

CHAPTER II Operations
SUBJECT 4 Emergency Medical Operations
TOPIC 5 Carbon Monoxide Incidents

A. SCOPE

This procedure provides specific information to be used at the scene of Carbon Monoxide Incidents. Unless specifically superseded by this plan, all other Fire Department Procedures shall be used in operations involving Carbon Monoxide Poisoning.

B. PRIORITIES

1. Ensure scene safety for all emergency responders
2. Remove all immediate victims of Carbon Monoxide Poisoning to safe atmosphere. Adult victims with a significant exposure should be transported to University Hospital (only hospital locally with Hyperbaric Chambers). All children should be taken to Children's Hospital.

Note: All suspected CO victims should be administered Oxygen at 15 L/Min via a non-rebreather mask.

3. Investigate cause of CO detector activation if applicable.
 - Eliminate the Carbon Monoxide source if possible.
4. Determine if dangerous levels of CO are present.
 - Evacuate area if necessary
 - Ventilate as required and search for other possible victims.
 - Reset or clear CO detectors where activated. Document readings on any activated CO detectors.
5. Notify other agencies as required.
 - Building Department/HVAC 10 PPM or more in ambient air
 - Cincinnati Health Department
 - CINERGY (Cincinnati Gas & Electric)
 - OSHA
 - EPA

C. SAFETY

1. The safety of the emergency responders is paramount at all times. A carbon monoxide response may require the use of an SCBA and protective EMS equipment. The SCBA shall be worn in any untested atmosphere until it is determined that it is safe to remove and permission is given by the OIC.
2. Members should conduct an arm's length test when entering an area suspected of containing Carbon Monoxide. A CO monitor shall be held at arms length and a reading taken approximately every four feet as the tester enters the area to be sampled. If 35 PPM or greater is recorded in the general air, member must be protected by an SCBA.

D. DISPATCH

Report of a CO detector sounding, no illness – Closest Engine or Ladder Company

Any CO dispatch with a report of a person ill – Closest Engine or Ladder Company an Ambulance or a Rescue Unit as necessary

E. SCENE CONTROL

First arriving company shall determine if anyone is exhibiting signs or symptoms of possible CO poisoning and if so, are there other possible victims. Officer or member in charge should size-up the situation, ventilate, and request medical transport units as deemed appropriate, providing medical care as per current EMS guidelines. Possible CO victims should have oxygen administered at 15L/min via non-rebreather face mask.

Hospitals should be notified in advance of the number of actual or potential victims to be transported to their hospital and the status of the victims. If there are more than 5 victims, the Incident Commander should have Paramedics consult with University Hospital Base about the feasibility of activating the Disaster Network. Adult victims should be transported to University Hospital and children should be transported to Children's Hospital. Note: University Hospital has 3 Hyperbaric Chambers to treat victims of CO as deemed necessary. A multi-patient Hyperbaric Chamber is also available through University Hospital at Wright Patterson Air Force Base in Dayton, Ohio.

If a victim appears to have only minor CO poisoning, they can be transported to a facility other than University Hospital.

F. INVESTIGATION

If there is reason to believe that CO is present or there is a CO detector sounding start the investigation by observing and interviewing the occupants. Note: some victims may not be aware that they are suffering from the effects of CO, infants, the elderly, and also observe any pets in the area.

The interview should determine the following:

1. What were the activities of the occupants for several hours before the arrival of the Fire Department?
2. Were any combustion appliances operating and for how long?
 - Furnace
 - Water heater
 - Gas range-was it being used to heat house
 - Gas oven-was it being used to heat house
 - Gas or wood burning fireplace
 - Space heater (gas or Kerosene)
 - Cooking grills gas/charcoal – inside or outside
 - Vehicles
 - Small engines – lawn mowers etc.
3. Location of any power vents; bathroom, kitchen, clothes dryer, etc.
4. Any recent repairs or installations of combustion equipment
5. Is there a history of people feeling ill – if yes, do they feel better when they are away
6. Were any appliances shut off prior to the arrival of the Fire Department?
7. Were any doors or windows opened prior to the arrival of the Fire Department?

G. TESTING FOR CARBON MONOXIDE

All fire companies carry meters capable of detecting and measuring CO. Where possible, use the pump accessory with the meter when conducting a survey. Readings are in part-per-million (PPM), 10,000 PPM equals 1 percent concentration.

Before entering the area to be tested take a reading in fresh air to determine if there is a baseline of CO in the ambient air. CO in the ambient outside air could be due to weather conditions, automobile fumes from a nearby expressway, factories, etc. If there is a CO reading outside, use this number as your baseline. Any increase from this number in the area to be surveyed will be the amount of CO generated by internal sources.

Once the meter has been zeroed-in take a reading as you enter the area with the meter at arms length. If the reading is in excess of 35 PPM of CO, don SCBA. Continue the survey, checking the general air in each room, and at a distance of 1 to 2 feet from each gas appliance, fuel/vent and fireplace.

Inspect all flues, vents, and chimneys for defects including but not limited too:

- missing – pipe, collars, inverters
- holes
- rusting
- obstructions
- lack of a ¼ inch rise per foot
- improper multiple flue installations
- detective chimney

Check flame for color (should be blue; however CO can still be present if there is a blue flame). An orange color may indicate incomplete combustion and the production of CO. Soot formation and condensation on windows may also be indicative of a CO problem.

If the survey fails to find the source of CO or there are no readings hazardous readings obtained the survey can be repeated, at which time the owner/Occupant should be advised to consult with the Building Department, Cinergy, or a qualified service to technician if they desire additional follow up.

1. READINGS RESIDENTIAL/NON WORKSITE OCCUPANCIES

Because infants, the elderly, and people with certain health problems are at a greater risk for complications from CO poisoning and tend to have longer exposure periods in the home, the following guidelines should be followed:

If no one exhibits symptoms of Carbon Monoxide poisoning and there is less than 10 PPM CO in the general air the Fire Department will:

- Attempt to locate the source of CO or the reason the CO detector is sounding. If a gas appliance is found to be leaking CO (reading 1 to 2 feet from appliance) but is less than 10 PPM, notify Building Department/HVAC Section and advise of the situation or notify CG&E. Remain on the scene until the arrival of the requested department or the unit has been sealed off.
- If unable to locate and CO is present but below 10 PPM, notify CG&E to respond for a CO investigation. This has the same priority as a gas leak and allows a CG&E representative to be pulled off of a non-priority job. The Cincinnati Building Department/HVAC may also be requested if there is a concern for the health and welfare of the occupants. Remain on the scene until the arrival of CG&E or the Building Department.
- If a CO detector is sounding and no CO is found after an investigation, reset detector if possible and tell occupant to call 911 if alarm sounds again.

Readings 10 PPM to 35 PPM CO ambient air or at appliance:

- Advise occupants that readings in this range are considered above normal.
Recommend that all occupants leave the building until it can be rendered safe and begin ventilation.
- Attempt to identify source of CO.
- Request the Building Department/HVAC Section to respond if 10 PPM or more CO is encountered. Unless the CO situation is severe, leave the defective appliance as found so that the HVAC inspector can investigate the problem and order repairs. If there is an issue of safety, use good judgment and shut appliance off. CG&E can also be called to the scene at the discretion of the Incident Commander.

- Remain on the scene until the arrival of the HVAC inspector.
- When corrective action is taken (defects fixed or unit sealed off) use meter to assure area is safe.
- After the area has been rendered safe and if a CO detector is present, reset if possible. Advise occupants to call 911 if the CO detector activates again.

Reading over 35 PPM of Carbon Monoxide in ambient air:

- Don SCBA
- Order all occupants to leave the building and begin ventilation.
- Attempt to identify source of CO.
- Request the Building Department/HVAC Section to respond. Unless the CO situation is severe, leave the defective appliance as found so that the HVAC inspection can investigate the problem and order repairs. If there is an issue of safety, use good judgment and shut appliances off. CG&E can also be called to the scene at the discretion of the Incident Commander.
- Remain on the scene until the arrival of the HVAC inspector.
- When corrective action is taken (defects fixed or unit sealed off) use meter to assure area is safe.
- After the area has been rendered safe and if a CO detector is present, reset if possible. Advise occupants to call 911 if the CO detector activates again.

2. READINGS WORKSITE

If no one is exhibiting symptoms of Carbon Monoxide poisoning and there is less than 35 PPM CO in the general air the Fire Department will:

- Attempt to locate the source of CO or the reason a CO detector is sounding, if applicable. If a gas appliance is found to be leaking CO (reading 1 to 2 feet from appliance) but is less than 10 PPM, notify Building Department/HVAC section and advise of the situation and notify CG&E. If the reading is 10 PPM or more at the appliance or in the general air request the Building Department/HVAC to respond to the scene. Remain on the scene until the arrival of the requested department.
- If unable to locate and CO is present but below 10 PPM, notify CG&E to respond for a CO investigation. This has the same priority as a gas leak and allows a CG&E representative to be pulled off a non-priority job. The Cincinnati Building Department/HVAC Section may also be requested if there is a concern for the health and welfare of the occupants. Remain on the scene until the arrival of CG&E or the Building Department.
- If a CO detector is sounding and no CO is found after an investigation, reset detector if possible and tell occupant to call 911 if alarm sounds again.

READINGS > 35 PPM BUT < 100 PPM in general air

- Don SCBA
- Order all occupants that readings in this range are considered above normal. Recommend that all occupants leave the building until it can be rendered safe and begin ventilation.
- Attempt to identify source of CO
- Request the Building Department/HVAC Section to respond to the scene. Unless the CO situation is severe, leave the defective appliance as found so that the HVAC inspector can investigate the problem and order repairs. If there is an issue of safety, use good judgment and shut appliance off. CG&E can also be called to the scene at the discretion of the Incident Commander.

- Remain on the scene until the arrival of the HVAC inspector.
- When corrective action is taken (defects fixed or until shut off) use meter to assure area is safe.
- After the area has been rendered safe and if a CO detector is present, reset if possible. Advise occupants to call 911 if the CO detector activates again.

READINGS 100 PPM or more/general air

- Don SCBA
- Order all occupants to leave the building and begin ventilation
- Attempt to identify source of CO
- Request the Building Department/HVAC Section to respond. Unless the CO situation is severe, leave the defective appliance as found so that the HVAC inspector can investigate the problem and order repairs. If there is an issue of safety, use good judgment and shut appliance off. CG&E can also be called to the scene at the discretion of the Incident Commander.
- Remain on the scene until the arrival of the Building Department/HVAC inspector.
- When corrective action is taken (defects fixed or unit shut off) use meter to assure area is safe.
- After the area has been rendered safe and if a CO detector is present, reset if possible. Advise occupants to call 911 if the CO detector activates again.

Carbon Monoxide Procedure Matrix**Residential:**

CO PPM	SCBA	EVACUATE	CG&E	Bldg. Dept.	Health
0	reset detector, call 911 if alarm sounds again				
<10	As needed	Until Clear	Yes	As Needed	As Needed
10 to 35	As needed	Recmd.	Yes	Required	As Needed
>35	Yes	Order Out	Yes	Required	As Needed

Worksite:

CO PPM	SCBA	EVACUATE	CG&E	Bldg. Dept.	Health
0	reset detector, call 911 if alarm sounds again				
<10	As needed	investigate	Yes	Yes	As Needed
10 to 35	As needed	advise	Yes	Required	As Needed
35 to 100	Yes	Recmd.	Yes	Required	As Needed
>100	Yes	Order Out	Yes	Required	As Needed

ADDITIONAL NOTES:

If occupants are exhibiting symptoms of CO poisoning, order area vacated until it can be checked thoroughly or rendered safe.

Any suspected CO situations or CO detectors sounding must be checked with a CO meter.

The Cincinnati Building Department/HVAC Section must be notified whenever 10 PPM or more CO is found in the ambient air. They are required to respond to the scene when this notification is made. If less than 10 PPM is found in the ambient air and the Incident Commander has a concern for the health and welfare of the occupant, he may request that the Building Department HVAC inspector to respond to the scene. This request will also be honored by the Building Department.

The Cincinnati Health Department is an additional resource for CO incidents. They will respond to the scene if requested by the Incident Commander or can do follow-up test and evaluation by contacting them during business hours.

Worksite CO scale assumes healthy adult workers working an 8 hour shift. If worksite area involved includes infants, elderly, or ill people, use the residential guidelines for procedure to be followed.

H. SUSPECTED CARBON MONOXIDE FATALITIES

If a fatality has occurred, have Fire Dispatch make the required notifications. Request that a District Chief respond, if not already on the scene.

Following are those that may be notified of the fatality:

- Operations Chief – after business hours, Duty Chief
- Fire Chief
- Building Department/HVAC Section, except suicide by auto exhaust
- Police Division – Homicide
- Coroner's Office

NOTE: Notify Fire Chief and Operations Assistant Chief (Duty Chief after hours) if there are over 5 non-fatal victims.

I. CARBON MONOXIDE SCENE OPERATIONS

Where it is possible and practical to do so, the situation may be temporarily remedied i.e.

- Vent pipe disconnected or a Vent pipe pushed too far into chimney.

These repairs are only temporary to mitigate the immediate hazardous condition. The owner/occupant should be advised to seek permanent repairs by a qualified service technician.

If there is an obvious hazardous defect in the gas appliance seal it O.O.S. Have the gas company respond if the appliance is suspected as the source of the problem.

In any case, where a correction has been made it is recommended that a Carbon Monoxide test be made after the appliance has been back in service for a period of time, to be sure that the situation has been fully corrected.

At no time should we leave premises that are going to be occupied if there is a possibility of further CO poisoning. Nor should we leave unoccupied property without having taken all possible measures to secure it from illegal entry.

If a fatality has occurred, have Fire Dispatch make the required notifications. Request that a District Chief respond, if not already on the scene.

Air monitor readings shall be taken and recorded. The PPM and the proximate location of each reading shall be documented. If there are victims, take and record air monitor reading at the location of the victims. All pertinent information shall be included on the run report. A follow up F-47 Chiefs Report may be necessary to convey all the information.

The location, activation, and reading of any residential CO detector shall be documented.

J. NOTIFICATIONS

It is very important that the Building Department has an opportunity to respond to the scene of a Carbon Monoxide incident as soon as possible after such an incident. The Heating Inspections Section of the Building Department must be notified immediately of any significant CO incident. The Incident Commander shall direct Fire Dispatch to contact the Building Department during regular business hours and the proper on-call person after hours.

A Fire Division representative shall remain on the scene until arrival of Building Department personnel.

The Incident Commander shall ensure that the Fire Prevention Bureau is notified, The Fire Prevention Bureau shall forward a formal, written referral to the Building Department as soon as possible.

K. CARBON MONOXIDE SUPPLEMENTAL INFORMATION

What is Carbon Monoxide (CO) and who is at risk?

CO is a colorless, odorless tasteless, non-irritating toxic gas. It is a by-product of incomplete combustion. CO is slightly lighter than air, having a vapor density of .96. Since warm air rises, CO rises with it and stays in the upper strata of air.

CO poisoning is the leading cause of accidental deaths in the U.S. According to medical authorities, exposure to CO causes about 1500 accidental deaths and about 10,000 illnesses annually. CO poisoning can be easily mis-diagnosed as the flu. Data from a medical study showed that about one fourth of patients complaining of the flu had elevated levels of carboxyhemoglobin.

Carbon monoxide enters the body by respiration. It is transferred to the blood via

the lungs by bonding with blood's hemoglobin to form carboxyhemoglobin (COHb). COHb reduces blood's ability to transport oxygen (O₂) to the body.

Carbon Monoxide Facts

Because CO can be present without people being aware of it, it can injure or kill before its presence is recognized. CO can pose a danger in new homes as well as older ones. New homes are built much more weather-tight to reduce energy costs, but this restricts the dissipation of CO. Older homes that are being weatherized can create the same problem.

CO from appliances that burn fossil fuels such as natural gas, propane, oil, coal and wood can reach dangerous concentrations if proper steps are not taken. Charcoal-burning appliances can emit up to 200 PPM. Gas ranges can emit up to 800 PPM when cold and up to 400 PPM after reaching operating temperature. Regarding gas ranges, their CO emission levels are not considered a safety problem because ranges are used intermittently, so the CO normally dissipates to a lower level throughout a home.

Some people feel that it is safe to run an automobile in a garage as long as the garage door is open. This practice is not safe because the home may be under a negative pressure and pull CO-laden air through the door jamb and spaces around doors and windows.

Everyone is at risk from CO poisoning, but some persons are at higher risk than others. Infants have higher respiration rates and greater need for oxygen than adults, so they can be affected by lower CO concentrations. This applies to others who may be oxygen-deprived, such as people with heart problems.

Why is Carbon Monoxide dangerous?

CO is highly toxic, is undetectable without special instruments, and provides no early warning signs of its negative effects. It suffocates its victims by displacing oxygen in the bloodstream.

Reduced oxygen in the blood harms life-support function (brain, cardiac and respiratory activity), and can cause death. Hemoglobin in the blood transfers O₂ from the lungs to organs and returns CO₂ to the lungs for exhalation. Hemoglobin has a greater affinity (200-300 times) for CO than O₂.

Low level CO poisoning can mimic flu symptoms, causing headaches

(mild/severe), fatigue, nausea, dizziness, confusion, and irritability. Higher levels of COHb can cause, vomiting, drowsiness, and loss of consciousness. Extreme levels of COHb can cause seizures, comas, permanent brain damage, and eventually death.

Where does Carbon Monoxide come from?

Carbon Monoxide is a by-product of combustion, so it may be present wherever fuel is burned. It can result from blocked chimneys, corroded or disconnected flues, engine exhaust (auto, lawn mower, snow blower, generator), charcoal grills in or near enclosed areas, gas clothes dryers, fireplaces, furnace heat exchangers or flues, gas ranges, wood burning stoves, water heaters, space heaters, portable heaters (kerosene, propane), downdrafts, and reverse stacking.

In properly vented homes with properly operating appliances, CO is safely dissipated and vented to the outside. When homes are made “energy efficient” homes, however, this may not be the case. Weatherization designed to keep warm air in during winter months can allow CO concentrations to increase. An inadequate air supply can cause reverse stacking, forcing contaminated air back into the home. This is especially true where 2 vented appliances are enclosed and there is inadequate air supply for both units at the same time.

Symptoms of Carbon Monoxide poisoning

CO poisoning can cause a number of symptoms, depending upon the length and severity of exposure. Mild exposure can result in a slight headache, nausea, vomiting, and fatigue. These are often described as “flu-like” symptoms. Medium exposure can produce severe throbbing headaches, drowsiness, confusion, and fast heart rate. Extreme exposure can produce unconsciousness, convulsions, heart and lung fatigue, brain damage and eventually death.

A 1986 study of emergency room patients found that 24% of patients reporting flu symptoms had low level CO poisoning. Medical reports also indicate that CO can aggravate cardiovascular conditions. Medical experts estimate that one third of all cases of CO Poisonings go undetected, and that one third of survivors of CO poisoning may have lasting memory deficits or personality changes.

Unborn babies can be at risk when exposed to lower levels of CO. A University of Utah report revealed that in 50 percent of emergency room cases studied, expectant mothers single exposure to high levels of CO resulted in death of the fetus while the mother survived. Medical evidence suggests that lower lever

exposure to CO, even at 20 PPM, can be hazardous to children, infants, the unborn, the elderly, and those with heart or lung disease.

Extreme CO poisoning can disorient and impair motor skills. This may affect a person's ability to open doors or perform other simple tasks. Upon exposure to CO, the rate of COHb increase in blood varies with each individual. This rate is a function of the concentration of CO, length of exposure (PPM), the age and health of the individual, and the amount of physical exertion taking place during exposure. Since children have a higher respiration rate than adults, their COHb levels rise more quickly than adults.

Carbon Monoxide Exposure Levels and Detector Alarm Standards

There is no consensus on acceptable exposure levels to CO. The various exposure thresholds set by different regulatory agencies reflect differences in the purposes of their regulations. The table below contains a sample of the exposure thresholds set by federal agencies.

Federal Exposure Standards

Organization	Time Period	Recommended Maximum Exposure Level
CPSC	8 hours	15 PPM
CPSC	1 hour	25 PPM
EPA	8 hours	09 PPM
EPA	1 hour	35 PPM
OSHA	8 hours	50 PPM

Ambient Conditions

The EPA standard for ambient air is 9 PPM/8 hours. The air in several U.S. cities exceeds this threshold two or more times year. Outdoor CO levels in Los Angeles can reach 30-50 PPM. In Chicago, a weather inversion in 1994 created 10 PPM throughout the city. Denver regularly has outdoor CO levels that exceed the EPA threshold.

Measuring Carbon Monoxide

Exposure to CO is expressed in parts per million over time. The higher the concentration, the shorter the time period needed to affect the body.

Underwriters Laboratories Standard 2034

A. General features

UL Standard 2034 requires that CO detectors pass over 37 tests of safety, reliability and performance. One test requires that CO detectors activate when exposed to specific levels of CO.

The higher the CO concentration, the shorter the time allowed for the detector to activate. The concentrations and time periods selected for the tests are levels that will cause a CO detector to activate before an average healthy adult begins to experience symptoms of CO poisoning. For example, exposure to 100 PPM for 20 minutes may have no effect on an average healthy adult, but a four-hour exposure to the same level may produce a headache. Exposure to 400 PPM for 35 minutes may cause a headache, but a 2-hour exposure to same level of CO could be fatal.

B. Sensitivity Test, Section 37

To comply with UL 2034, detectors must activate before the concentration of CO would result in a 10 percent COHb level in a healthy adult. The consensus of the medical community is that a healthy adult can handle up to 10 percent COHb with no perceptible effect. Some medical evidence suggests that chronic effects may occur at levels as low as 2-3 percent COHb.

Specifically, UL Standard 2034, Section 37.1.1., states, "A carbon monoxide detector shall operate at or below the plotted limits for the 10 percent COHb curve specified in Figure 37.1 and Table 37.1."

UL Table 37.1, Part A

CO Exposure/Alarm Level	Maximum Time Period
100 PPM	Before 90 minutes
200 PPM	Before 35 minutes

400 PPM

Before 15 minutes

C. False Alarm Resistance

Part B of Table 37.1 contains CO concentrations over specified time periods for which CO detectors must not activate.

UL Table 37.1, Part B

CO Exposure Tolerance	Time
100 PPM + 5 PPM	16 minutes
60 PPM + 3 PPM	28 minutes
15 PPM +/- 3 PPM	30 days ¹
35 PPM +/- 3 PPM	See Note 1 and 2 below

Note 1 - Effective October 1, 1995

Note 2 - Rush-hour test –30 cycles of 35 PPM/1 hr, then 6 hrs cleans air, then 35 PPM/1hr, then 16 hrs clean air

D. Reliability

Both the biomimetic-type and semiconductor-type CO detectors pass the reliability tests in UL 2034. UL also conducts periodic unannounced factory inspections to select additional units for testing.

By virtue of its design, a biomimetic sensor can only detect CO. Semiconductor sensors that comply with UL 2034 are highly selective for CO, and are only affected by relatively high concentrations of other gases, much higher than would be expected in a normal residential environment.

Sensor Technology & Operating Principles of CO Detectors**A. General**

Carbon monoxide detectors are designed to continuously monitor indoor air and activate before CO reaches unsafe concentrations. It is important to note that CO detectors are designed specifically to detect the presence of CO, and are not

intended to replace smoke detectors.

CO detectors may be hard-wired only, battery only or hard-wired with battery back-up. The AC-powered units may have pigtails for direct connection, or they may have appliance cords or plugs for connection to an outlet.

At present, CO detectors use one of two technologies. The first one uses a sensor employing a chemical reaction and is called biomimetic. The other type of technology uses a semiconductor.

B. Biomimetic

Biomimetic means to *mimic life*, in this case a biological system. The biomimetic process is sometimes referred to as gel cell because of the translucent disks used in the sensor. The disks are molecularly engineered synthetic hemoglobin. This product mimics the reaction of natural hemoglobin to CO because it is designed to form a molecular *keyhole* that only CO can fit. As CO attaches to the artificial hemoglobin, the disk darkens. A light-emitting diode (LED) monitors the degree of optical change. When the concentration of CO on the disk reaches the activation threshold, the detector activates.

Biomimetic sensors do not accumulate CO. Like the human body, the sensors attract and discharge CO at the same time, but the discharge rate is slower than the pickup. CO half-life is the same for both human body and these sensors, about five hours. For example, assume that a person who was exposed to CO has a COHb level of 20%. After being in fresh air for five hours, the person's COHb level will be 10%. Depending upon CO concentration and exposure period, cleansing may take several hours.

CO detectors that use biomimetic sensors comply with UL 2034 Performance tests. They are designed to activate at chronic exposure levels as well as acute levels. They may sound an intermittent alarm as CO levels build. Per UL 2034, the detector will sound a trouble signal (one short beep every minute) when the battery or sensor need to be replaced. The batteries have a 2-3 year lifetime, depending upon how often the detector has activated. The overall life expectancy of the detector itself is 10 years.

C. Semiconductor

1. General

Semiconductor-based CO detectors use an electrically-powered sensing element that is monitored by an integrated circuit, or computer chip. The majority of manufacturers use the Figaro TGS-203 Gas Sensor. The TGS-203 sensor is highly selective to CO. The sensing element is a thin layer of tin dioxide that covers a ceramic base. Wires on the same circuit are embedded into each end of the ceramic. Because it is not a conductor, the ceramic base creates an open circuit and the tin dioxide maintains as electrical continuity between the wires.

2. Operating principles

The surface of the electrically-charged tin dioxide attracts O₂ and CO. O₂ restricts the flow of electrons, thus increasing the electrical resistance between the wires. CO causes the electrons to flow more easily, reducing the electrical resistance. The lower the resistance is the higher the CO level recorded by the microchip. The sensors work in 2.5 minute cycles, monitoring air quality, burning off CO collected during last test cycle, and conducting a self-test. The microchip records each sampling and will cause the detector to activate if the samples continue to show CO levels over the UL 2034 concentration/time thresholds.

Humidity can increase the sensitivity of the semiconductor sensor. To compensate for this, the sensing element heats to a high temperature for 60 seconds, then to a low temperature for 90 seconds. During the high-temperature cycle, any water vapor that was deposited on the surface is burned off along with the CO. During the low-temperature cycle, the microchip measures the amount of CO that is deposited on the sensor surface, then cycles to the high-temperature stage to burn it off before the next sample phase.

3. Design, optional features

Semiconductor detectors meet the requirements of UL 2034. They are all AC-powered and feature a reset button. Different models come with a variety of features, such as a digital, readout showing PPM of CO detected and a dual alarm for chronic and acute levels of CO. These detectors have a life expectancy of 5-10 years.

Common Installation Practices

Emergency response personnel should be familiar with the proper methods for locating and installing CO detectors for three primary reasons. First, detector location is a factor in the investigation of possible causes for detector activation.

Second, emergency response personnel can advise occupants on proper installation practices. Finally, this information should be included in public education programs to reduce CO detector calls.

At present, there is no installation standard for CO detectors. The recommended installation depends upon the type, model and manufacturer of the device. The Consumer Product Safety Commission (CPSC) does recommend, however, that there be at least one CO detector per household, located outside the sleeping area. Most manufacturers recommend additional CO detectors for each level and bedroom of a residence. The NFPA may publish an installation standard for CO detectors in the future.

Until an installation standard is published, owners of CO detectors are advised to follow manufacturer's instructions. The instructions generally agree that detectors should be near sleeping areas so they can be heard at night, in areas with fuel-burning appliances in order to respond to CO buildup, and on each level of a residence so that they are within hearing distance.

Detectors designed to be wall-mounted should be placed with the test/reset button at the bottom of the unit. If installed on a sloped ceiling, CO detectors should be placed at least three feet horizontally from the peak of the ceiling. Generally, CO detectors should be placed in every room where people spend a lot of time.

Common Installation Problems

There are a number of common problems associated with the installation of CO detectors, which may hinder their performance. The most fundamental problem is the failure of owners to read the instruction manual. Consequently, detectors are sometimes installed:

- Too close to cooking and heating appliances in common areas of multi-family dwellings.
- In very cold or very hot areas.
- In dead air space.
- In locations where the detector is obstructed.
- In the path of turbulent air from a ceiling fan.
- In locations where they accumulate grease and soot.
- In unvented rooms with cleaning supplies and other contaminants.
- On switched electrical outlets.

All of these locations can prevent a CO detector from opening properly.

Investigative Techniques

An effective CO investigation is logical and systematic, just like a fire investigation. All possible sources must be checked and each potential source systematically eliminated. Care should be taken so that nothing is inadvertently overlooked. Effective investigation is the key to achieving the goal – mitigating the hazard. Systematic investigation assists in determining the danger level, identifying CO sources, mitigate/eliminating CO sources, and advising occupants.

Investigation Steps

1. Consider firefighter safety

CO detection instruments should be checked for proper calibration and an initial test of the instrument should be conducted at the door before proceeding through a residence. In some cases CO may be present in the ambient air outside and should be considered when assessing CO readings.

2. Interview occupants

Firefighters should observe occupants to help confirm CO symptoms. Remember to observe the behavior of pets, since they are likely to exhibit symptoms sooner than adult humans. Check for presence of people in at-risk groups (very young, elderly, pregnant females, anyone already ill). Ask about activities of the occupants over the past several hours, since lower concentrations can take several hours to activate the detector.

3. Determine condition of home prior to detector activation

Through discussion with occupants, emergency response personnel should determine what combustion appliances were operating and for how long. Were ranges or oven being used to heat the home? Have there been any recent installations or repair of combustion equipment?

The location of CO detector(s), by area and level in a residence should be determined. Emergency response personnel should also determine if any occupants are presently feeling ill or had been feeling ill earlier. Did the

occupants open any windows or doors? Did the occupant shut off any appliances?

4. Create a worst-case scenario

In order to isolate possible sources of CO, emergency responders should begin by closing all windows and doors in the residence.

Next, turn on all fuel burning appliances and all exhaust fans (kitchen/bath). Let appliances reach operating temp. (10 minutes). Then check potential sources of carbon monoxide. Supplement instrument readings with visual inspection. Investigate every potential source.

5. Checklist

A checklist helps the investigator conduct a systematic and thorough investigation. The checklist can be used in two steps. First, check the premises and confirm the presence of all potential CO sources. Then go back and record any CO concentrations found at each item. This will ensure that potential sources are not overlooked. The checklist also becomes a record of the investigation as well as an aid to follow-up for other agencies.

Appliances and CO sources

Check furnaces flue pipes for corrosion, rust holes, loose or missing connections, and blockage and down drafting. Flue pipes must also be installed so that there is a ¼ inch rise on the run from the appliance to the chimney. Down drafting can occur when the air pressure inside a home becomes lower than outside, causing flue gases to reverse and flow into the house. Furnaces may also contribute to reverse stacking. Reverse stacking is a reversal of airflow in a flue or chimney when two or more appliances are competing for the same air. An example is a furnace pulling outside air back through the water heater flue. This is especially true where the water heater and the furnace have been located in an enclosed area.

Check the furnace fan for proper installation (direction of flow). Burner and pilot light flames should be blue (note: a blue flame does not mean that there is not a CO problem). Examine the combustion chambers for corrosion and cracks from metal fatigue. It is not possible to visually inspect the entire combustion chamber. To check for a cracked heat exchanger, take readings at air register discharges. The register closest to the furnace may be the best indicator.

Check the condition of all flues. The flue should be free of rust holes, loose or missing connections and blockage. Examine the draft inverter on water heaters for soot and rust deposits. Burners and pilot's lights should be checked to be sure that the flame is properly adjusted (blue). Note: only 1 draft inverter should be installed on a water heater. Older instantaneous water heaters require no draft inverter.

On kitchen ranges, check the burners and pilot lights for proper adjustment. Kitchen ranges are allowed to emit CO under normal operation. Each brand will vary, but they are allowed to emit up to 800 PPM on start-up and 400 PPM when at their operating temperature. These levels are not considered to pose a risk if the home has sufficient make-up air to dissipate the CO and if the range is used intermittently.

The combustion chambers and flue pipes of wood-burning stoves should also be inspected for cracks or loose connections. If a gas clothes dryer is present, check the pilot and burner flame for adjustment. Check the exhaust flue for blockages or other damage.

The combustion area and operation of space heaters should be checked, as well as the practice of opening a window for fresh make-up air when the space heater is used. Inspect fireplace flues/chimneys for cracks or blockage.

Confirm if a barbecue grill was being used indoors or outside near a window that would allow CO to enter. CO from running automobile engines can enter living areas even if they are being operated in a garage with the garage door open.

Gas-operated refrigerators can still be found and need to be inspected like any other gas-operated appliance.

Testing & Returning Carbon Monoxide Detectors to Service

Biomimetic Detectors

This type of detector is self-testing. It will produce a trouble alarm, consisting of one short beep per minute, to indicate that the sensor pack needs replacement. If the detector is not sounding, push test button (10-20 sec) to confirm that the detector is operational. If the detector is operating properly and the sensor has purged the CO, the horn should sound for 5-10 sec and then silence.

If the detector is sounding, remove the sensor pack to silence the alarm. Place the

sensor pack in fresh air to regenerate. It may regenerate in as little as an hour if the CO concentration was low.

If the detector activates when the sensor pack is reinserted, remove it for a longer period, 2 to 48 hours. The biomimetic sensor mimics the human body's hemoglobin, and CO takes just as long to clear from the sensor as it does the body. The sensor module can be permanently damaged by a high concentration of CO, just as a person can die in spite of medical intervention when the percent of COHb is high.

Semiconductor Detectors

These types of detectors are self-testing and will sound a trouble signal if a component fails. The trouble signal consists of one short beep per minute. This indicates that the detector needs to be replaced. If the detector is not sounding, push the test button to confirm if the detector is operational. If the detector is sounding, push the button to silence the detector. Pushing the test button initiates a 60-second high-heat cycle to burn off any CO, water vapor, and other gases. After this cycle, the detector should reset and return to normal operational mode.

If the trouble signal continues or the horn does not respond to test, the detector needs replacement. High concentrations of contaminants can kill this type of detector. In addition, it is important to note that the sensor in these types of detectors becomes more sensitive with age, and therefore, the detector eventually needs replacement.

PUBLIC EDUCATION

The first priority of a public education program should be to prevent CO emergencies from occurring. The next priority is to reduce the number of unnecessary CO calls due to poor placement of detectors, poorly maintained detectors, and occupant misunderstanding of detector operation.

Advising the public on preventive measures:

The methods for public education on CO detectors are the same ones used for general fire prevention. They include group presentations, community council meetings, civic clubs and media interviews. Public education efforts should include advice on the need to test

and maintain fuel-burning equipment annually, as well as the role of public utilities, private fuel companies and appliance repair firms. Check with the E.S.S. Bureau for the availability of hand-outs and videos regarding CO.

The importance of cleaning chimneys and flues yearly should be stressed. This should include an explanation of why this is important, along with maintenance tips. Equally important is the need for regular inspections by qualified personnel of all fuel-burning appliances. The public should be reminded to watch for excessive rust and scaling, burners and pilot lights, which need adjustment (consistently yellow flame means fuel is not being burned completely, a source of CO), and check for downdraft and reverse stacking.

Public education programs should include tips on the safe use of appliances, e.g., not using charcoal grills, keeping outdoor barbecues away from open windows and doors, not using a range for heating, venting clothes dryers outside, slightly opening windows for fresh air, and not running a car in a garage, even with the overhead door open.

The public needs to be taught what to do when CO poisoning is suspected and advised about the fact that CO poisoning can mimic flu symptoms.

UNDERSTANDING THE AFFECTS OF CARBON MONOXIDE ON HUMAN BEINGS

09 PPM: The maximum allowable concentration for continuous exposure in any 8 hour period according to EPA

35 PPM: The maximum allowable concentration for continuous exposure in any 8 hour period according to OSHA

100 PPM: In an average healthy person the blood level will not reach a level higher than 10% Carboxyhemoglobin within 90 minutes, which means it will have little or no affect on the average healthy person

200 PPM: Slight headache, tiredness, dizziness, nausea after 2 to 3 hours exposure

400 PPM: MAXIMUM carbon monoxide concentration for exposure at any time as prescribed by OSHA

600 PPM: Frontal headaches within 1 to 2 hours of exposure - Life **threatening** after 3 hours (Minimum PPM in flue gas according to EPA & AGA/GAMA)

800 PPM: Dizziness, nausea and convulsions within 45 minutes - Unconsciousness within 2 hours Death within 3 hours

1600 PPM: Headache, nausea, dizziness within 20 minutes - **Death** within 1 hour

3200 PPM: Headache, nausea, dizziness within 5-10 minutes. **Death** within 30 minutes

6400 PPM: Headache, nausea, dizziness within 1-2 minutes. **Death** within 10-15 minutes

12,800 PPM: DEATH within 1 to 3 minutes

NOTE: A car can produce as much as 100,000 PPM carbon monoxide per minute during start up and warm up periods. This level is reduced once engine is at normal operating temperature.

NOTE: PPM represents **P**arts **P**er **M**illion in the atmosphere. 1% of carbon monoxide in the atmosphere equals approximately 10,000 PPM.