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4. OGI Quantification

Quantifying concentration and leak rate values, based on OGI technology, is a very complex and challenging task, which requires innovation and problem-solving skills in every step of the process. Recently, Opgal has developed special proprietary algorithms for accurately determining path integrated concentrations (PIC), or concentration-length (CL) for a pixel in the OGI image and mass flow leak rate (MFLR) for a series of acquired OGI images. In this original process, Opgal had to formulate a new language off terms and set of equations. PIC values are calculated as an intermediate stage for determining the average MFLR (equivalent to mass emission rate) of the target leak event.

Figure 1 below describes the components, retrieved from an acquired series of OGI images, needed for determining the MFLR of a leak event.

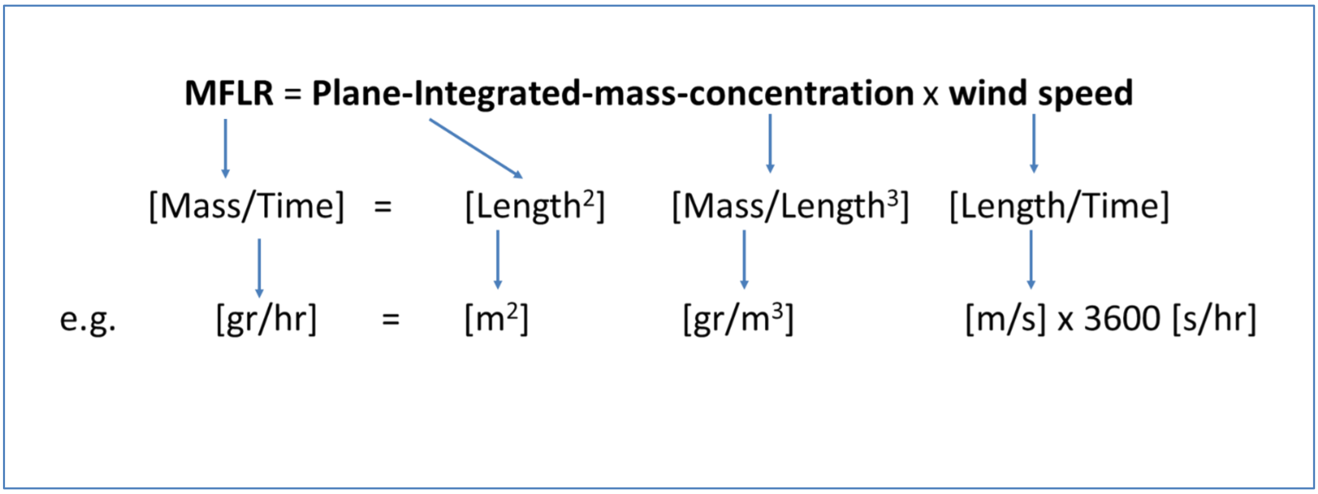

Figure 1. The retrieved components from a series of OGI images for calculating MFLR

For calculating the plane -integrated mass concentration for a line of pixels downwind from a leak, we first need to determine the PIC (same as CL) for each pixel in that line of pixels. We define, from the camera specific OGI Equation (M1), the compound specific response **spectrum**, *CRS(λ,CL)*:

$$CSR(\lambda, CL) = \left[1 - \tau_g(\lambda, CL)\right] t(\lambda) \qquad (1)$$

Figure 2 demonstrates the good match between the compounds specific response spectrum and the camera standard filter (SF), for a wide range of CL values. The unique capability of optimizing this match by replacing the camera filter, allows Opgal achieving better sensitivity and consequently more accurate determination of PIC values at any range.

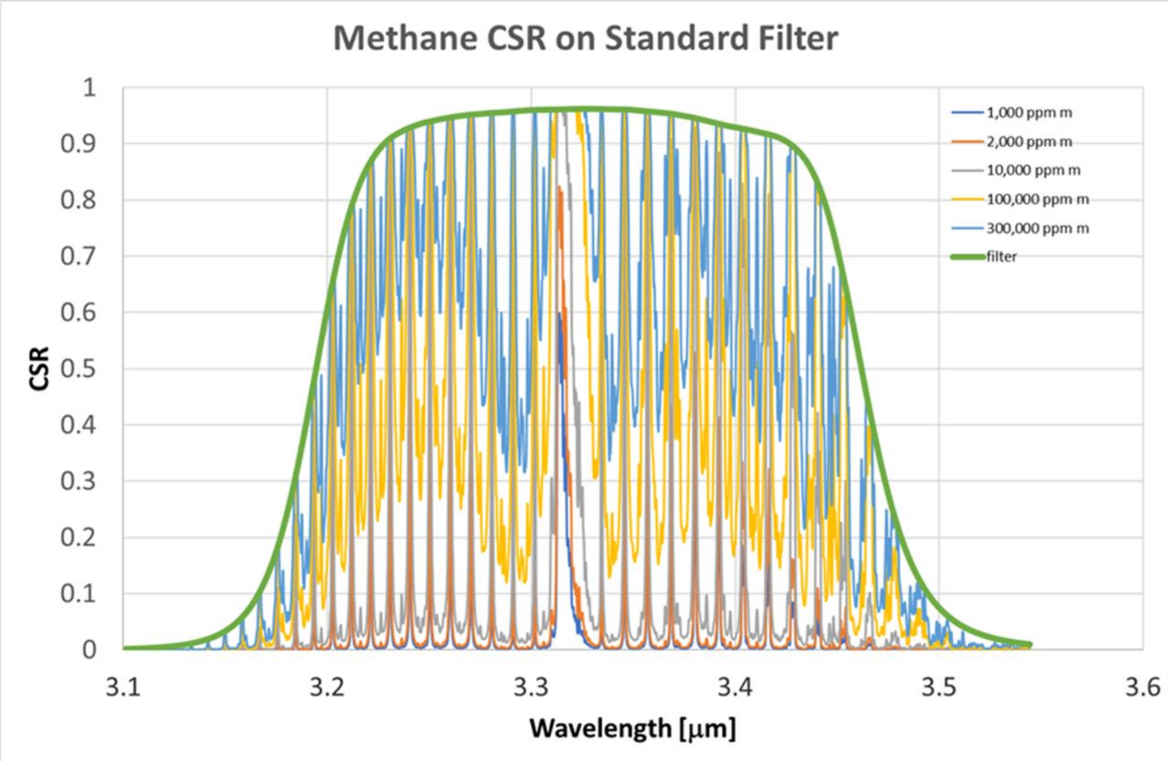

Figure 2 compounds specific response spectrum and the camera SF, for a wide range of CL values.

Unlike other OGI quantification software that uses response factors (RF) relative to propane response, Opgal has developed an algorithm for determining PICs, based on compound specific response function, *CSR(CL)*. Integrating Equation 1 over the bandwidth of the filter, we define the CL dependent CSR function as:

$$CSR(CL) = \int_{\lambda_1}^{\lambda_2} \left[\left(1 - \tau_g(\lambda, CL) \right) \cdot t(\lambda) \right] d\lambda \qquad (2)$$

Opgal's software include a very precise theoretical integration information of CSR function for each compound. This predetermined library of functions is calculated using very high-resolution absorption coefficient data from the Pacific Northeast National Laboratory (PNNL) infrared library, the EyeCGas2.0 Standard Filter transmission spectrum, and proprietary theoretical calibration procedure. These functions behavior with CL values are specific for the absorption coefficient spectrum and bandwidth filter transmission.

Figure 3 compares this behavior for propane and methane. It is apparent that this OGI camera is more sensitive for detecting propane than for detecting methane, and that these functions are not linear and significantly different for various compounds (logarithmic scale for the CL axis). Also, these functions are independent of the environmental scene (ΔT – temperature difference between background and air) and therefore are precalculated in Opgal's software, to serve as reference data for determining the PIC from the acquired relative contrast for each pixel and each frame. Once a series of images (hundreds of

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frames) is collected for a target detected leak event, temperature dependent CSR is acquired for each pixel in each frame. A priori knowledge of the leaking compound allows the algorithm, using the predetermined library of CSR functions, to calculate concentration-length (CL, typically in ppm m) for each pixel in each frame. It is important to note that this measured relative contrast is corrected by taking the ratio of the measured contrast and the foreground air transmission, τ_a, calculated for the specific atmospheric and dimension variables of the measurement scene.

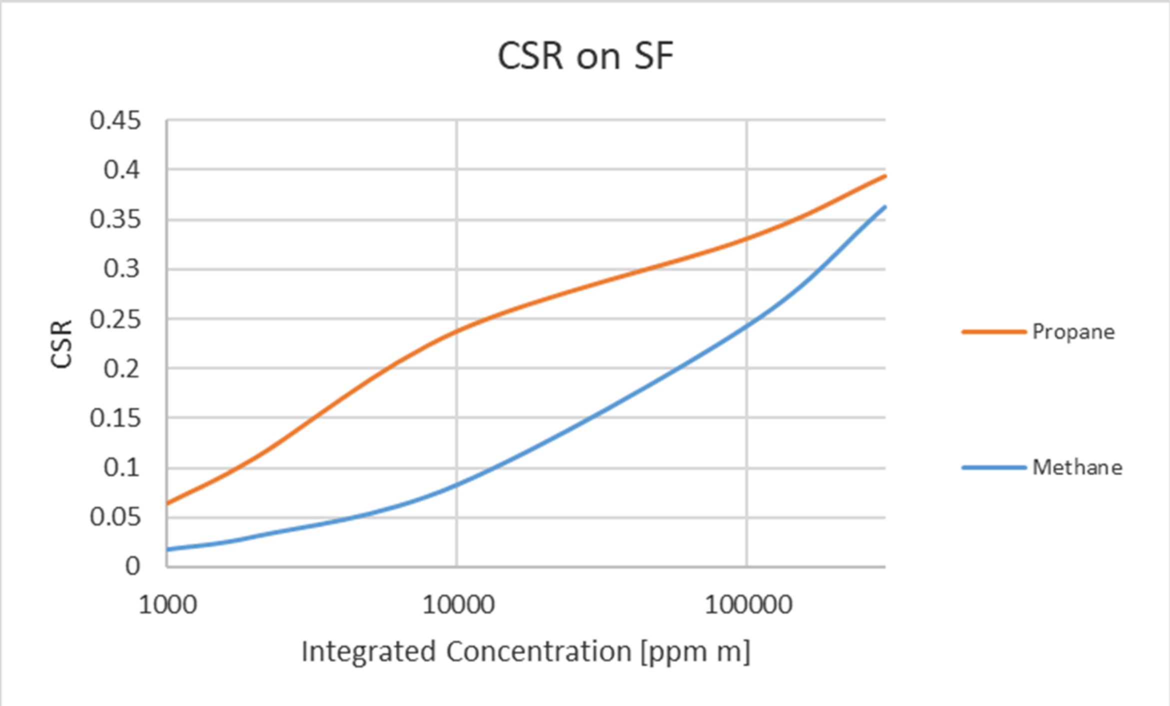

Figure 3 CSR function on SF for Propane and Methane

The next step is calculation of windspeed, by examining movement of the plume between frames. The last step is integrating the CL over a line of pixels for estimating the plane-integrated concentration (See Figure 1), and multiply it by the retrieved windspeed to get a MFLR in mass per time units for each frame in the collected series of images. Taking the mean and standard deviation of all calculated leak rates of the series, provides the average leak rate of the target leak event and the uncertainty associated with it.

References

M1. OGI 101 – OGI Equations