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FLEX 4 SERIES

A Guide to CO-H Gas Sensing

Honeywell

CARBON MONOXIDE GAS SENSING

Carbon monoxide (CO) is one of the most dangerous and widespread industrial hazards. Present in many industrial and commercial applications, to say nothing of being a hazard to anyone working around motor vehicles, the primary danger with carbon monoxide is that it is colorless, odorless, and tasteless and so cannot be easily detected through human senses alone: sensors specifically designed to alert to its presence are necessary.

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GAS OVERVIEW

Carbon monoxide (CO) is colorless, odorless, and tasteless and therefore, almost undetectable without sensors developed to be specifically sensitive to its presence. The poisonous gas consists of just two elements, one atom each of carbon and oxygen, is slightly less dense than air, and mixes readily with air. Poisoning occurs from inhalation and can be fatal quickly. When mixed with air, large quantities of carbon monoxide can sometimes be highly flammable and explosive.

CO is derived from the incomplete burning of gasoline, wood, coal, oil, propane gas, or anything else that contains carbon. While the exhaust from internal combustion engines powered by fossil fuels is the chief source of workplace exposure to CO in many industries (trucks, material handling equipment, some conveyor systems, etc.), smelting operations, furnaces, and ovens also produce large amounts of the gas, especially when they are not properly maintained.

Truck drivers, forklift operators, or anyone working near such equipment are potentially exposed. Facility environments that may be particularly dangerous include enclosed areas such as manholes, splicing vehicles, garages, tunnels, loading docks, warehouses, and vehicle repair shops.[1]

Of course, carbon monoxide is also produced by humans and other oxygen-breathing creatures when exhaled, so technically we are also a CO source!

Carbon monoxide enters the bloodstream through the lungs and combines with hemoglobin, the red pigment in the blood that carries oxygen. Although carbon monoxide follows the same path as oxygen, the poisonous gas combines with hemoglobin 210 times faster than does oxygen. This means that even though there may be ample oxygen in the surrounding atmosphere, carbon monoxide will get into the bloodstream first. High blood-level concentrations of the compound will prevent sufficient amounts of oxygen from reaching the heart and brain, which can lead to suffocation, capillary hemorrhaging, permanent damage of nerve tissues and brain cells, and even death .[2]

1. https://cwa-union.org/national-issues/health-and-safety/health-and-safety-fact-sheets/carbon-monoxide-and-workplace
2. https://cwa-union.org/national-issues/health-and-safety/health-and-safety-fact-sheets/carbon-monoxide-and-workplace

Once within the body, CO combines with hemoglobin in the blood to produce carboxyhemoglobin, which potentially affects gas exchange and can quickly be highly toxic. Concentrations as low as 667 ppm may cause up to 50 % of the body's hemoglobin to convert to carboxyhemoglobin and may result in seizure, coma, and fatality. In the United States, OSHA limits long-term workplace exposure levels to 50 ppm.[3]

The initial symptoms of carbon monoxide poisoning can easily be confused with other possible causes or health conditions. Low-level exposure can cause headaches, dizziness, drowsiness, or nausea. Further exposure will aggravate these symptoms and can accelerate to include rapid pulse, confusion, loss of coordination, or collapse. The long-term effects of low-level exposure have not been confirmed but should be avoided.

High exposure can lead to convulsions, coma, or death and even if recovered, highly exposed victims may still suffer permanent damage of the brain or nerve tissue. Sudden exposure at high levels can kill in just a few minutes. During World War II in Italy, over 500 persons were killed almost instantly when their overloaded train became stuck in a steep, icy tunnel and toxic gas from the burning coal suffocated them[4]

WHY DEDICATED CO GAS SENSORS ARE IMPORTANT

CO exposure is dangerous enough that many communities require detectors in homes. Unfortunately, this can also lead to the use of home CO detectors in business environments or even industrial facilities. This is not appropriate and can lead to hazardous conditions.

Home CO detectors are typically designed using Underwriters Laboratories Inc. Standard UL2034 alarm points for these concentration levels of carbon monoxide:

- 400 ppm – Alarm between 4 and 15 minutes of exposure
- 150 ppm – Alarm between 10 and 50 minutes of exposure
- 70 ppm – Alarm between 60 and 240 minutes of exposure

The OSHA personal exposure limit (PEL) for CO is 50 ppm. The threshold limit value (TLV) from the American Conference of Governmental Industrial Hygienists (ACGIH) for CO is 25 ppm. NIOSH has established an instantaneous 200 ppm ceiling level. So in workplaces, it is possible to exceed all of these limits without a peep from a detector made for residential use. Even models with digital readouts often won't display concentrations below 30 ppm, and calibration is nearly impossible.

When using proper sensors for workplace settings, alarms often trigger more than sirens: because CO cannot be detected with human senses, a first reaction is sometimes that the sensor is wrong, it's not powered correctly, or someone accidentally triggered it. This is especially the case where there are no combustion sources, not a lot of fueled vehicles currently running or present, or when most vehicles in an area have been converted to battery power. However, this can be a critically wrong reaction.

Many CO sensors are not CO-specific, and there are a lot of other gases that can create interferences and set off your detector. When further exploration shows that CO was not the trigger, workplaces may develop a skeptical reaction to future alarms and of course that can be deadly.

Hydrogen gas is a particularly frequent culprit in setting off detectors that are not single-gas devices or not able to be set up to always alert to the presence of CO.

CO
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3. https://en.wikipedia.org/wiki/Carbon_monoxide

4. https://cwa-union.org/national-issues/health-and-safety/health-and-safety-fact-sheets/carbon-monoxide-and-workplace

Also important in the selection of CO-specific detectors is the ability to calibrate it for a specific workplace environment. This calibration should include knowing reaction times to alarms (in other words, how quickly can personnel be evacuated and assets secured, if necessary), specific concentration levels, potential for CO interference with any other gases or materials in the area, and so on.

With the information above in mind, here is a look at the acceptable levels of workplace exposure to CO from a number of national and international health and safety organizations[5]:

Physical Symptoms
physical symptoms may include headache, fatique, dizziness and/or nausia.

0 ppm	**Recommended Safe Level**	
6 ppm	WHO 24 Hour Average	
9 ppm	ASHRA 8 Hour Average EPA 8 hour 8 Hour Average NAAQS 8 Hour Average WHO 8 Hour Average	
25 ppm	ACGIH 8 Hour Average	
30 ppm	WHO 1 Hour Average	
35 ppm	NIOSH 8 Hour Average NAAQS 1 Hour Average	Physical symptoms after 6-8 hours.
50 ppm	OSHA 8 hour Average (PEL)	
30-69 ppm	UL 30 Day Alarm	
87 ppm	WHO 15 Minute Average	
70-149 ppm	UL 1-4 Hour Alarm	
200 ppm	NIOSH 15 minute STEL	Physical symptoms after 2-3 hours.
150-399 ppm	UL 10-50 Minute Alarm	
400+ ppm	UL 4 Minute Alarm	Physical symptoms in 1-2 hours. Life threatening 3 hours.
		Physical symptoms in 45 minutes. Unconscious in 2 hours. Fatal in 2-3 hours.
800 ppm		Physical symptoms in 20 minutes. Fatal within 1 hour.
1,600 ppm		Physical symptoms in 5-10 minutes. Fatal within 25-30 minutes.
3,200 ppm		
6.400 ppm		Physical symptoms in 1-2 minutes. Fatal within 10-15 minutes.
12,800 ppm		Fatal within 1-3 minutes.

CO-H

5. https://www.co2meter.com/blogs/news/carbon-monoxide-levels-chart

In the U.S., the Occupational Safety and Health Association (OSHA) personal exposure limit (PEL) for CO is 50 parts per million (ppm) and exposure to more than 50 parts of CO gas per million parts of air averaged during an 8-hour time period is prohibited. The 8-hour PEL for CO in maritime operations is also 50 ppm. Maritime workers, however, must be removed from exposure if the CO concentration in the atmosphere exceeds 100 ppm. The peak CO level for employees engaged in short-term roll-on roll-off operations during cargo loading and unloading is 200 ppm.

As shown, standards are a bit tighter for entities governed by the National Institute for Occupational Safety and Health (NIOSH), which is the US federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. NIOSH recommends no more than 35 ppm time weighted average (TWA) exposure limit and no more than 200 ppm short-term exposure limit (STEL) for 15 minutes.

While short- and long-term carbon monoxide levels recommended by the organizations differ somewhat, there is consensus that…

- 9 ppm (parts-per-million) is the maximum indoor safe carbon monoxide level over 8 hours
- 200 ppm or greater will cause physical symptoms and is fatal in hours
- 800 ppm of CO or greater in the air is fatal within minutes

Personal protective equipment (PPE) in cases of CO exposure include a full-face piece pressure-demand self-contained breathing apparatus (SCBA) certified by the National Institute for Occupational Safety and Health (NIOSH), or a combination full-face piece pressure demand supplied-air respirator with auxiliary self-contained air supply[6].

6. https://cwa-union.org/national-issues/health-and-safety/health-and-safety-fact-sheets/carbon-monoxide-and-workplace

APPLICATION OVERVIEW

Carbon monoxide is present and/or produced in many industrial processes including metal manufacturing, electricity supply/power generation, mining metal ore and coal, food manufacturing, oil and gas extraction and refining, and production of chemicals, cement lime, plaster and concrete. It's also a significant hazard in mining, where it is known as "whitedamp" or the "silent killer" – it can be found in poorly ventilated areas in both surface and underground mines (of note, the low-temperature oxidation of coal can lead to CO being present even in less confined areas).

Let's take a look at two of these, steelmaking and refining of oil and gas.

CO -H

STEEL PRODUCTION

Steelmaking is a melting, purifying, and alloying process carried out at approximately 1,600°C (2,900°F) in molten conditions. Various chemical reactions are initiated throughout the process, either in sequence or simultaneously, and many of the chemicals, materials, or elements (such as fire) can or should interfere with one another. These interactions necessitate close monitoring of environmental conditions to ensure worker and asset protection. There are numerous toxic and combustible gas hazards present in steel production, including:

- CO
- CO_2
- Combustibles
- H_2S
- NH_3
- NO_2
- SO_2
- VOCs

A very important chemical reaction during steelmaking is the oxidation of carbon. Its gaseous product, carbon monoxide, goes into the off-gas and is eventually emitted out of the facility. CO is generated during the smelting process, where heat and chemical agents decompose the ore and leave the metal behind. Risky areas for CO exposure include blast furnaces, coke ovens, and boiler rooms, and many other work areas in steel plants involve working in and around confined spaces, such as tanks, furnaces, and pipes.

Only a few of breaths of CO can be enough to inflict permanent damage to the heart and nervous system or at high enough concentrations, even cause death. But while CO is one of the most prevalent gases in steel production, many others, including potentially hazardous gases such as carbon dioxide (CO_2) as well as explosive gases such as methane (CH_4) are also released.

While CO_2 is considered minimally toxic by inhalation, exposures above 10000 ppm can begin to have negative effects such as headaches and drowsiness and breathing oxygen-depleted air caused by extreme CO_2 concentrations (over 50000 ppm) can lead to death by suffocation. In the steel industry, CO_2 may be used as an inert gas in welding and fire extinguishers, as a pressurizing gas in air guns and oil recovery, and as a supercritical fluid solvent in supercritical drying.

This means that the atmosphere must be permanently monitored using highly reliable, durable, and precise gas detection devices for CO, CO_2, and any other gases that could cause even minimal harm. In the case of CO, as noted earlier, the simultaneous presence of hydrogen (H_2) can contaminate CO sensors and lead to false alarms.[7]

With methane and other explosive and highly flammable gases that are always present in some form in steel production facilities, it is important to ensure that oxygen levels are within safe parameters and also that gases with known explosive interactions amongst themselves are also carefully monitored and controlled to minimize fires and associated damages and injuries.

It should be noted that as climate considerations become more important, many steel-making facilities need to find ever-more efficient and cost-effective ways to “scrub” CO and CO_2 from their emissions. Equipment and processes to accomplish this require high-quality CO detectors as exposure is often to high concentrations on a continual basis and CO_2 detection may be more important as well since emission concentrations are likely higher in these applications.

One option that is being reviewed is so-called “green steel” manufacturing in which hydrogen replaces coal in the manufacturing process. The 2022 Inflation Reduction Act in the U.S. and additional infrastructure bills passed by Congress are seen as instrumental in exploring and implementing these innovative technologies[8].

7. https://www.britannica.com/technology/steel/Primary-steelmaking
8. https://www.marketplace.org/2023/05/22/the-steel-sector-is-carbon-intensive-green-steel-could-be-a-game-changer/

OIL AND GAS REFINING

As one of the biggest industries that involves combustion of fossil fuels as an actual product, it's easy to see why the oil and gas refining industry is a major producer of CO and therefore its presence in the workplace must be carefully monitored.

Products produced through oil and gas refining include gasoline, kerosene, liquified petroleum gas (LPG), distillate fuels, residual fuels, coke, asphalt, solvents, petrochemicals, lubricants – in other words, products that incorporate in many ways and are nearly ubiquitous in everyday life.

The largest sources of greenhouse gas (GHG) emissions at petroleum refineries, most of which include CO or other toxic gases to some degree, are stationary fuel combustion units such as steam boilers, process furnaces, and process heaters. Additional process emissions come from catalytic cracking units, fluid coking units, delayed coking units, catalytic reforming units, coke calcining units, asphalt blowing operations, heat exchangers, cooling towers, vacuum distillation units, blowdown systems, storage tanks, equipment leaks, compressor engines, loading operations, flares, and sulfur recovery plants.

As with steelmaking, the oil and gas refining process can also involve many chemicals. Common refinery chemicals include:

- Leaded gasoline additives
- Oxygenates
- Caustics
- Sulfuric acid and hydrofluoric acid

Again, as with steelmaking, the potential for chemical interactions is a constant source of potential hazards in oil and gas refining. The need to carefully monitor individual gases both for their individual toxicity as well as the potential for toxic or flammable interactions with other gases cannot be underestimated.[9]

Getting raw materials for oil and gas refining to the refinery and then out to customers after they have been rendered into saleable products presents another application for effective detection of CO and other toxic gases. As noted earlier, logistics such as barge or ship loading and gasoline loading racks specifically located at petroleum refineries represent potentially hazardous situations.

Hydrogen sulphide (H_2S), for example, is a potential problem in the transport and storage of crude oil as the cleaning of storage tanks is a highly hazardous process. Many confined-space entry problems can occur here, including oxygen deficiency from previous inerting procedures, rusting, and oxidation of organic coatings.

Inerting is a safety step that reduces the oxygen levels in a cargo tank to remove the oxygen element required for ignition, but carbon monoxide (CO is often present in the inerting gas. In addition to H_2S, depending on the characteristics of the product previously stored in the tanks, other chemicals that may be encountered include metal carbonyls, arsenic, and tetraethyl lead. All of these require careful monitoring to avoid toxic levels of concentration.[10]

Like steel-making, this industry is also being critically reviewed for its role in climate pollution and as such, the need to clean and/or reduce emissions is a high priority. As refineries work to develop new ways of handling their toxic waste products, the ability to manage those wastes through process improvements, will lead to the need for ever-more effective monitoring through the use of efficient gas-sensing devices to better protect both the environment and facility workers.

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9. https://www.epa.gov/sites/default/files/2016-11/documents/refineries_2013_112516.pdf

10. https://www.crowcon.com/blog/the-importance-of-gas-detection-in-the-petrochemical-industry/

OTHER APPLCIATIONS

The risk of carbon monoxide poisoning exists in many industries and applications, requiring early detection for worker safety. CO is used by the chemical industry, for example, for the synthesis of many compounds such as acetic anhydride, polycarbonates, and acetic acid. It is also used as a reducing agent in metallurgical operations, in the manufacture of metal carbonyls, and in organic synthesis. Carbon monoxide is also used in the manufacture of zinc white pigments.[11]

More Applications include:

- Warehouses
- Boiler rooms
- Pulp and paper production
- Loading docks
- Shipyards
- Blast furnace applications
- Welding
- Automotive repair garages
- Firefighting
- Carbon-black production
- Diesel equipment operation
- Refueling stations for aircraft and marine vessels
- Forklift and other material handling operations
- Marine terminal equipment
- Toll booth or tunnel maintenance
- Taxi operations (drivers, maintenance, garages)
- Vehicle occupations and operations (cars, trucks, boats, planes)
- Commercial restaurants or food processing (stoves, ovens, grills)
- Fireplace and furnace maintenance/repair
- Gas-powered portable generators maintenance/repair

11. https://www.ncbi.nlm.nih.gov/books/NBK153697/

CO-H

OUR SOLUTION HONEYWELL BW™ FLEX 4 SERIES

With a choice of 12 different sensor types, the Honeywell BW™ Flex protects workers from multiple gas hazards, in a small, rugged, and easy to use device. BW™ Flex keeps specialists operating in confined spaces, or general workers on a plant, safe from gas hazards while making safety compliance for the business easy.

For the detection of the most common gas hazards including: Flammable gas (LEL), oxygen (O_2), carbon monoxide (CO), hydrogen sulphide (H_2S), carbon dioxide (CO_2), sulphur dioxide (SO_2), chlorine (Cl_2), nitric oxide (NO), nitrogen dioxide (NO_2), and hydrogen cyanide (HCN)

WORK THE WAY YOU WANT TO

The IntelliFlash™ and ultra-bright alarm LEDs provide users an instant overview of the detectors status. Red for stop, amber as a warning, and green you're good to go, gives that simple view inexperienced users need. The display can also be configured to show all the gases at the same time or one at a time. Either way the operator gets all they need to know at a glance.

MORE GASES FOR MORE APPLICATIONS

Select up to 4 sensors from 12 different gas types. With common gases covered and a growing range of "exotic" sensors too, the Honeywell BW™ Flex can be used to protect workers in even more industries.

READY FOR THE CONNECTED FUTURE

Pairing the Honeywell BW™ Flex with your smart mobile device via Bluetooth™ allows remote measurement, field reporting of incidents, or even full instrument configuration and calibration. What's more everything is recorded for download when needed.

FEATURES

- **Reliable –** The Honeywell BW™ Flex can be used in potentiality explosive atmospheres. Indoor, outdoor, onshore or offshore
- **Advanced connectivity –** Using a smart mobile device or PC. operators can fully configure their device using Safety Suite solutions on iOS®, Android™, or Windows™ platforms
- **Easy to maintain –** The modular design makes service and maintenance easy. Compatibility with IntelliDoX automated test and calibration system, makes the routine efficient
- **Status at a glance –** The IntelliFlash™ status indicator enables quick visual compliance status checks in the field using an intuitive green, amber and red color coding
- **Responsive –** Offering instantaneous alarms, with time weighted average exposure levels (STEL/TWA), users are protected all round, from flammable, oxygen, and toxic gases
- **Easy to use –** The single pushbutton operation, intuitive user interface, and simple green/amber/red alarm system simplifies training and enables users to be up and running quickly

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