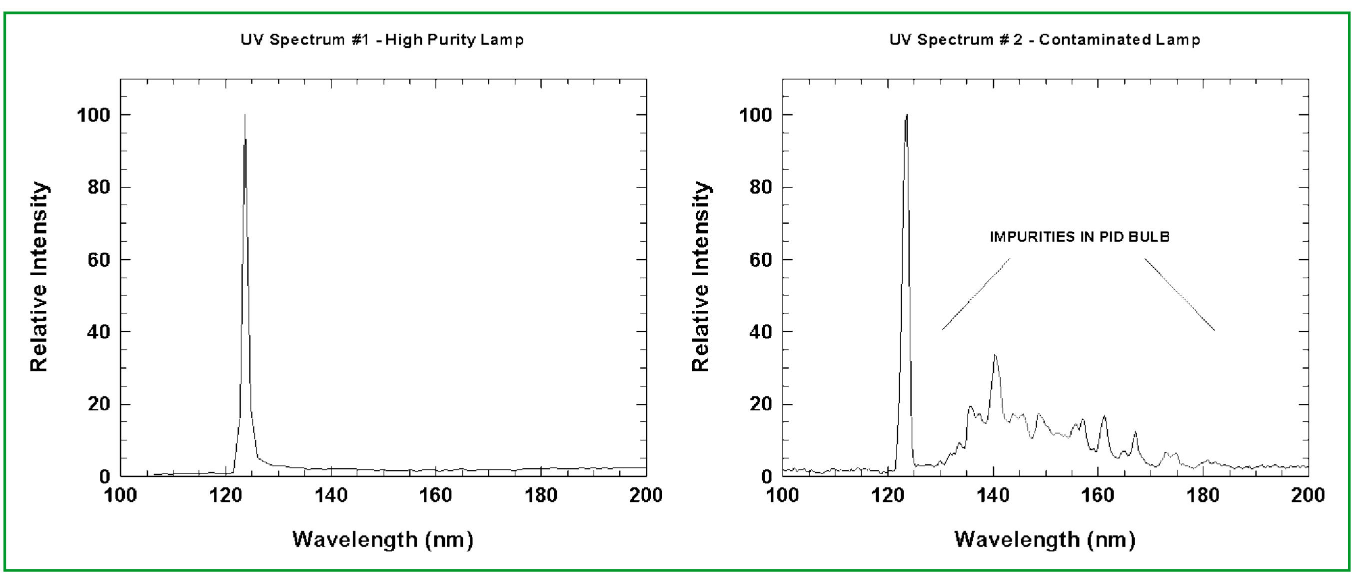

Figure 1. UV spectra of low-energy PID lamps from two different manufacturers.

10.6 eV lamps are usually advertised as requiring low maintenance and having a typical lifetime of one year. Lifetimes of three years for some PID lamps are now being offered, but of course the actual useful life and maintenance will largely depend on the hours of day-to-day use and the cleanliness of the atmosphere to which they are exposed in the field.

11.7 eV Lamps

High-energy lamps (11.7 eV) are also available for some PID models, which allow ionization of gases with higher IPs such as chloromethane and acetyl chloride. However, the theoretical ability of high-energy lamps to ionize larger numbers of compounds is offset by practical shortcomings. The lithium fluoride (LiF) windows of these lamps absorb water, causing the chemically unstable crystal to degrade more rapidly than those of lower energy lamps. Even in ideal applications with no water vapor present, the higher energy UV photons from these lamps naturally degrade the transmission of the LiF windows through an effect called solarization. With the presently available technology, the typical lifetime of these lamps varies from one to two months with intermittent use, to about 25 hours of continuous use. The absorption in the windows of water vapor from the air also prevents long-term exposed storage (unless a desiccator is provided), which is a practical consideration. Additionally, the cost of 11.7 eV lamps is generally quite high, despite their considerably shorter lifetimes compared with that of 9.8 eV and 10.6 eV PID lamps. Its many weaknesses have inhibited widespread use of the 11.7 eV lamp.

'No Cleaning' Lamps

A recent PID marketing trend concerns claims of "no cleaning" or "self cleaning" lamps. What does this really mean in useful terms? As a PID lamp is operated, its window is exposed to trace components in the sampled air. These easily ionized components tend to form a residual film on the window's surface, which in turn causes the lamp's UV output intensity to decrease slowly with operating time. This film can be removed simply by cleaning the lamp window with a methanol-dipped cotton swap, if the lamp is able to be removed from the unit. Fortunately, nature has provided a counter-balance to this reaction, as UV light emitted by a PID lamp will convert oxygen molecules in the background air into ozone molecules. Ozone, if allowed to build up enough concentration adjacent to the lamp's window, will loosen or even remove some of the residual film from the window.

In diffusion-type PIDs versus pumped-flow PIDs, there exists a trade-off. With a pumped PID unit, response and clear times are usually faster, but the ozone is typically continuously flushed out and the window surface film builds up and hence the eventual need for lamp cleaning as well as recalibration. With standard diffusion-type PIDs, ozone builds up and slows the production of the window surface film, but the response and clear times are noticeably slower. This characteristic is in addition to poor humidity response, which is inherent in diffusion-type PIDs. "No cleaning" or "self cleaning" lamps are misnomers. All PID lamps will build up a window surface film which needs to be cleaned, hence the lamp cleaning instructions included in manufacturers' operating manuals despite any other claims of "no cleaning necessary". Lamp cleaning frequency depends upon the specific PID design, the gases sampled, the ambient sampling environment and the sample/filter system.

The Importance of Customer Field Trials

Look for basic features such as resolution to assess the instrument's ability to measure at sub-part-per million (ppm) levels. Some instruments only provide readings at 5 or 1 ppm resolution, while others can display 0.1 ppm or even parts-per-billion (ppb). Calibrating the PID sensor before use and rechecking the calibration at the day's end will reveal the instrument's ability to hold its calibration. This calibration check can be repeated over a few days to a week to determine and establish the instrument's performance in your environment. When doing field tests, make sure to subject the unit to changes in temperature and humidity, as going from cool/dry to warm/humid conditions can cause condensation in the ionization chamber or on the lamp window in some designs. If this happens and the effect is not controlled by the PID, it can abruptly shift the zero level of the readout, which could produce a false reading of a significant concentration of organic compounds. And of course, the filter water-trap system should be tested.

Choosing the Right PID for Your Applications – A Basic Checklist

Some issues are crucial in the choice of a PID, especially for real-world applications. Be sure to incorporate the following guidelines when researching your choice of an instrument:

- Repeatability (consistent readings) in changing humidity conditions
- Ease of calibration and ability to hold calibration
- Adequate resolution in ppm and ppb
- Susceptibility to dusty and dirty environments
- Ability to quickly change response factors in the field
- Rugged housing of the instrument's design
- Convenience of replacing the water and dust filters
- Accessibility of PID lamp and ease of changing the type of lamp
- Ease and projected frequency of lamp cleaning

Summary

Select the right PID for your application by looking closely at the available technologies. Performance, ease of calibration, maintenance frequency and lamp access are key decision-making factors. All PID lamps will degrade in performance unless they are cleaned, and the appropriate frequency depends upon the application and the design of the overall system. Higher energy lamps will ionize a broader range of gases but have other significant disadvantages. Instrument field trials in dirty environments along with temperature and humidity changes will reveal a great deal more about PID performance than idealized specifications which may have been generated only under laboratory conditions. Many instruments are available with diverse price tags and real-world performance; be sure to compare wisely before choosing and investing in a PID instrument.

To learn more about PID sensor principles see MSA's White Paper 0803-11/January 2004.

Data Sheet-0800-33/Nov 2005

Corporate Headquarters:
P.O. Box 426, Pittsburgh
PA 15230 USA
e-mail info@MSAnet.com
www.MSAnet.com

U.S. Customer Service Center:
Phone 1-800-MSA-2222
Fax 1-800-967-0398

MSA Canada:
Phone 1-800-MSA-2222
Fax 905-238-4151

MSA Mexico:
Phone 52-55 2122-5770
Fax 52-55 359 4330

MSA International:
Phone (412) 967-3354
Fax (412) 967-3451

Offices and representatives worldwide
For more information: