HONEYWELL BW™ FLEX 4 SERIES

A Guide to HCN Gas Sensing

Honeywell

HYDROGEN CYANIDE GAS SENSING

Hydrogen cyanide (HCN) is one of the most hazardous gases used throughout industries today. It not only causes serious internal organ damage if adequate protections are not provided, but exposure can be fatal. As such, accurately and reliably detecting its presence is critical in applications where it plays a role.

HCN

GAS OVERVIEW

Hydrogen cyanide (HCN), also known as prussic acid, is a colorless gas with a bitter, almond-like odor. It is extremely poisonous; exposure interferes with the body's use of oxygen and as a result may cause harm to the brain, heart, blood vessels, and lungs or even be fatal. As with most toxic gases, harm depends on the dose, duration, and work being done.

As a liquid, it boils only slightly above room temperature (25.6 °C or 78.1 °F, below which it is a pale blue liquid). Above that temperature, it exists in gaseous form, which is more toxic than solid cyanide compounds due to its highly volatile nature. It is weakly acidic and ionizes partially in water. The gas is lighter than air and rapidly disperses into the atmosphere; in air, it is explosive at concentrations above 5.6%.

Whether hydrogen cyanide is an organic compound or not is a topic of debate among chemists, and opinions vary. Commercially, HCN is produced by the reaction of ammonia, methane, and air over a platinum catalyst or from the reaction of ammonia and methane. HCN is also obtained as a by-product in the manufacture of acrylonitrile and may be generated as a by-product in a number of other manufacturing processes as well.[1] HCN is present too in vehicle exhaust and smoke from burning nitrogen-containing plastics.[2]

1. https://www.ncbi.nlm.nih.gov
2. www.britannica.com

WHY ARE DEDICATED HCN SENSORS IMPORTANT?

There is probably no more impactful way to emphasize why dedicated HCN sensors are critical wherever this gas is employed than to briefly describe how it has been used as a poison.

Hydrogen cyanide is highly toxic through inhalation, ingestion, or skin contact because it inhibits cellular oxidative processes. Most adults can withstand 50–60 parts of hydrogen cyanide per million parts of breathing air for an hour without serious consequences. Exposure to concentrations of 100–200 ppm in breathing air, however, will kill a human within 10 to 60 minutes and 200–500 parts per million of air for 30 minutes is usually fatal. At a concentration of 2000 ppm (about 2380 mg/m^3), death will usually result in just one minute.

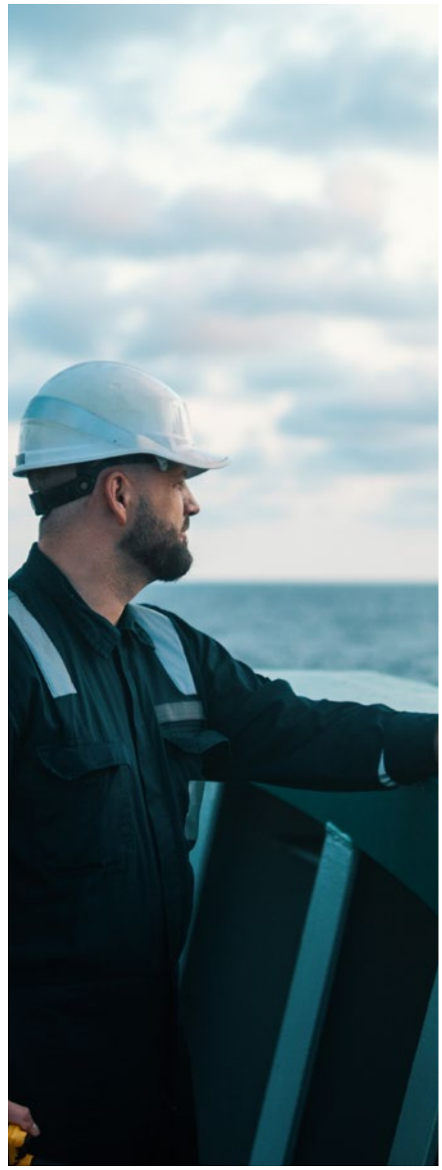
The time weighted average (TWA) for HCN as mandated by OSHA is 10 ppm, its lower explosive level (LEL) is 5.6 %, and is immediately dangerous to life or health. The airborne concentration value (IDLH) as developed by the National Institute for Occupational Safety and Health (NIOSH) is 50 ppm.

As it relates to other signage, warnings, and limits, the following is also applicable for HCN.

TABLE 1. REGULATION LIMITS

Limit/Level	Type	Organization
1.0 ppm	AEGL-1 (8 hrs)	EPA
2.5 ppm	AEGL-2 (8 hrs)	EPA
6.6 ppm	AEGL-3 (8 hrs)	EPA
10 ppm	TWA (8 hrs)	OSHA
4.7 ppm	ST	NIOSH

Source: EPA, NIOSH, and OSHA



HCN

APPLICATION OVERVIEW

HCN

MARINE ENVIRONMENTS

The marine industry is growing as more vessels enter the market every year. These ships transport vast quantities of hazardous materials, including highly regulated fumigation products and insecticides for food production. Stringent safety standards govern the industry, and marine workers need portable and fixed gas detection systems to help protect them from toxic and flammable gases in a wide variety of settings including merchant ships, ferries, Coast Guard vehicles, fishing boats, frigates, submarines, drill rigs, shipyards, and even some manufacturing facilities for products sold to these types of customer, such as lifeboat and fiberglass boat manufacturers.

Because of the tight quarters on most marine vehicles, internal ventilation is often relatively poor, making sensors important to warn against dangerous gas concentrations. Sewage and most waste products from cleaning or engine servicing are also often retained on board, resulting in a significantly increased risk of dangerous gas accumulation that can be exacerbated by bad ventilation. Besides protecting personnel, gas detection also protects onboard equipment and cargo.

In addition to frequently insufficient ventilation, marine environments are usually harsh, and gas detectors should have appropriate resistance against moisture and corrosion (fixed gas detectors are often stainless steel). Equipment is also subject to vibration[3].

Another challenge for instruments in marine environments is the fact that vessels can remain at sea for weeks at a time with limited or no access to spare parts or service support until their next berthing. As such, gas detectors for these applications need to be durable, reliable, and easy to maintain.

An everyday activity that exposes marine workers to the risk of toxic and flammable gases is confined space entry. Workers enter confined spaces, often around tanks, to perform routine tasks like inspection and cleaning. During this activity, they could be exposed to any of the gases listed below.

TABLE 2. COMMON MARINE GASES

Category	Gas	Sources	Potential Risk
Toxic	H_2S	Crude oil and petroleum products	Toxic to humans
	CO	Exhaust gases	Toxic to humans
	O_2	AEGL-3 (8 hrs)	Need a minimum level for breathing
	CO_2	Exhaust gases	Toxic to humans
	HCN	Fumigation	Toxic to humans
	PH_3	Insecticide	Toxic to humans
Flammable	Flammable gases	LNG, LPG, Natural gas, solvents	Fire or explosion
Toxic & Flammable	VOCs	Crude oil and petroleum products	Fire or explosion Toxic to humans

3. https://www.noventis.com.au/application-marine-gas-detection

Container vessels account for more than 3,000 of the marine vehicles and require several types of specialized gas detection sensors in addition to sensors that monitor other gases found on most types of vessels regardless of the vessel's purpose, such as the standard LEL and O_2 sensors to clean, repair and inspect the fuel and ballast tanks.

HCN is an important gas for several different types of gases encountered in marine applications, as there are often fumigants onboard container vessels so additional gas-specific sensors are needed to detect methyl bromide, phosphine, and a potentially broad range of other chemicals used to control pests or other cargo contaminants.

Fumigants can affect the commodity; or the nature of the commodity itself may affect the efficiency of a fumigant. Methyl bromide and phosphine may reduce seed viability, and methyl bromide can taint some products. Absorption of methyl bromide in oilseeds and other high oil content materials can reduce or even stop penetration of this gas into a bulk quantity of materials. In these conditions, hydrogen cyanide is the fumigant of choice for:

- Vertebrate pest control in enclosures (confined-space entry);
- Where a rapid treatment is required and germination must be preserved;
- Where a rapid treatment is required and the equilibrium relative humidity of the commodity is less than 60 % and methyl bromide may lead to taint or excessive residues.

In any fumigation operation, detection of gaseous concentrations is an essential prerequisite for both operational and safety reasons. Because HCN has minimal environmental impact compared to fumigants like methyl bromide or sulfuryl fluoride, when properly controlled it is often a fumigant of choice where environmental impact is important, including on marine vessels where onboard contaminants could be accidentally released into bodies of water.

Another primary application for marine gas-detection monitors is tank inspection. These confined-space tanks can be divided into four different groups:

- Cargo tanks (only on tankers and supply vessels)
- Slop tanks that carry water to clean the cargo tanks (only on tankers and supply vessels)
- Fuel tanks
- Ballast tanks that use seawater drawn from outside the vessel – and usually full of plants, mussels and even fish that will start to rot inside the tank

These tanks are generally being monitored for

- Sufficient oxygen
- Explosive gases
- Toxic gases based on the regulated limits

FIRE AND RESCUE

Another market where accurate HCN detection is critical is in fire and rescue operations. Because of building materials and materials used in home furnishings, the risk of poisoning associated with HCN-poisoning in fires that occur in closed spaces like buildings or mass transport has increased substantially.

CO (carbon monoxide) poisoning as a cause of serious poisoning or death in smoke-filled environments has long been recognized but beginning in the 1960s, HCN poisoning started to become a major cause of serious or fatal smoke inhalation victims. Unfortunately, firefighters are routinely exposed to dangerous levels of hydrogen cyanide at fires without even realizing it.

In addition to being present in fighting active fires, overhauling is a high-risk environment for HCN exposure. Overhauling is the late stage in a fire-suppression process during which the burned area is carefully examined for remaining sources of heat that may re-kindle the fire. This activity often coincides with salvage operations to prevent further loss to structures or their contents, as well as fire-cause determination and preservation of evidence.

During this stage of firefighting, there is no fire and little to no smoke in the environment, and firefighters are likely to work without their self-contained breathing apparatus (SCBA). In overhauling, the smoldering fumes of a recently controlled fire can be filled with dangerous and toxic gases and vapors that threaten the life and health of firefighters as they sift through piles of materials or take down rafters and walls to eliminate falling hazards.

As they do so, poisonous gases such as carbon monoxide, sulfur dioxide, hydrogen cyanide, nitrogen oxides, formaldehyde, benzene, and phosgene are released from the materials or are churned and become airborne particles that can be inhaled. Direct exposure to these dangerous aerosols and particles presents a real risk for immediate harm or acute and longer-term chronic health problems.

Two of these can be especially harmful when combined: HCN and CO. According to the NIOSH publication, “Preventing Fire Fighter Fatalities Due to Heart Attacks and Other Sudden Cardiovascular Events,” HCN is formed in a fire incident by incomplete combustion of any substance that contains carbon and nitrogen (both naturally occurring and synthetic), such as laminates, synthetics, foams, and plastics, as well as treated and untreated wood. It cannot be readily ascertained with a sensing device and although it can be relatively safe in non-gaseous form, when it heated it can become a lethal concern. It targets the central nervous system, cardiovascular system, thyroid, and the blood, causing firefighters to lose focus and become disoriented and agitated.

HCN

Carbon monoxide (CO), on the other hand, causes tissue hypoxia when inhaled and is also impossible to distinguish through human senses alone. When inhaled it prevents the blood from carrying sufficient oxygen and can cause dizziness, nausea, headache and, at higher concentrations, convulsions, tachycardia and death from suffocation.

Breathing these gases together is one reason firefighters can suffer further harm when they take off their masks once they’re out of air from their SCBA or if they feel they’re out of immediate danger from active flames. When inhaled together, the synergistic effect of these so-called “toxic twins” can cause even more harm than concentrations of either toxicant alone:

- HCN is 35 times more toxic than CO
- HCN can enter the body by absorption, inhalation, or ingestion and targets the heart and brain
- HCN often incapacitates the victim within a short period of time
- HCN is again produced after the flame is out and the materials continue to off-gas when no smoke may be visible

HAZMAT

As reviewed earlier, HCN can be present in a wide variety of situations, both fire-related and otherwise. HCN has been known to be used in terrorist attacks on food, water, and environmental resources as well as in direct contact with targeted victims. Since the gas is very hard to accurately detect without specific sensors, most hazardous materials (HAZMAT) training programs recommend that such sensors are readily available in HAZMAT response vehicles.

Personal protective equipment is also required to combat harm from HCN gases in HAZMAT incidents. PPE is rated from A to D in terms of protection levels, with A being the highest and most dangerous. HCN exposure has an A rating, requiring that first responders wear a completely encapsulated suit with respiratory protection provided by a positive-pressure self-contained breathing apparatus[4].

Anyone whose clothing or skin is contaminated with cyanide-containing solutions can secondarily contaminate response personnel by direct contact or through off-gassing vapor. This applies to potential victims as well as first responders, who operate on the principle that a person exposed to a lethal amount of cyanide will die within 5 to 10 minutes of exposure. Because it can be difficult to clearly identify when first exposure occurred, confirming the presence of HCN via reliable sensors is critical to quick response and positive health outcomes.

Sensors are also important in decontamination efforts to ensure that victims and responders are cleared of any lingering traces of HCN[5].

4. https://remm.hhs.gov/ppe_classification.htm
5. https://chemm.hhs.gov/cyanide_prehospital_mmg.htm
6. https://www.firehouse.com/tech-comm/atmospheric-monitoring/article/21274295/oxygen-and-lel-metering-by-firefighters

Don’t forget oxygen!

The need to accurately measure oxygen levels in firefighting applications – and fire prevention applications too – is also clearly important. As threats to first responders have increased with the amount and variety of chemicals they encounter when fighting fires, the ability to detect the gases produced by those chemicals has also increased.

The most common sensor configuration of a four-gas meter is oxygen, lower explosive limit, carbon monoxide, and hydrogen sulfide. The oxygen sensor is arguably the most important because sensor readings are based on normal oxygen levels in clean air.

Most oxygen sensors have two alarms: low (19.5 %) and high (23.5 %). These alarm levels are considered IDLH (immediately dangerous to life and health) atmospheres and even at low, SCBAs should be worn to protect against possible toxicity, flammability or hypoxia hazards. At 23.5 %, there’s also an increased fire risk.

Firefighting gas detection equipment also includes LEL sensors, which usually use a catalytic bead technology, to alert to the presence of methane[6].

Preventing fires in the first place is also a role for oxygen sensors. Oxygen-deficiency is a threat to life, leading to unconsciousness and death. In industrial locations where nitrogen or other inert gases are in use, undetected gas leaks can displace oxygen from the air, resulting in respiratory difficulty.

However, in areas where pure oxygen is used, an oxygen leak is equally dangerous. As the percentage of oxygen in air increases above the normal 20.9 %, the air is said to be enriched, which can cause fires burn hotter and more readily than normal, including causing many materials to burn with almost explosive force.

Related to these two potential problems, oxygen reduction systems represent a fire prevention technology used with increasing frequency, particularly in information technology (IT and server rooms), warehouses (including small-load carrier, hazardous material and deep freeze stores) and archives. These systems reduce the oxygen content of the air to levels that will prevent the outbreak of fire, based on the materials being stored or the equipment being protected.

METAL ORE REFINING

As the demand for metals has increased with the demand for new types of batteries for applications like solar power stations and electric vehicles, mining companies are finding new ways to get more metals out of "old" mines. Rather than extracting metals from tons and tons of rock, biomining is much more efficient, cost-effective, and when done properly, less invasive for the environment.

This is where cyanide comes into play, because of its ability to bond well with gold and a wide variety of other metals as well. It is one of the main substances used in a process called cyanide leaching or cyanidation.

The use of cyanide to chemically extract metals from rock has proven to be both commercially acceptable as well as cost-effective. As might be expected, though, safety is critical when working with the types of chemicals that are required.

These operations depend on effective gas sensors, particularly hydrogen cyanide (HCN), for safe, ongoing operation. In leaching, the alkaline cyanide solution used in this extraction method is stable and generally safe. However, if the solution's pH drops below a certain point, it can emit HCN.

As described earlier, HCN can cause death by asphyxiation. The severity of the reaction depends on the exposure time as well as the concentration of HCN. In addition to potentially fatal consequences, long-term effects are also possible, including chronic headaches, ongoing weakness, permanent changes in taste and smell, and continual eye and throat irritation, vomiting, abdominal colic, excessive salivation, nervous instability, and thyroid gland swelling.

Confined spaces without adequate ventilation, which can be common in mining and mining-related operations, are often risk areas and require continuous HCN gas detection. High-risk zones of HCN release can also be monitored to warn the staff of potential hazards before entering a specific area in order to increase their awareness of danger and improve use of protective personal equipment (PPE) where appropriate.

While the smell of hydrogen cyanide can be detected from 0.58 ppm – which is lower than the ceiling value (10 ppm), the IDHL (50 ppm) and the LEL (5.6 % or 56,000 ppm) – not all people can detect it and using human smell as the only detection for HCN is both unreliable and irresponsible. Only by using quality HCN sensors can operations ensure that they are relying on the best possible HCN detection technologies[7].

Best practices in cyanide usage are regulated by "The International Cyanide Management Code" with a goal of protecting mine workers as well as the flora and fauna of mining environments. There are multiple steps in the process outlined in the code ranging from handling and storage all the way through mine decommissioning[8].

Another relatively new method of extracting metals that are commonly bound up in solid minerals uses the concept that some microbes (microorganisms) can oxidize those metals, allowing them to dissolve in water to make them more easily recoverable than trying to extract them from solid rock. Another biomining technique for metals which are not dissolved by microbes uses microbes to break down the surrounding minerals to recover a metal directly from the remaining rock. Biomining is also used to clean up sites that have been polluted with metals.

HCN

7. https://www.spi.com/en/blog/respiratory-protection/mining-gas-detectors-protection-against-no2-and-hcn?setContextLanguageCode=en
8. https://www.sciencedirect.com/science/article/abs/pii/S016745280515008X

Most current biomining operations target valuable metals like copper, uranium, nickel, and gold that are commonly found in sulfidic (sulfur-bearing) minerals.

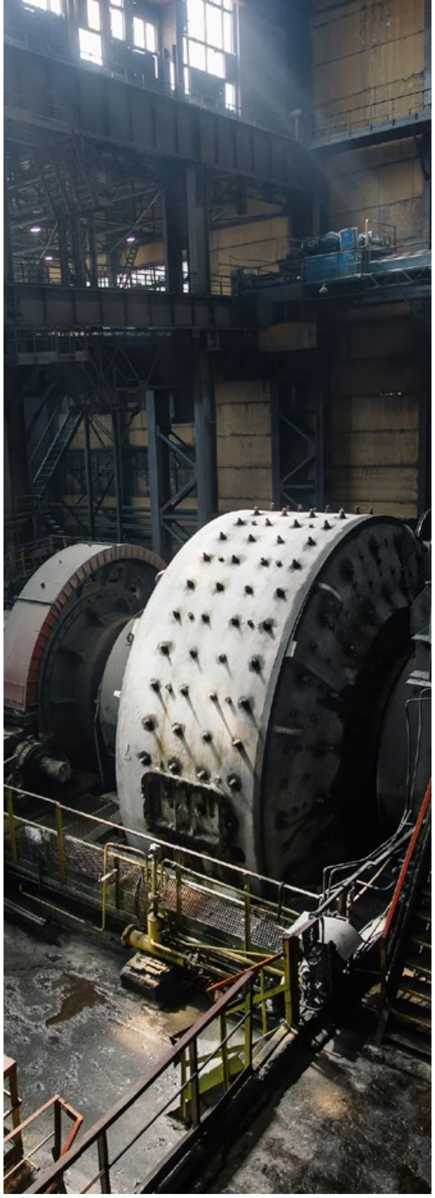
The most common processes used in biomining are:

- Heap leaching: freshly mined material is piled into heaps that are then bioleached
- Dump leaching: low-value ore or waste rock is placed in a sealed pit and then bioleached to remove valuable metals from the waste
- Agitated leaching: crushed rocks are placed into a large vat that is shaken to distribute the microbes and material evenly and speed up the bioleaching process

Leaching times vary from days to months, making this process slower than conventional mining, and most current biomining operations use naturally occurring microbial communities, making environmental risks relatively small.

Just because the leaching is being done with microbes instead of chemicals does not mean that effective sensing of off-gases is not needed or important: depending on the type of metal being leached, the type of rock in which it exists, and the biological process(es) that occur when the two are put together, appropriate sensing is still important for worker safety as well as ensuring efficiency and environmental protection.

Biomining is currently only a small part of the overall mining industry, but it is growing. Worldwide, 10-15 % of copper is extracted using bioleaching. Biomining is also important in the gold industry, where roughly 5 % of global gold is produced using bio-oxidation[9].



HCN

OTHER APPLICATIONS

Hydrogen cyanide and its compounds are used for many other chemical processes beyond those outlined here, including:

- Fumigation in other industries beyond marine operations
- Case hardening of iron and steel
- Electroplating
- Preparation of acrylonitrile, which is used in the production of acrylic fibers, dyes, synthetic rubber, and plastics
- Insecticide production
- Jewelry making
- Photographic processes
- Agricultural applications

9. (https://www.americangeosciences.org/critical-issues/faq/what-biomining

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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