

Crowcon Whitepaper

Correction factors – correcting for the hazards of VOCs



Introduction

There are many volatile organic compounds (VOCs) derived from the oil refining and petrochemical industries. Characteristically, VOCs are hydrocarbons and, at room temperature, are liquids that give off highly flammable vapour. They also tend to be toxic and have low occupational exposure limits. In fact, long before a concentration sufficient to register on a combustible gas indicator is reached, the toxic exposure limit has usually been exceeded. Increased awareness of the toxicity of VOCs has led to lowered exposure limits and increased requirements for direct measurement.

For the most part, VOCs are chronically rather than acutely toxic. This means that their effects are not apparent until some time after exposure. A particularly toxic VOC is benzene. Among the well documented adverse health effects of chronic benzene exposure are anaemia and leukaemia¹.

Monitoring against toxic exposure

Occupational exposure limits (OELs) are designed to protect workers against the negative health effects of exposure to toxic substances. The OEL is the maximum concentration of an airborne contaminant, often expressed in parts per million (ppm), to which an unprotected worker may be exposed during the course of workplace activities. For example, in the United Kingdom, OELs are listed in EH40/2005 Workplace Exposure Limits². This document currently lists enforceable exposure limits for around 500 substances. A personal gas detector is the only sure way to monitor gas levels against the OEL to ensure they are not exceeded. Responsibility for this falls to the employer.

In general, OELs, are defined in two ways:

Long term exposure limit (LTEL)

Calculated as an 8-hour Time Weighted Average

Short term exposure limit (STEL)

The maximum allowable concentration over a shorter time period, usually 10 or 15 minutes

Abstract

» Volatile organic compounds (VOCs) pose a significant toxic threat. The nature of this threat makes it vital to monitor individual exposure to these compounds over time. The degree of hazard posed by each VOC is different, further increasing the complexity of the task of keeping people safe. Among the most useful tools are personal monitors equipped with sensors based on photo-ionisation detection (PID) technology. However, their safe use requires knowledge of the environment in which they are to be used and correct interpretation of the results obtained. Employment of the right correction factors is an essential part of this process.

Photo-ionisation detection (PID) is generally considered the technology of choice in portable detection units for monitoring toxic exposure to VOCs. This technology uses a PID bulb to determine the amount of energy needed to remove an electron from the gas molecule, i.e. its ionisation potential (IP). The most commonly used PID bulb is 10.6eV. It is highly sensitive but not specific, and it will respond to any VOC with an IP of 10.6eV or less³. The magnitude of the response is directly proportionate to the concentration of the gas. However, 50ppm of one gas will give a different reading to 50ppm of a different gas. To cope with this, correction factors (CFs) must be employed.

Photo-ionisation based sensors are always calibrated to isobutylene. Correction factors differ depending on the sensor being used, and are manufacturer specific. It is vital to ensure the correct manufacturer CFs are being used. The correction factor relative to isobutylene is employed to calculate an accurate gas level reading. Each gas has a different CF, so the gas must also be known for the right CF to be applied.

Use of PID in a single-VOC environment

Imagine a working environment where exposure to isopropanol is a risk, and PID technology is being used to monitor it. As stated, a PID sensor will be calibrated to isobutylene. Interpretation of a reading caused by isopropanol requires the specific CF. The monitor gives a reading of 300ppm. This isobutylene equivalent (I.E.) reading is converted by multiplying it by the

manufacturer specific CF*, in this case 4.35. The result is a calculated isopropanol concentration of 1350ppm.

In a different scenario, the I.E. reading of 300 is obtained again, but this time in an environment where ammonia is the significant hazard. Here, the manufacturer specific CF* is 8.5. This indicates an ammonia concentration of 2550ppm.

Table 1: Conversion of PID reading to actual ppm using correction factors

I.E. Reading	VOC	Correction factor*	Calculated ppm
300	isopropanol	4.35	1350
300	ammonia	8.5	2550

In these examples (table 1), it can be seen how impossible it is to assess the PID reading without knowing the CFs. In both circumstances, the unit indicates 300ppm, but the actual concentrations of the two gases are very different.

To add to the complexity, different VOCs have different toxicities, so the ppm still does not give the true hazard level. In the following illustrations, the exposure limits used are those laid down in *EH40/2005 Workplace Exposure Limit*², which details the prescribed maximum workplace exposure limits in the UK. The principle is the same regardless of the regulatory standards being followed.

Continuing with the previous examples, the short term exposure limit (STEL[†]) for ammonia is 35ppm, while for isopropanol, it is 500ppm.

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Table 2: Use of correction factors with exposure limits

I.E. Reading	VOC	Correction factor*	Calculated ppm	STEL [†]
300	isopropanol	4.35	1350	500ppm
300	ammonia	8.5	2550	35ppm

From table 2, it can be seen that an I.E. reading of 300 in an environment contaminated with isopropanol could be of some concern. Exposure to isopropanol at 1350ppm can result in nausea, headache, lightheadedness, drowsiness and loss of coordination⁴. However, an environment containing ammonia giving the same I.E. reading of 300 is highly dangerous as an ammonia level above 2500ppm is life-threatening⁵. So to stay safe, it is critical to establish the relevant I.E. exposure limit if an alarm is to be set, the calculation of which is discussed later in this white paper.

Using PID with a VOC mixture

But what if there is a mixture of VOCs? There are many working environments in which multiple VOCs present a hazard but as part of a variable mixture. As the relative proportions of gases are unknown, the safest approach is to determine which VOC has the lowest I.E. exposure limit. This is used as the control compound, and alarm levels can be set accordingly.

As we have seen, this cannot be done by simply comparing the respective ppm exposure limits, as the correction factors must be taken into account. To see how this works, consider the compounds isopropanol, diisopropyl ether and toluene (table 3), all potential components of fuels.

From the STEL exposure limits, it would be easy to assume that the control compound of the three should be toluene, as it has the lowest limit. However, the correction factors which adjust for the calibration setting of the PID sensor have not yet been applied. These compounds have CF* values of 4.35, 0.68 and 0.51, respectively. By dividing the exposure limit with the correction factor for each (table 4), the resulting I.E. STEL determines that the control compound of these three VOCs is isopropanol. This is also used to set the alarm levels.

Table 3: Example VOC components of fuel

VOC	STEL [‡]	Correction factor
isopropanol	500ppm	4.35
diisopropyl ether	310ppm	0.68
toluene	100ppm	0.51

Table 4: Calculation of alarm setting from CF and STEL

VOC	STEL [‡]	Correction factor*	I.E. STEL (alarm level)
isopropanol	500ppm	4.35	114.9
diisopropyl ether	310ppm	0.68	455.9
toluene	100ppm	0.51	196.1

If the gases are known and the relative levels remain constant within the mix, the correction factor and the exposure limit can be calculated. This will allow the correct alarm setting for the PID sensor to be established for the mix as a whole.

The calculation is in three parts. The exposure limit of the mixture is determined by dividing the sum of the relative ratios of each VOC multiplied by its own exposure limit value into one, as illustrated in fig 1a. The correction factor is calculated in a similar fashion, using the manufacturer specific CFs (fig 1b). The alarm setting for a detector using PID is then calculated by dividing the exposure limit by the CF previously calculated (fig 1c).

Fig 1: Calculation to determine PID alarm setting for a constant gas mixture

The composition of a mix of 3 VOCs: A, B and C:

VOC A = 50% (= 0.5) of mix, STEL = A_{STEL} CF = A_{CF}

VOC B = 30% (= 0.3) of mix, STEL = B_{STEL} CF = B_{CF}

VOC C = 20% (= 0.2) of mix, STEL = C_{STEL} CF = C_{CF}

Fig 1a: To calculate the mix exposure limit

$$\text{The } \mathbf{MIX}_{\text{STEL}} = \frac{1}{(\mathbf{A}_{\text{STEL}} \times 0.5) + (\mathbf{B}_{\text{STEL}} \times 0.3) + (\mathbf{C}_{\text{STEL}} \times 0.2)}$$

Fig 1b: To calculate the correction factor for the mix

$$\text{The } \mathbf{MIX}_{\text{CF}} = \frac{1}{(\mathbf{A}_{\text{CF}} \times 0.5) + (\mathbf{B}_{\text{CF}} \times 0.3) + (\mathbf{C}_{\text{CF}} \times 0.2)}$$

Fig 1c: To calculate the PID alarm setting for the mix, divide the exposure limit by the correction factor

$$\frac{\mathbf{MIX}_{\text{STEL}}}{\mathbf{MIX}_{\text{CF}}}$$

An example commonly used to illustrate how this works is paint. In terms of VOCs, paint solvents comprise 15% styrene and 85% xylene. The exposure limits (STEL[‡]) for styrene and xylene are 250ppm and 100ppm, respectively. The calculation (fig 2a) gives an I.E. exposure limit for the paint mixture of 110ppm.

Fig 2: Calculation to determine PID alarm setting for paint

The composition of paint:

Styrene = 15% (= 0.15), STEL[‡] = 250, CF* = 0.44

Xylene = 85% (= 0.85), STEL[‡] = 100, CF* = 0.43

Fig 2a: To calculate the exposure limit for paint

$$\begin{aligned} \text{STEL of paint} &= \frac{1}{(250 \times 0.15) + (100 \times 0.85)} \\ &= 110\text{ppm} \end{aligned}$$

Fig 2b: To calculate the correction factor for the mix

$$\begin{aligned} \text{CF of paint} &= \frac{1}{(0.44 \times 0.15) + (0.43 \times 0.85)} \\ &= 0.43 \end{aligned}$$

Fig 2c: To calculate the PID alarm setting for paint, divide the exposure limit by the correction factor

$$\frac{\text{calculated STEL}}{\text{calculated CF}} = \frac{110}{0.43} = 256\text{ppm}$$

A similar calculation is required to obtain a CF. Again, the relative ratio of the VOCs in the mix (0.15 and 0.85) is used, this time multiplied by the CF* values for the respective gases; 0.44 for styrene and 0.43 for xylene. Fig 2b shows the resulting CF of 0.43. This gives an I.E. exposure limit alarm setting for the PID sensor of 256ppm (fig 2c). In this way, if the ratios

of VOC in a mix are constant, alarm levels for monitoring with PID sensors can be established with confidence.

* Crowcon Gas-Pro PID correction factors are used in this white paper

‡ For the purposes of our illustrations, the workplace short term exposure limits (STEL) according to EH40/2005 are used



Summary

Many personal gas detectors monitor for multiple gases, and may include a variety of combinations of electrochemical sensors for specific toxic gases, pellistors or IR sensors to ensure the safety of the individual. Fixed installations use an even broader array of technologies to monitor the environment. In this white paper, we have looked at the use of PID to prevent unsafe exposure to VOCs. While it really only scratches the surface of the field of health and safety in respect to gas hazards, it provides a useful overview of how PID technology plays an important role in assessing the gas-related hazards.

For information about Crowcon gas detection solutions for the oil & gas and petrochemical industries, visit www.crowcon.com/industries-and-applications/oil-and-gas-exploration-and-production.html

“Increased awareness of chronic toxic effects of VOCs has led to reduced occupational exposure limits (OEL) and increased requirements for direct measurement..”

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