Application Solution

Detecting CO and NO2 Gases

DANGERS OF CARBON MONOXIDE AND NITROGEN DIOXIDE

Carbon Monoxide (CO) and Nitrogen Dioxide (NO2) are potentially toxic airborne gases resulting from an incomplete combustion processes from gasoline and diesel engines. Motor vehicles are the most common source of these gases. Other examples include generators, propane or wood cooking and heating devices, cigarettes, and even natural causes like forest fires and lightning.

When an engine runs in a confined space, such as parking garages, emergency vehicle bays, mechanical rooms, or factories, dangerous gas concentrations may accumulate.

The National Institute for Occupational Safety and Health Administration (NIOSH) recommends an average exposure of no more than 35 ppm of CO or 1 ppm of NO2 throughout the day. The Occupational Safety and Health Administration (OSHA) limits permissible average exposure levels of 50 ppm CO and 3 ppm NO2. These averages are based on a full work day or 10-12 hours. Exceeding 200ppm of CO or 5 ppm NO2 will cause noticeable health symptoms such as headache or throat irritation and higher concentrations or extended exposure can be life threatening.

HOW GAS SENSORS WORK

Most CO and NO2 sensors available today utilize electrochemical sensing elements. Electrochemical sensors deploy an electrode that conducts only when a certain gas is present. The level of conduction is proportional to the concentration of gas present and can be electrically measured to provide a gas concentration reading.

As with most gas sensors, the gas particles needs to come in physical contact with the electrochemical element, so a sensor is technically measuring only what gas is present at the exact location of the sensor.

It is important to understand dispersion in order to monitor gases effecively.

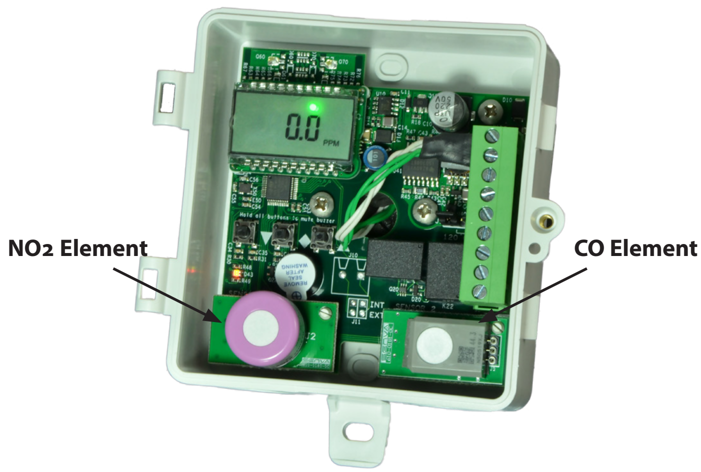

Figure 1: Typical Toxic Gas Sensor with NO2 and CO elements

HOW GAS MOVES

All gases are made up of tiny particles which move continuously in random patterns that make it difficult to predict the path a concentration of gas will take. Generally, a gas will diffuse outward from its source in all directions. In an ideal world, a concentration of gas will diffuse and mix with other gases over time and will eventually be evenly distributed in the space it occupies. Consequently, the ultimate concentration of a gas can be measured at any point in the space it occupies. However, the time to reach equilibrium will vary based on several variables and a toxic gas sensor should be able to identify the presence of gas in a reasonable and safe amount of time. Variables affecting the time of distribution include gas density, volume and airflow in the space in question, and temperature. These variables are investigated in the following sections.

Density's effect on gas movement

The density of a gas affects its ability to diffuse or mix with surrounding air. Air has a density of 1.29kg/m^3, CO has a density slightly lower at 1.25kg/m^3 and NO2 is more dense at 3.39kg/m^3. As CO is less dense than air and NO2 is more dense, it is commonly believed that CO will rise and NO2 will fall when each is mixed with air. This is true for NO2 but not CO.

Detecting CO and NO_2 Gases

A study published in the Journal of Emergency Medicine [1] investigated the distribution of CO in an 8 foot tall chamber when applied from different heights. The results of the study show the time taken to reach equilibrium when applied and sensed at three heights: 0 feet, 4 feet, and 8 feet. For the typical application, gas is coming from an exhaust pipe, so the results of applying CO gas from the bottom and middle of a chamber are shown in Figure 2. Exhaust gas height would likely fall in between the two.

The results show that a sensor placed at 4 feet (middle) is able to register a high concentration of CO in under 10 minutes when the gas source is at 0 feet (left image in Figure 2) and much quicker when the gas source is also at 4 feet (right image in Figure 2). With CO applied at 4 feet, all three sensor heights registered the gas in about the same amount of time (right image in Figure 2). This experiment was performed in a chamber, effectively isolating the effects of mixing or temperature. In a real world application, these effects would lend to an even quicker distribution. The study concludes that CO was reasonably detectable from any height in the chamber, regardless of the height of the source gas.

Another study tested and modeled the dispersion of a heavy gas in a building using computational fluid dynamics (CFD) [2]. This study models the dispersion of SF_6, as shown in Figures 3 and 5. SF_6 has a density of 6.17 kg/m^3 which is close to twice the density of NO_2 so is a much more extreme scenario. However, it does illustrate how a heavier gas is likely to diffuse outward before upward. It can be estimated that NO_2 will behave similarly. As NO_2 is significantly less dense, it is likely that its diffusion would be faster and possibly distribute upwards more readily.

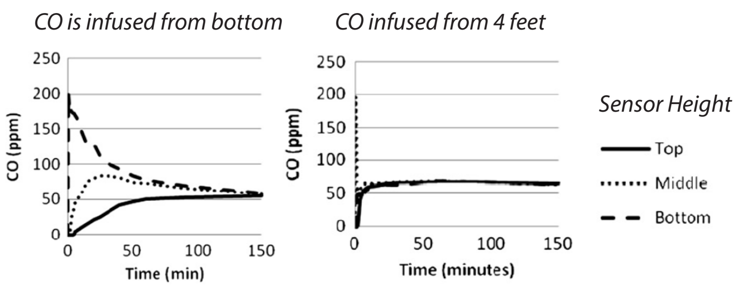

Figure 2: From study [1]. Concentrations sensed versus time for sensors placed at 0 (bottom), 4 (middle), and 8 feet (top) while CO is infused from the bottom of a chamber (Left) and applied at 4 feet (right).

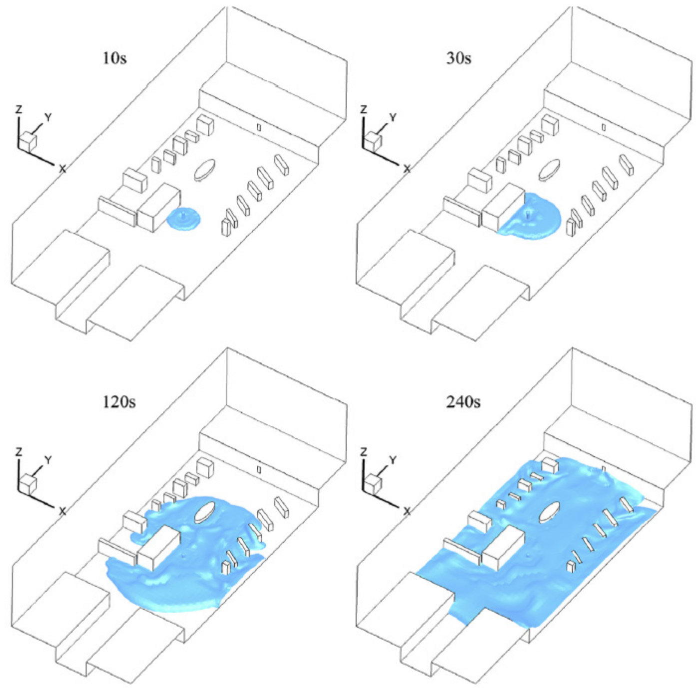

Figure 3: From study [2]. CFD model of how a concentration of a heavy gas diffuses in an indoor space.

Airflow's effect on gas movement

It is possible to estimate how gas will behave in an ideal situation but, in reality, gas movement will also be affected by things such as fans, wind, moving vehicles, pressure, and temperature differentials. Thus, airflow's effect on gas is nearly impossible to quantify. It can be logically stated that increased airflow results in increased speed of gas diffusion. Additionally, if an air-stream is present, gas will tend to flow with it.

Temperature's effect on gas movement

Temperature, or heat, affects how fast particles move. As temperature increases, particles move faster and their volume expands. Thus, adding heat into the equation will make gases diffuse faster.

Additionally, the density of a gas changes with temperature. For example, NO2 actually becomes less dense than air at around 200°C. At this temperature, the diffusion of NO_2 can be estimated to behave a lot more like CO when mixing with air.

While the exhaust system of a diesel vehicle can reach temperatures of over 400ºC, it quickly cools as it disperses with the cooler surrounding air. Figure 4 shows a thermal image of the exhaust pipe on a Ford FX4 diesel truck at idle after driving in which the temperature of gas just two inches from the 72ºC tailpipe has reduced to about 24ºC.

For common exhaust applications, it can be concluded that the temperature of the exhaust does not play a large role in how quickly the gas will diffuse. However, if more heat is present in the entire system, such as a hotter day or a heated garage, diffusion will happen more quickly.

IDEAL DETECTION HEIGHT

Based on the analysis in the "how gas moves" section, it can be concluded that a CO sensor can detect gas reasonably when mounted at heights between 0 and 8 feet. For SF_6, as shown in Figure 5, the highest concentration of gas stays at 1m or below. However, the modeled gas would be reasonably detectable with a sensor mounted at 2m or lower and NO_2 is significantly less dense. Therefore, it can be conservatively estimated that NO_2 can be effectively detected anywhere below 2m height.

A CO/NO_2 sensor should be mounted between 3 and 6 feet to ensure the fastest gas detection and protect people of all heights.

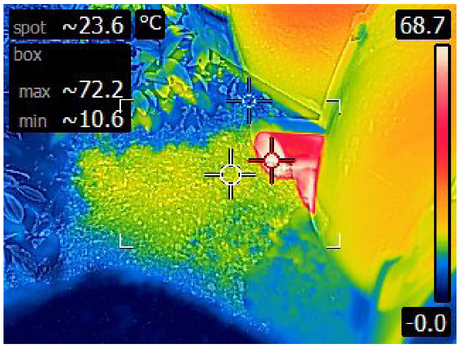

Figure 4: Exhaust temperature of a diesel truck

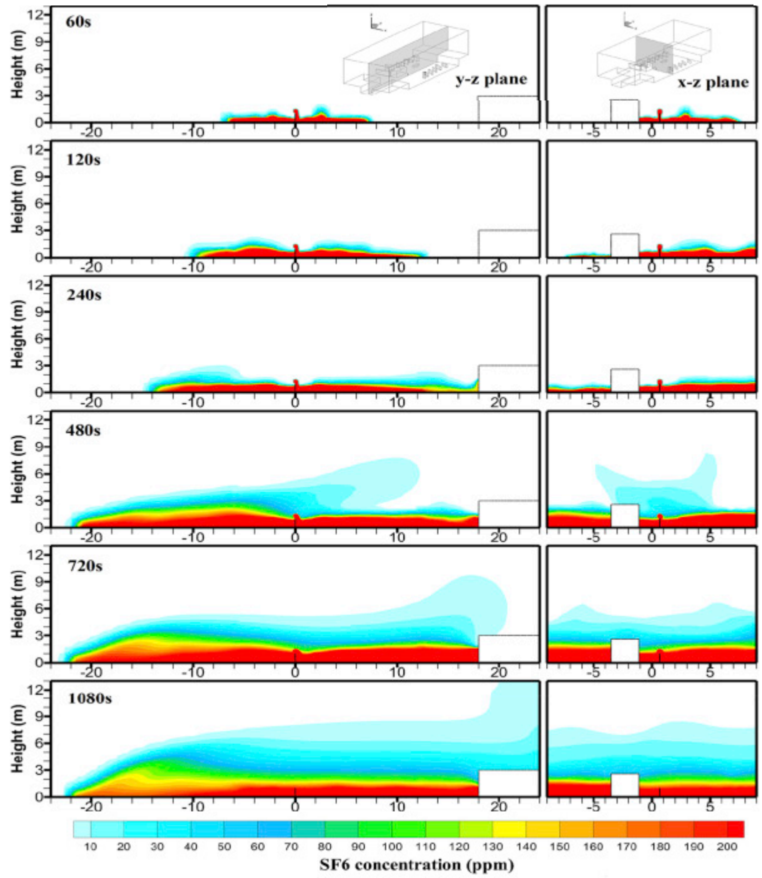

Figure 5: From study [2]. CFD model of how a concentration of gas disperses over distance and height in an indoor space.

COVERAGE AREA OF A TOXIC GAS SENSOR

The coverage area of a toxic gas sensor determines what area of space a sensor can reasonably protect. This rating, again, is based on an understanding of how gas flows in an outward direction. It is based on the distance from any point a sensor can be placed and still be expected to provide safe and reasonable gas detection.

The above density analysis proves that heavy gases tend to disperse the slowest. Thus, study [2] can further be analyzed to also determine the worst-case dispersion rate in an outward direction.

Detecting CO and NO_2 Gases

From Figure 5, it is illustrated that a very heavy gas will reach 14 to 16 meters from it's source after 4 to 8 minutes. There is a significant drop-off in dispersion rate at about 20-24 meters from the source. Beyond 24 meters from the source, the gas may not accurately be detected after 24 minutes.

Based on this model, a sensor of a dense gas such as NO_2 should be able to provide accurate and timely gas detection within a radius of 14 to 16 meters or 42 to 48 feet. As CO is significantly lighter and likely to disperse more quickly, this coverage area should be more than adequate.

SUMMARY

- Detecting CO and NO_2 requires sensors to be placed such that a concentration of gas will diffuse to the location of the sensor in a reasonable and safe amount of time
- Relative to air, CO has a lower density; NO_2 has a higher density
- Lower (or similar) density gases, such as CO diffuse with air quickly
- High density gases, such a s NO_2, diffuse more slowly and tend to stay at lower heights
- Airflow directly impacts diffusion rates but is difficult to quantify
- Temperature directly affects diffusion rates
- Recommended mounting height for a CO/NO_2 sensor is 3 to 6 feet
- Recommended coverage distance for a CO/NO_2 sensor is 42 to 48 feet
- Recommended coverage area for a CO/NO_2 sensor is 5500-7200 square feet

REFERENCES

[1] Hampson, Neil B., et al. "Should the Placement of Carbon Monoxide (CO) Detectors Be Influenced by CO's Weight Relative to Air?" The Journal of Emergency Medicine, vol. 42, no. 4, 2012, pp. 478–482., doi:10.1016/j.jemermed.2011.03.015.

[2] Dong, Longxiang, et al. "Simulation of Heavy Gas Dispersion in a Large Indoor Space Using CFD Model." Journal of Loss Prevention in the Process Industries, vol. 46, 2017, pp. 1–12., doi:10.1016/j.jlp.2017.01.012.

SOLUTION

Senva TG Series sensors are the perfect solution for combination CO/NO_2 sensing and parking lot demand ventillation. Visit Senvainc.com or call your Senva sales rep today at 1-866-660-8864.

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- Warning indicators alert occupants when element's lifecycle is near end for replacement
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