2. OGI sensitivity – Environmental Variables

Optical Gas Imaging (OGI) technology has proven to be a very effective tool for locating very small leaks and fugitive emissions primarily in petroleum refineries and other Oil & Gas facilities. The sensitivity of OGI technology for a specific compound is typically defined in terms of mass flow rate (grams per hour) of the leak. The objective of this short monograph is to discuss the generic sensitivity evaluation process for any OGI technology in controlled environmental condition and to highlight the main environmental variables that affect the sensitivity of OGI technology.

In a 2011 third party study (test report is available upon request), a contractor has tested and established that the mass flow detection limit (MFDL) of the EyeCGas cooled detector camera for methane as 0.35 g/hr at a temperature difference ΔT=2 ^{0}C, and at distance of 2 meters from the leak (indoors laboratory settings, no wind). This minimum detectable flow rate for methane in indoors laboratory settings can be extrapolated to other gases given the spectral absorption response in the spectral region of the camera's filter. This extrapolation is performed considering the bandpass filter transmission and the absorption coefficient curves of the reference compound with known sensitivity (methane) and of the extrapolated target compound. Figure 1 provides example of such absorption coefficient curves for several volatile organic compounds (VOCs).

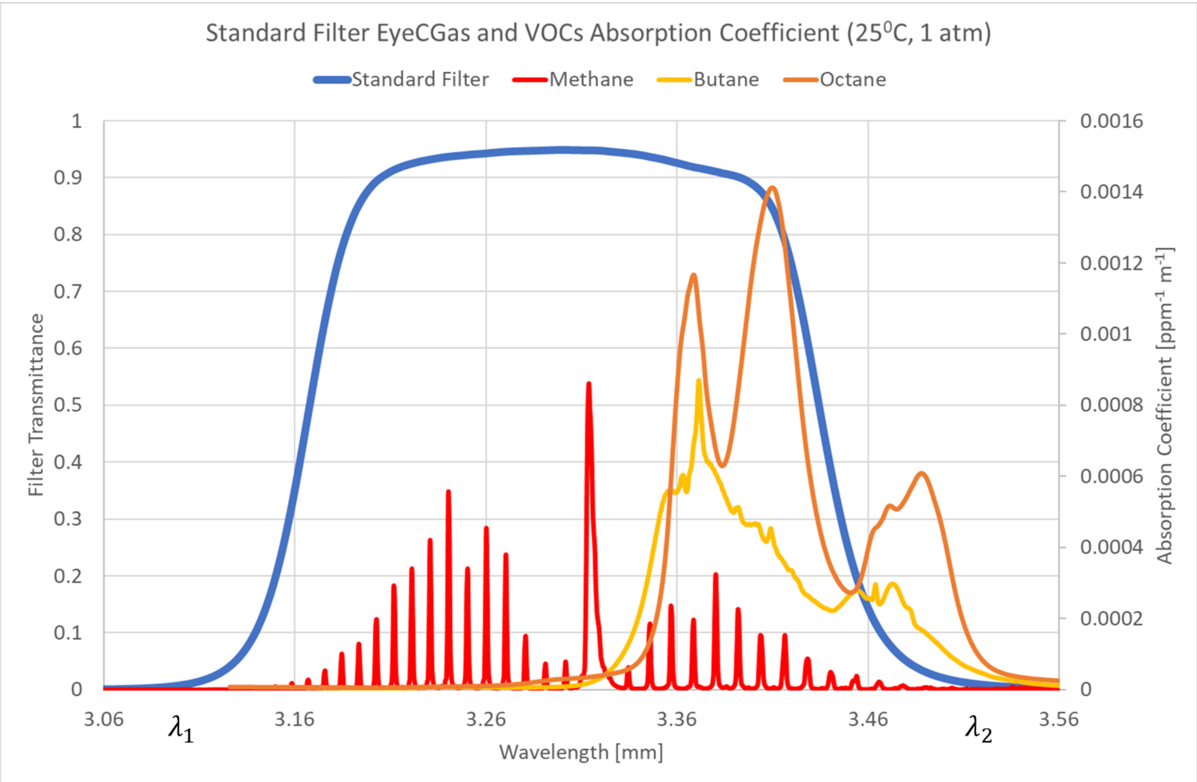

Figure 1 Examples of absorption coefficient curves for 3 VOCs and EyeCGas2.0 standard filter transmission

The response factor, $RF_{target/reference}$, is calculated for any other target compound, using methane as the reference for the EyeCGas2.0 camera, by:

$$RF_{target/reference} = \frac{\int_{\lambda_1}^{\lambda_2} \alpha_{target}(\lambda) \cdot t(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} \alpha_{reference}(\lambda) \cdot t(\lambda) d\lambda} \quad (1)$$

Where

α_{target} – absorption coefficient of the target gas in the plume typically in ppm^{-1} m^{-1}.

$\alpha_{reference}$ – absorption coefficient of the reference gas in the plume typically in ppm^{-1} m^{-1}.

$t(\lambda)$ – bandpass filter transmission as a function of wavelength λ.

The absorption coefficient is defined for integrated volumetric concentration, ppm·m [M1], and therefore for calculating the MFDL for any target compound from the known MFDL of methane, one has to consider the molecular weights (MW) of methane and the target compound as follows:

$$MFDL_{target} = MFDL_{methane} \frac{MW_{target}}{MW_{methane}} \cdot RF^{-1}_{target/methane} \qquad (2)$$

Table 1 below summarizes MFDL values calculated for typical industrial compounds for the EyeCGas2.0 standard filter. These values are based on the verified MFDL for methane at 2 meters and $\Delta T = 2^0C$ in indoors settings.

Table 1. EyeCGas MFDL values for typical industrial compounds in indoors settings (2 meters and $\Delta T = 2^0C$).

Compound	MFDL [g/hr]
Benzene	1.5
Butane	0.3
Ethanol	0.6
Ethylbenzene	0.8
Ethylene	1.0
Heptane	0.4
Hexane	0.3
Methane	**0.35**
m-Xylene	0.9
Octane	0.4
o-Xylene	0.9
Pentane	0.3
Propane	0.3
p-Xylene	0.8
Toluene	1.0

The statement “at 2 meters and $\Delta T = 2^0C$ in indoors settings” reveals that the three primary environmental variables that affects the OGI technology’s sensitivity for each camera and compound:

1. Distance to the leak (range)

2. Temperature difference between the background and gas plume

3. Wind speed.

Figure 2 below demonstrates which term of the OGI Equation [1] is responsible for each of the 3 variables above.

As explained before while deriving the OGI Equation [M1], the foreground air transmission, τ_a, may significantly reduce the OGI camera sensitivity in longer ranges due to aerosols (dust, haze, or fog) extinction and humidity (see

Figure 2 below). This is more relevant for OGI fixed solutions, such as EyeCGas 24/7 series of products, where the camera is expected to automatically alert for leaks from longer distance.

$$\Delta I = I_{no\ gas} - I_{gas} = \overbrace{\tau_a}^{\text{Range}} \left[\overbrace{\left[L(T_b) - L(T_g)\right]}^{\Delta T} \int_{\lambda_1}^{\lambda_2} \left[\overbrace{\left(1 - \tau_g(\lambda)\right)}^{\text{Windspeed}} \cdot t(\lambda) \right] d\lambda \right]$$

Figure 2 Range, ΔT, and windspeed in the OGI Equation

It is also obvious from Figure 2 that the greater the difference between the background temperature and the gas plume temperature, the larger the difference between the thermal radiance, $L(T)$, between these assumed "blackbody layers". Consequently, for a given leak rate, the contrast seen in the camera image, ΔI, is larger and sensitivity is better when this temperature difference is greater.

Finally, fast winds dilute the emitted gas plume and drive down the thermal radiance absorption term of the gas plume in the OGI Equation, $\left(1 - \tau_g(\lambda)\right)$. As a result, the contrast is reduced, and sensitivity decreases with increase of windspeed values.

References

M1. OGI 101 – OGI Equations