A P P L I C A T I O N S   G U I D E

System-Connected Carbon Monoxide Detectors

SYSTEM SENSOR®

System-Connected Carbon Monoxide Detectors

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Preface

The use of early warning carbon monoxide (CO) detectors can result in a significant reduction of CO-related poisonings and death. Furthermore, system-connected, monitored carbon monoxide detection provides an extra level of protection for building residents or occupants who cannot appropriately respond to a local CO detection alarm. The sooner occupants and authorities are notified of dangerous CO levels in a given environment, the better the outcome for avoiding serious injury or death. This document provides guidance for the proper operation of system-connected CO detectors.

Correct installation and maintenance of CO detectors helps prevent unwanted alarms and ensures proper functioning of devices. The latest generation of CO detectors, when installed and maintained properly, significantly limits the nuisance alarms that initially desensitized occupants when repeated nuisance alarms occurred in earlier-generation CO detectors. Today's CO detection devices are effective, trustworthy, and the only means to detect the odorless, tasteless, and deadly carbon monoxide gas.

Introduction

The purpose of this guide is to provide information on the proper application of system-connected carbon monoxide (CO) detectors in ordinary indoor locations (not to meet outdoor EPA or indoor OSHA requirements*). The guide outlines basic principles and standards that should be considered in the application of early warning CO detection devices in relation to the characteristics and effects of CO gas.

Section 1

Codes and Standards That Apply

International Code Council (ICC)
The ICC publishes numerous codes used to construct all residential dwellings and commercial buildings. A code specifies WHEN, what type of CO detection is required and the location of CO detectors.

National Fire Protection Association (NFPA)
Batterymarch Park
Quincy, MA 02269-9101

NFPA publishes standards for the proper application, installation, and maintenance of CO detection. NFPA 720-2015 is the *Standard for the Installation of Carbon Monoxide (CO) Detection and Warning Equipment*. A standard specifies HOW carbon monoxide detection and warning equipment is to be installed, tested, maintained and monitored.

Section 1.1.1 is primarily concerned with life safety, not with protection of property.
Section 1.1.2 covers the selection, design, application, installation, location, performance, inspection, testing, and maintenance of CO detection and warning equipment in buildings and structures.
Section 1.1.3 contains requirements for the selection, installation, operation, and maintenance of equipment that detects concentrations of CO that could pose a life safety risk to most occupants in buildings and structures.[1]

Highlights of the new standards, which should be reviewed in their entirety before specifying or installing CO detectors, follow. NFPA 720-2015:

- Nationally standardizes CO detection for all buildings, not just residences. This includes schools, hotels, nursing homes, apartment buildings and other commercial structures.

- Requires CO alarm signals to be distinct and "descriptively annunciated" from fire alarm, CO supervisory, and CO trouble signals. Furthermore, the CO alarm signal should take precedence over supervisory or trouble signals. CO detector trouble signals must be indicated visually and audibly at the control panel and supervising station. Therefore, the CO detector must have a means to signal the panel upon trouble conditions. For example, hardwired detectors require an integral trouble relay to send the trouble signal to the panel.

- Now holds CO detectors to the same life safety standard as smoke detectors: They will send trouble signals to the control panel and facilitate wiring supervision.

- Defines CO detector location more specifically than ever. In commercial buildings, CO detectors need to be located on the ceiling in the same room as permanently installed fuel-burning appliances. They also need to be centrally located on every habitable level and in every HVAC zone of the building. In dwelling units, CO detectors must be installed outside each separate sleeping area and on every level of a dwelling unit, including basements. Applicable laws, codes, and standards may require additional locations.

- Requires CO detection systems to have sufficient secondary power to operate the system under quiescent load (system operating in normal condition) for at least 24 hours. After that time, the system must operate all of the CO notification appliances for 12 hours if a supervising station does not monitor the system. If monitored by a supervising station, the 12-hour requirement can be reduced to 5 minutes.

- Includes CO detector testing requirements. However, the requirement to be able to functionally test the CO detector in a manner similar to testing smoke detectors with canned smoke. Note that the System Sensor CO1224T with RealTest® meets this testing requirement.

- CO detectors shall be replaced when the end-of-life signal is activated, the manufacturer's replacement date is reached, or when they fail to respond to operability tests.

- Clarifies what supervising stations should do when they receive a CO alarm signal. If the communications methodology is shared with any other usage, all fire alarm, CO alarm, supervisory, and trouble signals will take priority, in that order of priority, over all other signals unless otherwise permitted by the AHJ.

- The integral sounder of a CO detector may be sufficient for notifying occupants of commercial and residential buildings. It allows occupant notification to be limited to the notification zone encompassing the area where the CO signal is originated, if the CO alarm signal is transmitted to a constantly attended onsite location or off-premises location.

Testing Laboratories

Testing laboratories test smoke detectors, CO detectors, control panels, and other components of fire alarm systems to verify conformance with NFPA requirements and their own standards. Equipment that passes their tests is identified by a label and/or listing.

Underwriters Laboratories, Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062

455 E. Trimble Road
San Jose, CA 95131

1285 Walt Whitman Road
Melville, NY 11747

12 Laboratory Drive, P.O. Box 13995
Research Triangle Park, NC

2600 N.W. Lake Road
Camas, WA 98607

1. National Fire Protection Association (NFPA). "NFPA 720: Standard for the Installation of Carbon Monoxide (CO) Detection and Warning Equipment: Document Scope." NFPA.org. http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=720&cookie_test=1#.

* See page 7 for information on CO for worker safety.

The following UL standards apply to CO detectors:

ANSI/UL 2075 is the product standard for CO detectors connected to a control panel via conductors or low-power radio frequency (wireless).

ANSI/UL 2034 is the product standard that covers self-contained CO alarms that are not designed or listed to be connected to a control panel.

It is important to note that the alarm thresholds of UL 2034 CO alarms and UL 2075 CO detectors are the same. Section 15.1 (b) of UL 2075 requires detectors to operate within the sensitivity parameters defined by UL 2034. Table 38.1 of UL 2034 defines the actual alarm thresholds, which are:

- 30 ppm no less than 30 days
- 70 ppm 60 to 240 minutes
- 150 ppm 10 to 50 minutes
- 400 ppm 4 to 15 minutes

Section 2

Carbon Monoxide Overview

Carbon monoxide (CO) is an odorless, tasteless and highly toxic gas that results from the incomplete combustion of fossil fuels. It is often referred to as "the silent killer" because it is virtually impossible to detect without sensing technology. On average, from 2004 to 2006, over 20,000 people per year visited emergency rooms after accidental, non-fatal CO exposures.2 From 1999 to 2004, an average of 439 people died from accidental CO exposure.[3]

What is CO?

The CO molecule is made up of a carbon and an oxygen atom. CO has a density similar to air, but typically rises from the point of production due to the heat of combustion. As it cools to environmental temperatures, however, it circulates in the same manner as ambient air.

How CO Affects the Human Body

Through the normal process of respiration and circulation, oxygen molecules enter the lungs and are transported to cells throughout the body by attaching to hemoglobin in the blood. CO molecules, however, attach to hemoglobin far more readily than oxygen. When CO is present in the environment, these molecules interfere with the normal circulation of oxygen throughout the body by attaching to hemoglobin that would normally transport oxygen. (See Figure 1.) This can cause varying levels of injury and sickness, depending on length and level of exposure.

CO poisoning can result from prolonged exposure to low levels of CO or shorter exposures to higher concentrations. Table 1 shows the relationship between CO volume, length of exposure, and resulting symptoms to a person within a given environment.

Common Sources of CO

CO is formed from the incomplete combustion of fossil fuels. The operation of many common appliances, machinery, and heating equipment, if not working or vented properly, can result in dangerous CO build-up in a given environment. According to recent studies, the primary sources for CO fatalities are:

- Heating systems
- Power tools
- Charcoal grills or other charcoal sources
- Gas ranges or ovens
- Camp stoves or lanterns
- Other or multiple appliances

From 2004 to 2006, the top two sources for non-fatal, accidental CO exposures in the U.S. were home heating systems (16.4 percent) and motor vehicles (8.1 percent).[2] Other common sources of CO in and around the home include:

- Stove/gas ranges
- Gas line leaks
- Gas water heaters
- Blocked or clogged chimneys
- Gas or wood burning fireplaces
- Cracked heat exchangers
- Leaking, cracked, corroded, or disconnected flue or vent pipes
- Barbecue grills operated in enclosed areas, such as a garage
- Unvented gas space heaters

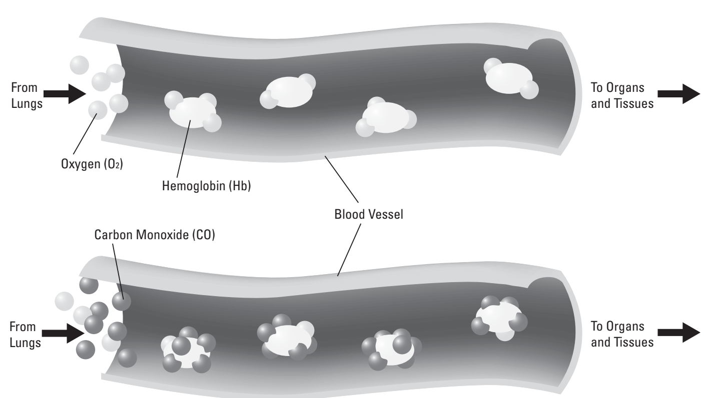

Figure 1. Carbon monoxide in the bloodstream

2. CDC. Unintentional non-fire-related carbon monoxide exposures in the United States, 2004-2006. MMWR 2008;57:896-899.
3. CDC. Carbon Monoxide-Related Deaths — United States, 1999-2004. MMWR 2007;56:1309-1312.
4. NFPA 720, 2012 edition, Annex B Dangers of Carbon Monoxide, B.1 Carbon Monoxide, Table B.1 Symptoms of Carbon Monoxide Exposure Based on Concentration.

CO Concentration in Parts Per Million (PPM)	Symptoms
50	No adverse effects with 8 hours of exposure
800	Headache, nausea, and dizziness after 45 minutes of exposure; collapse and unconsciousness after 2 hours of exposure
1,000	Loss of consciousness after 1 hour of exposure
6,400	Headache and dizziness after 1-2 minutes of exposure; unconsciousness and danger of death after 10-15 minutes of exposure

Table 1. Symptoms of carbon monoxide exposure[4]

Section 3
How Carbon Monoxide Detectors Work

Carbon Monoxide (CO) detectors are devices that monitor the amount of CO in the air over a given time period. Distinguished by their sensing technology, three basic types of CO detectors are used today: biomimetic, metal oxide semiconductor, and electrochemical.

Biomimetic CO Detector Operation

Biomimetic CO detectors mimic how hemoglobin in biological organisms reacts to CO. Specifically, a biomimetic sensor monitors infrared light that is passed through a disc of synthetic hemoglobin that darkens in the presence of CO. Thus, as CO concentrations increase, the light is obscured, triggering the alarm.

Sensor Technology	Advantage	Disadvantage
Biomimetic	– Low cost	– High false alarm rate – Long recovery after alarm
MOS	– Long life span	– High current draw – Expensive – Non-selective; sensitive to chemicals and gases other than CO
Electrochemical	– Reliable, few field defects	– High sensitivity to ammonia-based cleaners

Table 2. Comparison of carbon monoxide detection technologies

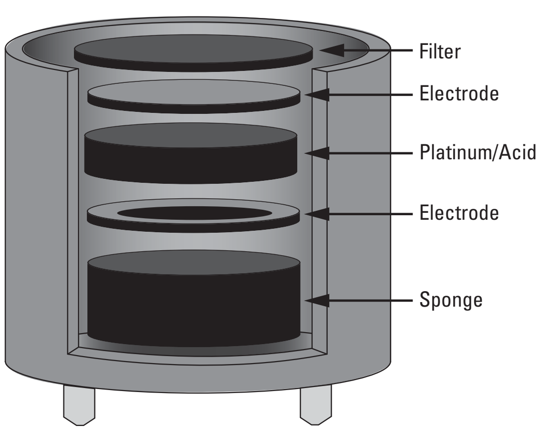

Figure 2. Cutaway view of an electrochemical CO sensor cell

Biomimetic detectors are low cost and require a low current draw to operate. However, these detectors are susceptible to false alarms if environmental conditions fluctuate outside peak operating ranges. Other types of sensors are much more reliable. Furthermore, biomimetic sensors have a shorter life than other types of CO sensors and they require a long recovery time after alarm.

Metal Oxide Semiconductor CO Detector Operation

With metal oxide semiconductor (MOS) detector technology, a tin dioxide semiconductor is heated by an electric current at periodic intervals. When tin dioxide reaches its operating temperature, it is capable of changing its resistance in the presence of carbon monoxide. Once the resistance change reaches its threshold, an alarm sounds.

MOS detectors have a long life span and can respond quickly to CO. However, they are more expensive to purchase and operate than other types of sensors. Because it uses an electrical current to heat the semiconductor, this type of sensor requires a high current draw. Furthermore, MOS detectors are susceptible to false alarms in the presence of some common household chemicals or gases other than CO.

Electrochemical CO Detector Operation

Electrochemical sensors use a platinum electrode and acid combination to promote a reaction between CO and the oxygen in the air, which then produces an electric current. When CO is present in the air over time, if the current increases beyond specific thresholds, the alarm is sounded.

CO detectors using electrochemical sensors have been in use in industrial applications for many years. These detectors are reliable, with few field defects, have a low current draw, and respond quickly to CO. However, they may be susceptible to false alarm in the presence of household cleaners that contain ammonia, such as glass cleaners.

The life of the electrochemical sensor is typically longer than that of biomimetic sensors. All CO detectors need to be replaced at the end of their sensors' lives.

Limited Life of System-Connected CO Detectors

All system-connected CO detectors on the market have a limited-life gas sensor and UL requires that CO detectors be replaced at the end of that component's life. Therefore, it is imperative that the gas sensor be supervised in order to avoid an undetected inoperable detector, which is a fundamental function of all fire alarm system devices and Central Station Service. **UL and NFPA 720 require every system-connected CO detector to provide a means to send the sensor's end-of-life signal to the control panel. To aid in ongoing maintenance and to ensure CO detectors are providing promised protection, it is highly recommended that you purchase CO detectors with an end-of-life signal.**

Section 4

Installation Guidelines

When installing a carbon monoxide (CO) detector, do not install it in any environment that does not comply with the detector's environmental specifications. All CO detectors should be installed in accordance with NFPA 720-2015 — the *Standard for the Installation of CO Detection and Warning Equipment* — which defines standards for both commercial and residential installations of CO detectors.

2015 Edition of the IRC

The 2015 edition of the International Residential Code (IRC), CO detectors are required in dwelling units shall be installed outside of each separate sleeping area in the immediate vicinity of the bedrooms that have a permanently installed fuel-burning appliance or an attached garage. Where the fuel burning appliance is located within a bedroom or its attached bathroom, a CO detector shall be installed within the bedroom.

2015 Edition of IFC/IBC

For the 2015 edition of the IFC/IBC, CO detection is now required in "sleeping rooms" of newly constructed hotels, apartment buildings, dormitories, hospitals, nursing homes, in classrooms of kindergarten through grade 12 (K-12) schools that have a permanently installed fuel-burning appliance or an attached garage. An open parking garage, as defined in the International Building Code, or enclosed parking garage ventilated in accordance with Section 404 of the International Mechanical Code shall not be deemed to be an attached garage.

For buildings that have a fuel-burning HVAC system, the IFC/IBC requires CO detection in each dwelling unit, sleeping unit or classroom that is served by forced air furnace. However the requirement provides the system designer with the latitude of not installing CO detection in these locations if CO detection provided in the first room or area served by each main duct leaving the furnace, and the CO alarm signal is automatically transmitted to an approved location. If the FBA is located outside a dwelling unit, sleeping unit or classroom, CO detection is then required to be installed on the ceiling of a room containing a FBA or in an approved location between the room containing the FBA and the dwelling unit, sleeping unit or classroom.

2015 Edition of NFPA 101

For the 2015 edition of NFPA 101, CO detection is required outside sleeping units in one- and two-family dwellings, rooming houses, hotels, dormitories apartment buildings, and kindergarten through grade 12 (K-12) schools. CO detection is required in these occupancies when they contain a permanently installed fuel-burning appliance or when they have a communicating attached garage. An open parking garage, as defined in the Building Code, or enclosed parking garage ventilated in accordance with Mechanical Code shall not be deemed to be an attached garage. In addition to the sleeping area requirements, CO alarms or detectors are required to be installed in the following non-sleeping locations in hotels, dormitories and apartment buildings. First, on the ceiling in rooms containing a permanently installed fuel-burning appliance. The second requirement is for detection to be centrally located within occupiable spaces served by the first supply air register from a fuel-burning HVAC system.

Placement and Spacing

The following provides general guidelines for CO detector placement and spacing. Always follow manufacturer instructions regarding placement and spacing of your particular CO detector.

When wall mounting a system-connected CO detector, it should be at least as high as a light switch, and at least six inches from the ceiling. The detector should not be mounted near the floor. As noted in "Section 2: Carbon Monoxide Overview," CO gas typically rises from the point of production and then mixes evenly throughout the air as it cools. Furthermore, higher placement protects the detector from potential damage caused by pets and tampering by small children.

When ceiling mounting a system-connected CO detector, the detector should be located at least 12 inches from any wall.

Section 5
Testing, Maintenance, and Service of Detectors

Carbon monoxide (CO) detectors are designed to be as maintenance free as possible; however, dust, dirt, and other foreign matter can accumulate inside a detector's sensing elements and change its sensitivity. They can become either more sensitive, which may cause unwanted alarms, or less sensitive, which could reduce the amount of warning time given if CO reaches a dangerous level. Furthermore, as discussed in "Section 3: How Carbon Monoxide Detectors Work," the sensing cell of CO detectors have a limited life span. Therefore, detectors should be tested periodically and maintained at regular intervals. Always follow the manufacturer's specific recommended practices for maintenance and testing. Also refer to NFPA 720-2015, sections 1.1.2 and 1.1.3.

Caution

Carbon monoxide detectors are sophisticated electronic devices that need periodic testing and maintenance. To maintain the integrity of any CO alarm system, it is important to have a qualified person periodically test the system.

Typical Inspection, Testing, and Maintenance Practices

It is recommended that a CO detector should be inspected visually and the functionality tested by the introduction of carbon monoxide into the sensing chamber immediately after installation and annually thereafter. This ensures that each detector remains in good physical condition and that there are no changes that would affect detector performance, such as building modifications, occupancy hazards, and environmental effects.

Notify the proper authorities that the CO detector is undergoing maintenance to avoid nuisance alarms and to prevent unwanted alarms and possible dispatch of emergency services. Next, make sure the detector's gas entry ports are not clogged. Follow the manufacturer's instructions to test the mechanical functioning of the detector. Typically, CO detectors come with a "Test" button for this purpose. Finally, perform a functional test of the CO detector's CO sensing cell (see "Future Testing Guidelines" below) if the detector has this capability. Again, refer to the manufacturer's recommended procedure for performing this test.

Once testing and maintenance is completed, restore the zone or system. Notify the proper authorities that testing has been completed and the system is again under normal operation.

CO for Worker Safety

In accordance with section 5.2.1* of NFPA 720, Standard for the Installation of Carbon Monoxide (CO) Detection and Warning Equipment, the products and systems covered in the standard are intended for the protection of life. CO detection to monitor air quality for public health or worker safety is not addressed in NFPA 720. Typical systems intended for monitor air quality for worker safety are underground or enclosed garages where the CO detection levels are lower than those addressed by NFPA 720.

The alarm threshold for parking structures, loading docks and automotive repair garages are considered to monitor the air quality for worker safety are determined by several governmental organizations:

- Occupational Safety and Health Administration (OSHA)
- The National Institute for Occupational Safety and Health (NIOSH).

The OSHA permissible CO exposure limit is 50ppm for 8 hours and the NIOSH permissible CO exposure limit is 35 ppm for 8 hours and 200ppm as a ceiling. The OSHA, and NIOSH requirements can be found at:

*http://www.osha.gov/SLTC/healthguidelines/carbonmonoxide/recognition.html

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