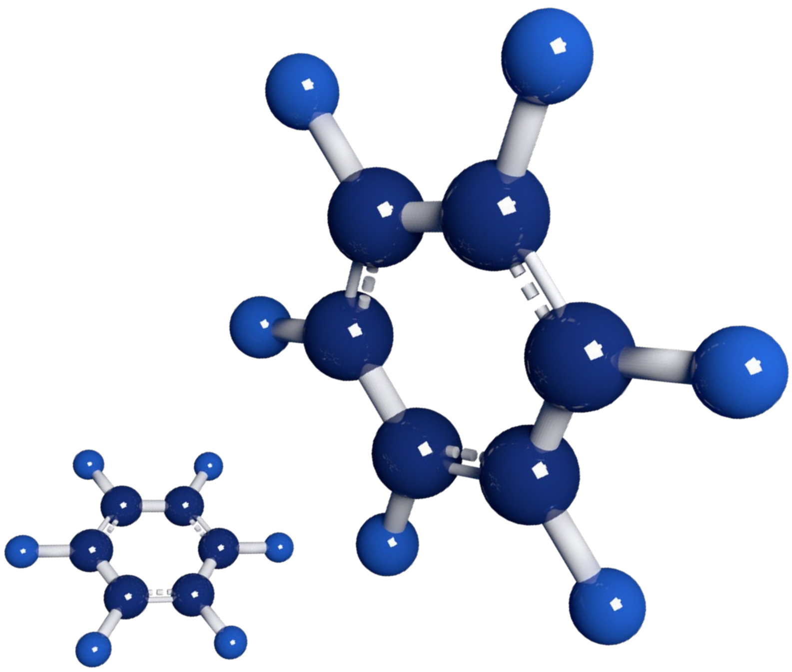
PID Buyers Guide for Benzene Monitoring

Fixed : Portable : Personal

"In a photoionization detector high-energy photons, typically in the vacuum ultraviolet (VUV) range, break molecules into positively charged ions. As compounds enter the detector they are bombarded by high-energy UV photons and are ionized when they absorb the UV light, resulting in ejection of electrons and the formation of positively charged ions. The ions produce an electric current, which is the signal output of the detector. The greater the concentration of the component, the more ions are produced, and the greater the current. The current is amplified and displayed on an ammeter or digital concentration display."

Source: Wikipedia



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Unlike other health and safety hazards, the only way to carry out a risk assessment for benzene exposure is to monitor quantitatively. Like other volatile organic compounds (VOCs), benzene evaporates easily and most people can just detect its distinctive 'aromatic' smell at concentration between 2.5 and 5 parts per million (ppm) in air but regulatory occupational exposure limits (OEL) are typically 1 ppm. However the 'direction of travel' for the OEL is towards 0.1 ppm and knowing that benzene is a hazardous, carcinogenic chemical, it is imperative that the measurement solution is sensitive and accurate.

It must also be capable of operating in harsh process plant environments in the likely presence of dirt, dust, high humidity and interference from other VOC/aromatic compounds. The photoionisation detector (PID) has proven to be an ideal solution but there are several considerations that must be borne in mind when choosing an instrument.

PID theory of operation

Figure 1 is a schematic of a typical PID sensor system. A UV lamp generates high-energy photons, which pass through the lamp window and a mesh electrode into the sensor chamber. Sample gas is pumped over the sensor and about 1% of it diffuses through a porous membrane filter into the other side of the sensor chamber. The inset on the 'lower right' of figure 1 shows what happens on a molecular level. When a photon with enough energy strikes a molecule M, an electron (e-) is ejected. M+ ion travels to the cathode and the electron travels to the anode, resulting in a current proportional to the gas concentration. The electrical current is amplified and displayed as a ppm (or part per billion (ppb)) concentration. Not all molecules can be ionized, thus, the major components of clean air, i.e., nitrogen, oxygen, carbon dioxide, argon, etc., do not cause a response, but most VOCs do give a response.

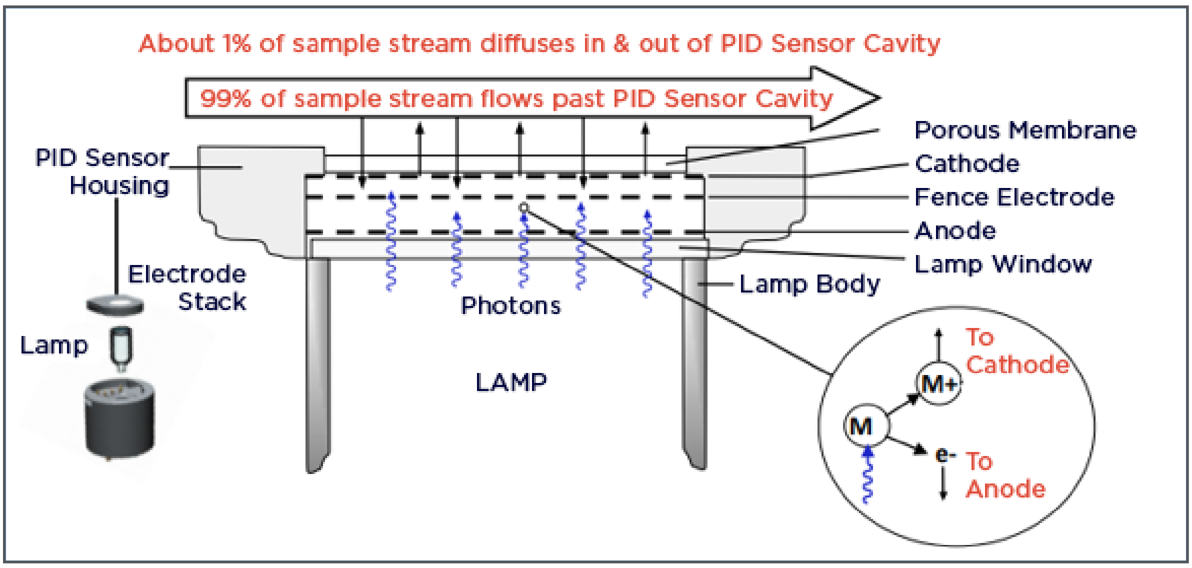


Figure 1: Ion Science Ltd PID sensor design

Which lamp do I need?

Typically, three lamps are available with maximum photon energies, measured in electron-volts (eV), of 10.0 eV, 10.6 eV, and 11.7 eV. Figure 2 illustrates that a lamp can only detect those compounds with ionization energies (IE) equal to or below that of the lamp. Thus, a 10.6 eV lamp can measure Methyl Bromide with an IE of 10.5 eV and all compounds with a lower IE, but cannot detect methanol or compounds with a higher IE.

The choice of lamp therefore depends on the application. When only one compound is present, one can use any lamp with enough energy, often the standard 10.6 eV lamp which has a lower cost point and has a long working life of up to a few years. Conversely the 11.7 eV lamp has a short life of only a few months.

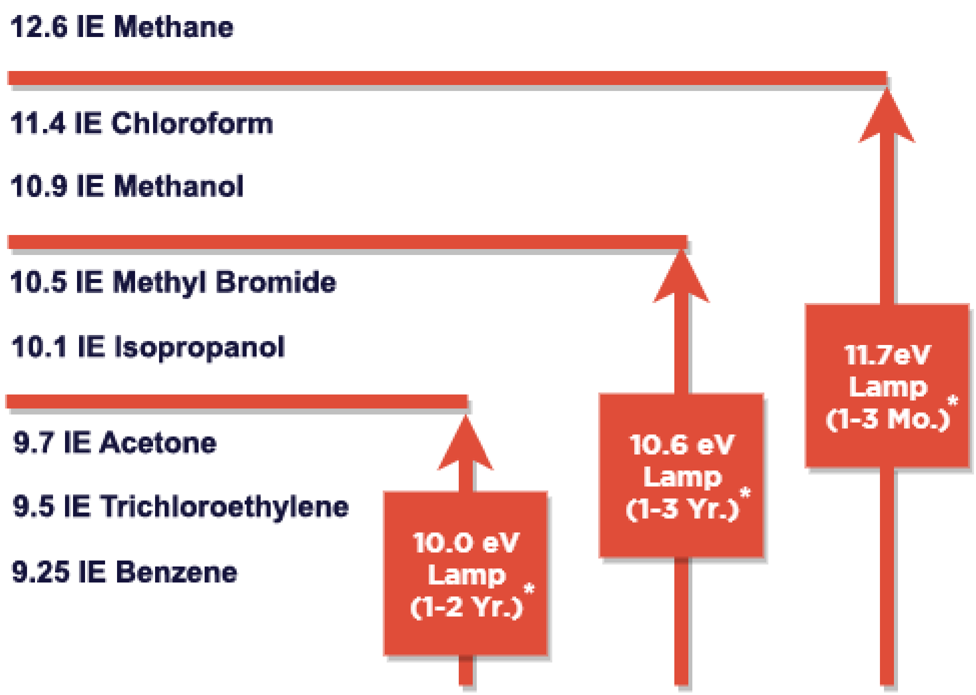


Figure 2: PID lamp energy thresholds

* expected lamp life subject to use and application

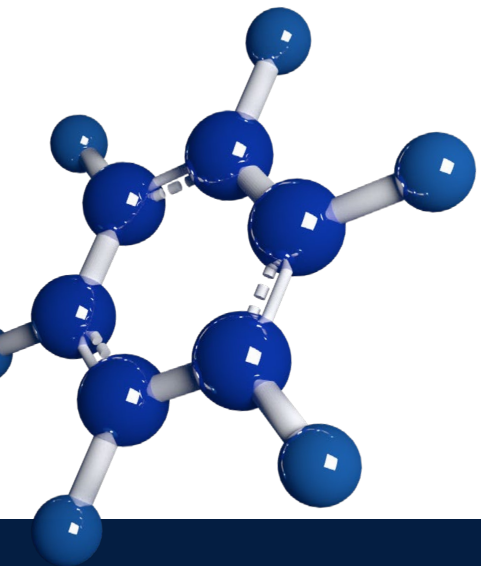
Benzene has a low IE value as shown in Figure 2 and it is often present in a 'cocktail' of other chemicals including aromatics and aliphatics. Using a proprietary 10.0 eV lamp means that only the aromatics are detected (amongst other gasses that may be present) and should the total aromatic compounds (TACs) be above the regulatory limit, a benzene pre-filter tube can be used to provide a more accurate reading on benzene specifically.

Effects of humidity

The presence of humidity in the sample gas can unfortunately disrupt the measurement leading to inaccurate results. Heated inlets to achieve a stable temperature (typically 50ºC) are power hungry and a challenge to achieve in, say a refinery, where stringent intrinsic safety (IS) requirements have to be met. However, looking at Figure 1, the presence of an additional fence electrode can overcome the problem and practically eliminate the effect of humidity. It does this by behaving as a conductive break when there is excess current flow caused by the presence of humidity.

For more information on this topic, look out for our forthcoming Guide on humidity and how instruments overcome this challenge.

Fixed, portable or personal monitoring?



Applications for PIDs include:-

- fixed systems for area or fenceline monitoring of fugitive emissions
- portable instruments for confined space entry checks or leak detection & repair
- personal instruments, to alert a worker to a concentration above the regulatory OEL

Each solution is optimised for the application offering specific features and benefits, but design compromises often have to be made due to your specific monitoring requirements.

Here are the definitive features to look out for:

Fixed systems

- be benzene specific i.e. require no calibration correction factor
- have real or near-real time continuous monitoring with industry standard 4-20mA and/or MODBUS outputs
- require no operator intervention during normal use

Portable

- have a specific benzene mode and pre-filter tube capability
- have a high resolution of 1 ppb to cope with the legislative trend i.e. towards an OEL of 0.1 ppm and in some cases lower
- have a long battery life capable of two 12-hour shifts to maximise data capture and to minimise system downtime

Personal

- be small and lightweight so as not to burden the wearer (the personal PID is having to 'compete' for space alongside gas and radiation detectors, portable radios and other monitoring instrumentation such as noise dosimeters and dust sampling heads/pumps)
- have a high resolution of say 10 ppb for compliance purposes
- have a high range of 5000 ppm to accommodate the high levels experienced during plant turnaround
- be capable of 1 second logging of actual exposure for later download and analysis which would highlight areas of concern and help identify where fixed systems could be situated

Environmental Protection

In order to meet mandatory IS requirements and achieve high IECEx ratings of Ex ia IIC T4, instruments have to be environmentally sealed against dust and water ingress that may otherwise lead to an explosion should a fault(s) in the instrument occur when in a flammable atmosphere.

An ingress protection (IP) rating of IP54 is a bare minimum and ideally should be IP65 for use in an outdoor, process environment.

Calibration and Maintenance

It is important that a PID is maintained due to the potential for contamination of the lamp due to dirty, humid environments plus, the PID requires regular calibration using a reference gas. Ideally a combination of all three instruments would provide maximum worker and environmental protection.

Disclaimer

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