Advanced Gas Leak Detection using Infrared Imaging Technique

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ABSTRACT

Recently, infrared imaging is used in industry as a method to detect fugitive leaks from equipment and pipeline systems. This technique is considered as smart LDAR (Leak Detection and Repair) because it can scan a large number of equipment in relatively short time compared to detection using Total Vapor Analyzer or 'gas sniffer'. In addition, the ability of infrared optical imaging system to visualize the gas plume which is not visible to naked eyes provides another advantage. However, this novel technique poses a lot of challenges in its application due to many uncertainties related to the sensitivity of the camera and factors which may affect measurement. This research evaluates some significant factors affecting measurement such as gas emissivity, atmospheric attenuation, and stimulated radiation from other objects than the target.

Potential use of infrared imaging technique for methane gas emissions estimation is suited in this research. This is carried out by assessing the sensitivity of the infrared camera to obtain the minimum detectable gas concentration that can still be observed by the camera under real meteorological conditions. From this test, the correlation of mass flow rate and distance to minimum detectable concentration will be withdrawn. Prior to the test, discharge and dispersion simulation of methane gas at various pressures, temperatures and leak sizes is performed to calculate the gas release rate and predict the downwind concentration of methane gas.

Several types of infrared imaging technique also have the capability as a non-contact temperature measurement and thus they can provide a spatial temperature distribution of a target object. This facility is used in this research to demonstrate the temperature profile of LNG gas plume in case of accidental spill of LNG on the ground. However, there is a high discrepancy of the cloud temperature measured using infrared camera to the thermocouple reading. This research has been able to identify where the most significant uncertainty comes from. The methane gas emissivity is not included in the detector's algorithm and therefore the apparent target temperature shows much higher value than the actual one. In this study, the methane gas emissivity is analyzed using band absorption model.

Figure 1. LNG cloud from LNG spill on concrete visualized by infrared camera.

Figure 1 shows the thermogram of LNG dispersion cloud resulting from LNG spill on concrete during LNG field test in Brayton Fire School in November 2007. In the thermogram, the highest temperature is given as 13.6 ^{o}C and the lowest is 10.2 ^{o}C. During the test, the average ambient temperature was 12.8 ^{o}C and the temperature of LNG coming out of the pit was 37 ^{o}C. The discrepancy in temperature was because the camera's detector does not include the emissivity value of the methane gas.

The emissivity of methane gas is estimated using absorption band method developed by Goody and the mathematical model developed by Elsasser. The data of effective band width and absorption band from Lee and Happel is applied and extrapolated to boiling point of LNG vapor (110 K).

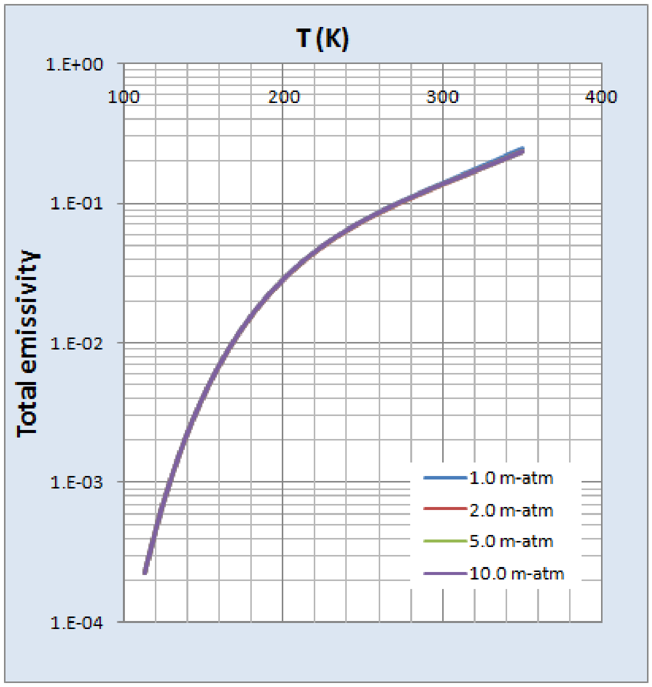

Figure 2. Methane emissivity as a function of temperature at different optical length.

Figure 2 shows the temperature dependency of methane gas emissivity at various optical lengths. From the graph, it is evident that the emissivity value of methane gas decreased significantly at low temperature. The emissivity value calculated from absorption band model is then applied to correct the apparent temperature measured from the infrared camera.

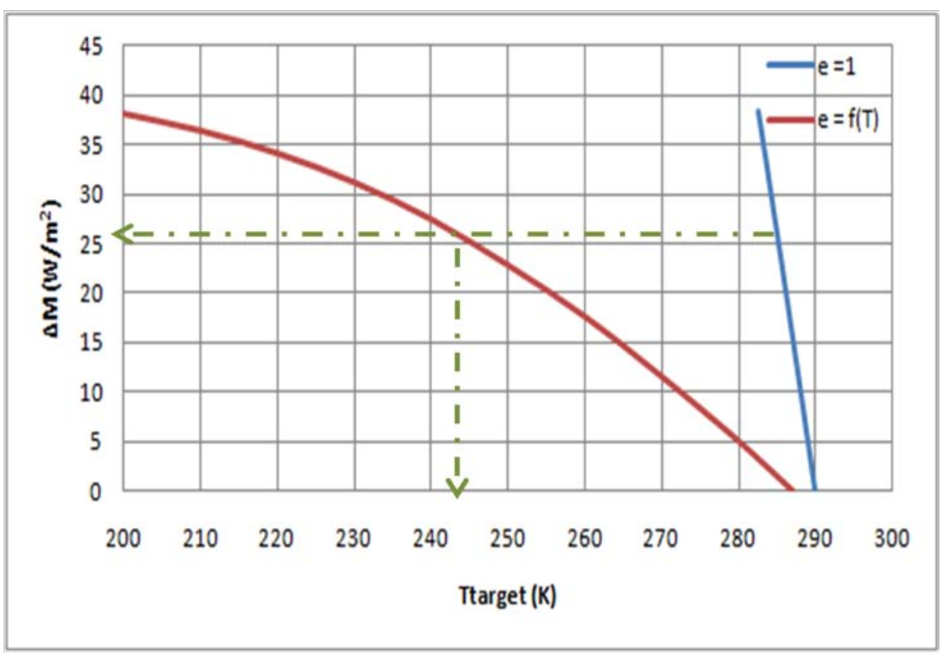

Figure 3. Actual target temperature vs. apparent target temperature from the thermogram

Eventually, the actual temperature of the methane cloud can be estimated by applying the emissivity function into Stefan-Boltzmann equation. Figure 3 above shows how the target temperature will change dramatically when emissivity value is considered. By including the emissivity value of methane gas the temperature of LNG at the outlet of the pit is estimated to be around 243 K which is in good agreement with the thermocouple reading.