Carbon monoxide: Creeping killer caught in the act

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People have known for centuries that carbon monoxide is life-threatening. Even today, thousands of people are killed by carbon monoxide incidents every year. Carbon monoxide prevention remains important, especially now that houses are better insulated for energy saving purposes. A carbon monoxide detector is an important tool in this respect, provided that detector is of good quality and meets the applicable requirements. And that is where independent testing, inspection and certification specialist Kiwa comes in.

If a thermal combustion is incomplete, for example if a gas appliance does not function properly, this can lead to the release of carbon monoxide (CO). When inhaled, carbon monoxide attaches to the oxygen transport protein haemoglobin in red blood cells, displacing oxygen. Because it attaches to haemoglobin much better than oxygen even a low concentration of carbon monoxide in the air can cause a relatively large concentration in the blood, causing poisoning or even death.

Over a million CO incidents per year

Although almost everyone knows that the invisible and odourless carbon monoxide can be life-threatening, CO incidents still occur on a daily basis. According to the Institute for Health Metrics and Evaluation (IHME) of the University of Washington in Seattle (USA), there are over a million cases of carbon monoxide poisoning worldwide every year, causing over 35 thousand deaths. Carbon monoxide is often referred to as a 'creeping killer' who can strike anytime, anywhere, as is illustrated by this first hand report from the Netherlands.

'Happy to retell it'

'My wife didn't feel well in the afternoon and went to bed. When I got home from work I put the children to bed, and there was nothing wrong. When I was watching football afterwards, I suddenly heard a dull bang. It turned out to be my daughter, who had fallen out of bed. When I got upstairs, it turned out that she had passed out. I picked her up, and she started throwing up. Meanwhile, my wife was still asleep. That's why I immediately said to my eldest daughter: get grandpa and grandma!'

'My parents, who live nearby, arrived and suspected there was more to it. That is why they called the emergency telephone number. The paramedics had a detector and immediately saw that it was carbon monoxide. They evacuated everyone and put them on oxygen. My wife was transported to hospital. For hours my wife fought for her life. We lived in uncertainty for about eight hours. In the meantime, we had no idea how she would wake up. Neither did the doctors.'

'In the end it all worked out. Nevertheless, our daughters are still bothered by that evening in October. My middle daughter has seen her mother being taken away and her youngest sister unwell. We have now hung up extra detectors to regain trust and we talk about it a lot. Soon afterwards I was asked by a friend of a fire chief to speak at a meeting about carbon monoxide poisoning. Many people ask if it doesn't annoy me to tell the story every time. But I'm happy I can retell it at all!'

Acute and chronic CO poisoning

A distinction is made between acute and chronic carbon monoxide poisoning. Acute carbon monoxide poisoning is caused by short-term exposure to a high concentration of CO. Chronic poisoning is caused by repeated or prolonged exposure to lower concentrations of carbon monoxide. The symptoms of mild poisoning are similar to those of other illnesses, such as the flu or food poisoning. As a result, mild carbon monoxide poisoning is easily overlooked.
A chronic poisoning, just like a mild acute poisoning, is difficult to recognise. The symptoms of chronic poisoning vary from physical complaints, such as headache and nausea, to psychological complaints such as confusion and psychosis. With repeated exposure, the symptoms get worse. The patient may become confused, often in combination with dizziness and balance disorders. Over time, serious symptoms can arise, such as character changes.

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Eventually a progressive mental decline with apathy ensues. Repeated fainting or short-term coma can also occur in severe chronic carbon monoxide poisoning. Young children who suffer from chronic CO poising can experience functional and developmental defects.

From caveman to canary

Without realising it, prehistorical humans probably 'discovered' carbon monoxide poisoning when they introduced fire into their dwellings. But it was Greek philosopher and scientist Aristotle who first recorded that burning coals produced toxic fumes. In years to follow Aristotle's fellow countryman and colleague Galen stated there was a 'change in the composition of the air that caused harm when inhaled' and other Greek and Roman scientists denoted similar toxicity symptoms. It is even said that famous Egyptian ruler Cleopatra may have died from carbon monoxide poisoning. Using CO for deliberately killing oneself or one's enemy also dates from Roman times. According to scholars like Livius and Cicero carbon monoxide was often used as a method of suicide in ancient Rome and emperor Lucius Verus executed prisoners by suffocating them with smoke.

Evil demons

Despite the ancient Greek and Roman knowledge of the toxicity of carbon monoxide, in the fifteenth and sixteenth century CO poisoning was often related to witchcraft and the paranormal. Medieval coal miners for example rather linked sudden death in the mines to evil spirits than to leakage of carbon monoxide from coal. It was not until 1716 that the first modern scientific investigation into CO poisoning by coal was carried out by German physician and chemist Friedrich Hoffmann, ending villagers claiming carbon monoxide casualties where the work of evil demons. That CO poisoning is dose-dependent was thoroughly investigated by several scientists in the end of the eighteenth century and the first controlled clinical trial studying CO toxicity took place in 1973.

Early warning system

As mentioned, in coal mines in particular CO poisoning was a serious plague for many centuries. Scottish scientist John Scott Haldane did a lot of research in this area. He investigated many mining disasters and in 1911 was the first to help miners detect dangerous CO levels underground by introducing small animals in the pit. Haldane discovered that because of their faster metabolism white mice and canaries had little tolerance for CO. The infamous canary in the coal mine served as an early warning system for over 75 years in British coal mines before it was replaced by a the electronic gas detector. But CO poisoning risks are still a part of daily reality in many coal mines around the world, as recent accidents in for example China and Turkey prove.

Carbon monoxide detectors

In residential homes and public and commercial buildings, the best way to prevent carbon monoxide poisoning is of course to make sure combustion appliances like central heating and hot water supply systems function properly. Home and building owners or housing associations should see to regular check-ups and maintenance of the appliance itself, the air inlet and the flue gas outlet. If things do go wrong, it is of vital importance to have a reliable warning system such as the electronic – optical or chemical - carbon monoxide detector. The purpose of a CO detector is to monitor the CO concentration in the air and to give an alarm signal when the carbon monoxide concentration exceeds a certain threshold for a certain time.

CO detector criteria

To be reliable, a CO detector must have certain properties:

- An efficient CO detector does not give an alarm at very low concentrations of CO, as can be the case in an environment where people are smoking, but does warn in time so that the victim is still able to react, before muscle weakness and loss of consciousness occur.
- The CO detector must not be sensitive to substances other than CO. A carbon monoxide detector works on the basis of an electrochemical cell. This cell can also be sensitive to substances other than CO, for example to solvents, which will cause the alarm to go off incorrectly.
- It must be guaranteed that the detector will continue to function properly over time, despite the presence of dust (laundry room), grease (kitchen), moisture (bathroom), intense heat (for example close to a coal stove) or large temperature fluctuations such as in the basement or attic.
- A CO detector should not only give a sound signal when the battery is flat, but also in the event of a short circuit, contamination of the cell or when the device needs to be recalibrated or replaced.
- When installing smoke detectors in addition to CO detectors, a clear distinction must be made between the sound signals of both devices. The measures to be taken are completely different: with a CO alarm, one should open the windows and ventilate as much as possible, while with a smoke alarm, ventilation should be avoided so as not to fan the flames.

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How does a CO detector work?
In most domestic carbon monoxide detectors the CO sensor consists of a gel. This gel contains sulfuric acid as an electrolyte, among other things. If the sensor in the carbon monoxide detector is exposed to higher concentrations (indicated as PPM, parts per million) of carbon monoxide than normally found in a household, a chemical reaction begins, triggering the alarm.

CO detector quality standards
Carbon monoxide detectors are complex devices that are produced by numerous manufacturers in numerous qualities. Because such a detector can literally be a matter of life or death, it is crucial the device complies with certain quality standards. Such standards are the EN 45544 series, the IEC 62990-1 and the EN 50291 (and the additional EN 50292). The EN 50291 describes test methods and performance characteristics for electrical equipment for the detection of carbon monoxide in residential buildings. The EN 50292 provides guidance for the selection, installation, use and maintenance of electrical equipment for the detection of carbon monoxide in residential buildings. Currently manufacturers of CO detectors are not obligated to certify their products against these standards. However, certification does guarantee a device is safe and reliable which helps manufacturers to stand out against their competition.

EN 50291 technical safety aspects
The quality standard EN 50291 describes a number of technical safety aspects:

- The sensitivity at CO concentrations 30, 50, 100 and 300 parts per million (PPM):
  - At 30 PPM, the detector should not alarm within 120 minutes;
  - At 50 PPM, the detector should respond between 60 and 90 minutes;
  - At 100 PPM, the detector should respond between 10 and 40 minutes;
  - At 300 PPM, the detector should respond in less than 3 min.
- Recovery from exposure to 5000 PPM to normal functionality;
- The sensitivity at different CO concentrations at both low and high temperature and varying humidity;
- The sensitivity to interfering gases (such as CO_2, H_2 and NO).

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How is a CO detector tested?

A CO detector's functioning and reliability naturally depends to a large extend on the construction quality and the components used. Manufacturers of carbon monoxide detectors who want to create trust in their products and make sure they meet applicable quality standards can put their detectors to the test at a specialised laboratory. Kiwa's Fire Safety and Security Products lab in Apeldoorn, the Netherlands is an ISO 17025 accredited laboratory where CO detectors can be assessed against, among others, the standard EN 50291.

Test	
Unpowered storage	Construction
Drop test	Transmittable output signal
Alarm Conditions	Alarm during warm up time
Temperature effect	Humidity effect
Speed of test gas	Supply voltage variations
Electromagnetic compatibility	
Response to mixtures of carbon monoxide and other gases	
Response and recovery to a high CO volume ratio	
Effects of other gases	Long term stability
Battery fault warning	Alarm sound level
Battery capacity	Battery reversal
Battery connections	Inter-connectable apparatus
Back-up power source	Stability in high humidity test
Stability to low humidity test	Unpowered storage
Unpowered storage	Apparatus using radio links

Extensive test program

To have their products tested and certified by Kiwa against the EN 50291, CO detector manufacturers send samples of their product to Kiwa's Fire Safety and Security Products lab. The extensive EN 50291 test program consists of several types of tests that have to be performed on several samples, to provide results that are representative for an entire product range. Besides, some of the tests are more or less destructive to the sample. That is why manufacturers usually provide Kiwa with about fifteen specimen of the same product.

Climate chamber

As soon as the samples arrive at the lab, Kiwa's testing experts determine the type of CO detector and its operating requirements. Is the detector battery of power grid driven? Is it a stand-alone type or is it an inter-connectable device supposed to be part of a linked network of similar sensors? Then the test program kicks off. To begin with, Kiwa's testing engineers check the detector's construction, components and power supply. In a specially designed climate chamber they also test the sensor's sensitivity to the different CO concentrations, under different climatological circumstances (e.g. humidity, temperature).

Speed of gas test

One aspect related to gas detectors that is mentioned in various standards concerns the effect of air speed on the performance of a detector. This also applies to CO detection based on EN 50291-1. Draft and other movements of gases can affect the way a gas concentration, such as CO, is dis'tunnel', gas detectors can be tested under various gas velocities and sensor orientations.

The flow-through chamber at Kiwa's Apeldoorn location is a distinguishing extra when it comes to CO detector testing. However, its design serves a much broader purpose. The setup is an integral part of the testing process for a wide variety of standards like the EN IEC 60079-29-1 (flammable gases), the EN IEC 62990-1 (detectors for toxic gases), the EN 50104 (oxygen), the EN 45544-1 (toxic gases and vapors), the EN 50545 (toxic and combustible gases in car parks and tunnels) and the EN 54-31 (multi-sensor fire detectors).

Constant awareness

If a CO detector passes all required tests the manufacturer is allowed to put it on the market with a 'EN 50291 proof' quality mark. The buyer of such a device can be sure the CO sensor is of good quality and is made to live up to the strict requirements of the EN 50291. But even then constant awareness is required. A certified detector will let you know loud and clear when battery life is ending, but as with smoke detectors, it is also necessary to check CO detectors regularly. If you push that 'test' button once a month, you can be sure of a well-functioning CO warning system. And that is still one of the best methods around to catch the creeping killer in the act and preventing it from affecting what matters most to you.

More information

For more information on Kiwa's services in the field of toxic gas detector testing, please mail Kiwa FSS Products at **nl.kiwa-fss@kiwa.nl** or contact **Henry Rutjes**:
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