

CARBON MONOXIDE & NATURAL GAS DETECTION FOR FIRE DEPARTMENT ENGINE COMPANIES

In recent years the fire service has recognized the need for engine company carbon monoxide (CO) detection. CO, a by-product of incomplete combustion, has always existed. However as energy efficiency has become more important, houses and offices have become tighter and the potential for CO build-up has increased. The number of CO calls has outstripped the ability of HazMat teams (the



gas detection experts) to respond to each call, so engine companies have often been tasked with and given the assets to do CO detection. Unlike HazMat teams, firefighters on engine companies typically do not have extensive experience in gas detection. Therefore, engine companies tend to neglect the “care and feeding” of their gas detectors. This neglect can affect the reliability of engine company CO readings. There tend to be two reasons for this: lack of calibration and lack of gas monitoring experience. Two verification methods, calibration and CO detector tubes, can quickly and easily bring reliability to engine company CO detection.

THE CO DETECTOR IS A “FLASHLIGHT”

A gas detector is a “flashlight” that lets people “see” gases that they would not normally be able to see. If one is going to use a flashlight to see in a dark basement, it is advisable to check to see if it is working before going down the basement steps. The same holds true for CO detectors. They are designed to help people see a toxic gas that they normally could not see. Like the flashlight, they need to be checked before use. Detector manufacturers call this “calibration.” When a CO sensor fails, its output drops to 0. So a failed CO sensor will provide a false reading of safety. The only way to verify that a



CO sensor is working is to calibrate it with a known concentration of CO. CO detectors often sit on an engine all summer without ever being used or calibrated. When heating season starts, the neglected CO detector may not provide good results.

CALIBRATING A CO DETECTOR

Firefighters often put a CO detector into the exhaust pipe of a car or truck to see if it works. This causes problems for two reasons. First, catalytic converters in new vehicles have drastically reduced the amount of CO present. Second, other products of combustion (water vapor, hydrocarbons and particulates) can clog sensor filters and membranes, permanently disabling the CO sensor.

IMPORTANT! Never use vehicle exhaust to test a CO sensor!

For the best service and reliable readings, CO sensors should be calibrated with a known calibration gas at the beginning of heating season and at least once a month during the heating season. Calibration gas is “confidence in a can.” If the CO detector is acting “funny,” then calibration gas can help to verify that it is performing properly. If possible, it is a good idea for calibration gas to travel with an engine company. This way, if someone gets a “funny” reading, it can be quickly “field verified” if the detector is working properly by exposing the detector to a known concentration of CO. It is easy to do this because CO calibration gas is cheap and stable.

Four Types of Calibration:

- **Bump:** The detector is shown CO gas, and the user just looks to see if the sensor responds.
- **Field Verification:** The detector is shown CO gas, and the user verifies that the detector’s display is within +10% of the value on the gas cylinder after the display has stabilized. Therefore, if the cylinder contains 50 ppm of CO, the detector should display between 45 and 55 ppm. If the detector is outside of this range, then a Field Calibration should be performed.
- **Field Calibration:** Takes field verification to the next step. The detector is shown CO gas, and if the reading is not within 10% of the value on the cylinder it is adjusted. In older detectors, this was accomplished by dials or a screwdriver. Newer detectors use a microprocessor to perform this function automatically, and field calibration is typically accessed by a special series of keystrokes.

- **Factory Calibration:** The detector is returned to the factory for calibration. This is typically only required on older detectors. When purchasing CO detectors one should make sure that Factory Calibration is not a requirement and that all calibration and maintenance is simple and can be performed by a qualified person in your department. Otherwise, you may need extra detectors just so that you still have use of a detector while one travels to and from the factory calibration center.

Lack of Gas Monitoring Experience

Many refer to gas monitors as gas “detectors” and like all detective work, the use of gas detectors require special skills. As discussed above, detectors require calibration to provide their best results. In addition, users have to have some idea about the behavior of gases. So if an engine company gets a CO call and they open doors and windows on entry, they are ventilating the structure and it will be difficult or impossible to track the source of the CO. Some common gases can provide false readings on a CO detector. Calibration, training and verification techniques can virtually eliminate these false alarms.

CO TUBES: LIKE READING A THERMOMETER

CO tubes are one of the oldest and most reliable techniques of measurement. A known volume of gas is drawn through a glass tube filled with silica substrate that has been treated with a chemical that changes color when exposed to CO. The CO reacts with the chemical on the silica to cause a color change. The concentration of CO is read on the tube much like one reads the temperature on a glass thermometer. Tubes are often dismissed because they are “old-fashioned” and “low-tech.” However, “low-tech” is their appeal for engine companies. CO tubes are factory calibrated. Properly stored,



CO tubes will last 2 years and don't require user calibration. Tube pumps sell for as little as \$165 (RAE Systems) and a box of 10 tubes sell for as little as \$30 (RAE Systems) so this means that an engine company can easily be outfitted for less than \$200 for two years. CO tubes have some disadvantages. Tubes only provide “snapshots,” they are not a continuous monitor so one needs to take a sample from every room that might have CO in it. Tubes are used once and then thrown away. Measurements are not instantaneous like CO meters. One must wait from one minute to five minutes for a reading. Bellows-style tube pumps are slower and can introduce significant user error if the bellows are not squeezed properly. Therefore, it is best for engine companies to consider the simpler and more rugged syringe-style pumps. Metal syringe-style pumps are virtually indestructible.



CO MONITORS FOR CONTINUOUS MEASUREMENT

CO detectors use an electrochemical CO sensor and provide highly accurate continuous measurement of CO. They typically provide very quick response in approximately 20 seconds. Quick response is important because it allows a user to move from room to room using the CO detector like a Geiger counter to locate the source of the CO. CO detectors can provide various features like Peak Hold, Short Term Exposure Limit (STEL) and Time Weighted Average (TWA), but the STEL and TWA values are OSHA average alarms often used by Industrial Hygienists that typically are not useful to engine companies. Engine companies are typically only interested in the instantaneous reading and the peak reading.

When purchasing a CO detector, it is important to choose one with a simple display that is easy to use. When outfitting an engine company with CO detectors one should consider putting CO gas on the engine also to allow for the CO detector to be calibrated monthly and to provide a means of verifying the performance of the CO detector.

VERIFICATION TECHNOLOGIES

CO detectors provide very quick response, yet they tend to be more costly and require more maintenance than tubes. Tubes are inexpensive and easy to use, but they have a higher cost per use and they don't provide continuous readings. However, CO detectors and CO tubes represent two drastically different techniques to reach the same goal of measuring CO. Used together, they have a complementary effect, and they can provide greater confidence in CO measurement and prevent false alarms. For example, if a homeowner feels that CO is present, yet the detector's digital display reads zero, then a CO detector tube can be used to verify the reading. If both the detector and tube read zero, then it is extremely unlikely that CO is present. To best understand this complementary effect, let's look at some more examples.

CO in a Printed Circuit Board Plant

A portable CO detector read 60 ppm in the cafeteria of a printed circuit board plant, with no obvious reason for it. When the detector was taken outside the plant the CO level on the detector dropped to zero, but a fresh air calibration was performed anyway. Upon reentering the plant the CO detector again showed a reading of 60 ppm. The detector was again taken out of the plant and 50 ppm CO calibration gas was applied. The meter read 47 ppm which showed that it was working properly, but for good measure it was

recalibrated. However, there was no obvious source of CO, so a CO tube was used, and it read approximately 50 ppm CO. With both the electrochemical CO sensor and the CO tube reading positively for approximately the same concentration of CO, it was safe to assume that CO was present. Using the CO detector like a Geiger counter, the source was located at a heat-shrink packaging machine that was producing 150 ppm of CO in the operator’s breathing zone. The company immediately had the machine tuned up.

CO in a Food Warehouse

In a food warehouse, a portable CO detector showed a CO concentration of 80 ppm. However, the facility used battery-powered rather than propane forklifts, so this ruled out the CO from the forklifts, which is a common source of CO in warehouses. The warehouse personnel pointed out that we were



making the CO measurement in an office located within the battery charging room. Without an immediate answer to the CO levels, a CO tube was used to verified the CO concentration. But it did not register any CO. Lead-acid batteries generate hydrogen gas while charging. Using a cross-sensitivity table supplied by the CO sensor manufacturer showed that 80 ppm on the CO sensor means that there was approximately 200 ppm of hydrogen present which is well below its Lower Explosive Limit (LEL) of 4% (40,000 ppm).

Engine Company Natural Gas Calls

The calls for “natural gas smell” seem to be almost as common as CO calls. If engine companies are to be tasked with CO measurement, then perhaps a tool should also be considered for natural gas calls because both seem to run together. Natural gas is a flammable gas consisting primarily of methane and other short-chain saturated hydrocarbons. Methane is flammable when present in concentrations of 5% volume or greater. 5% methane in air explodes if an ignition source is present. This minimum concentration of methane that supports combustion is called the Lower Explosive Limit, or LEL. Detectors that are used to measure combustible gases for safety purposes are often called “LEL meters” and read 0 to 100% of LEL. So if the detector reads 100 that means that the atmosphere is flammable. If the detector is reading 50, it means that the atmosphere is 50% of the way to becoming flammable. The OSHA limit for entry into confined spaces is 10% of LEL. For methane, 10% of LEL is 0.5% methane by volume.

Odorants Make Natural Gas Smell

Natural gas does not smell, so there is no way for someone to detect a leak without a proper measurement tool. Therefore, natural gas is “odorized” with a very smelly compound called methyl mercaptan. Methyl mercaptan has an olfactory threshold of between 0.0001 to 0.041 ppm (parts per million) or 0.1 to 41.0 ppb (parts per billion). This means that one can smell natural gas leaks well below the level that is dangerous. Also, the “sticky” nature of methyl mercaptan means that it tends to stick to clothes and equipment.

Only an LEL Monitor Can Tell You When it is Safe

Noses are not very accurate detection devices. They can quickly suffer from “olfactory fatigue” as they become acclimated to an odor. So one’s sense of smell can’t be trusted around natural gas leaks. LEL monitors can help establish whether it is safe to enter a building when natural gas odor has been noted. The LEL meter often reads 0, indicating that the area is not flammable, yet the natural gas smell is still there.

These numbers are summarized below:

Methane	%Volume	ppm	ppb
100% LEL	5	50000	50000000
10% LEL	0.5	5000	5000000
1% LEL	0.05	500	500000
0.1% LEL	0.005	50	50000
Odor Threshold Methyl Mercaptan	0.0000001	0.0001	0.1

What this table shows us is that the lowest concentration of methane that an LEL detector can measure is 50,000 ppb, while people can smell the odorant in natural gas at 0.1 ppb. So, people can smell the odorant at levels 500,000 times below the limit of detection of any LEL meter. An LEL detector can help increase the safety of engine company personnel when natural gas is smelled, and it can help show that building occupants are safe even though they might still smell some residual odorant.

CHOOSING THE RIGHT PRODUCT(S) FOR MEASURING CO

Determine how many calls each engine company makes a year. If they make less than 68 measurements per a year, then it might be best to choose gas detection tubes. If you feel that continuous monitoring is best, then tubes provide an excellent verification technique.

RAE Systems CO Gas Detection Tubes

A very affordable way to make CO measurements. The rugged metal syringe style pump is virtually indestructible and requires no training. Just pull and latch the handle and wait for the indicator to change color to read the tube. RAE offers CO tubes in the ranges of 5-100, 20-500 ppm and 0-2-4% and are the most affordable tubes in the market at just \$30 per box of 10.



ToxiRAE II CO Checker Kit

The CO Checker is a complete kit that gives you both a highly accurate CO monitor and the calibration gas necessary to verify it is reading accurately. The CO checker is a simplified CO detector that only provides continuous CO readings, PEAK hold, battery voltage and run time. It does not provide industrial hygiene alarms like STEL and TWA that might confuse users. The CO checker is also available without the kit.

ToxiRAE LEL Detector

The ToxiRAE LEL meter is a unique, compact, inexpensive meter that allows you to readily measure flammable gases and give you a readout in % of LEL. A rechargeable meter, the ToxiRAE LEL meter provides 10 hours of run time on its NiCd batteries. If one forgets to charge the ToxiRAE, it comes with an alkaline battery pack. One can always use the ToxiRAE as long as they can pick up 4 AAA alkaline batteries.



DRAE CO and LEL Detector

A simple two-gas monitor where the “D” in D-RAE stands for “Dual” or two sensors. As a CO/LEL monitor with lithium-ion batteries, the D-RAE lists for just \$790.00. The D-RAE is a unique, simple monitor that allows engine companies to make both CO and Natural Gas calls.



REFERENCES

RAE Systems: **Sensor Specifications and Cross-Sensitivities** (Technical Note TN-114)

RAE Systems: **Handbook of Gas Detection Tubes & Sampling Pumps** (Third Edition, 2005)