

## SUPPLEMENT 3

# Carbon Monoxide

*Editor's Note: Supplement 3 provides technical information on carbon monoxide to code users. This supplement consists of four parts:*

- *Part I, Carbon Monoxide (CO) Information and Data*
- *Part II, Guidelines for Fire and Other Emergency Response Personnel*
- *Part III, Sidewall Vented Appliances*
- *Part IV, Carbon Monoxide Incident Investigation*

*This supplement is a compilation of several existing documents. Jennifer Flynn, NFPA Research Analyst, provided the first part, which references her report Non-Fire Carbon Monoxide Incidents Reported in 2005 as well as stats from the CPSC and CDC. The second part is extracted from Responding to Residential Carbon Monoxide Incidents, published by the U.S. Consumer Product Safety Commission. (This report is updated periodically, and readers can obtain subsequent issues from NFPA.) The third part of this supplement is provided to inform code users of the complex interaction of factors that are evaluated during the investigation of a carbon monoxide incident. Thomas Crane of Crane Engineering provided the fourth part.*

*The editor gratefully acknowledges all the contributors to this supplement.*

### **PART I: CARBON MONOXIDE (CO) INFORMATION AND DATA**

Carbon monoxide is a colorless, odorless, poisonous gas that results from the incomplete burning of "common" fuels such as natural or liquefied petroleum gas (LP-Gas), oil, wood, or coal. When CO is inhaled, it enters the bloodstream and reduces the ability of the blood to carry oxygen to vital organs, such as the heart and the brain.

Fire departments and gas suppliers are often called to assist when people suspect that carbon monoxide might be present. Some of these calls are reported after a CO alarm sounds. Some may be in response to symptoms of CO poisoning.

In 2005, U.S. fire departments responded to an estimated 61,100 non-fire carbon monoxide incidents in which carbon monoxide was found, or an average of seven such calls per hour. The number of incidents increased 18 percent from 51,700 incidents reported in 2003 [1].

In the home, heating and cooking equipment that burn

natural gas, propane, and other fuels are potential sources of carbon monoxide, which is why installation codes and standards for fueled equipment emphasize arrangements for adjusting venting. Vehicles or generators running in an attached garage can also produce dangerous levels of carbon monoxide.

For example, in March 2004, a carbon monoxide leak from a gas furnace left two families suffering the effects of carbon monoxide poisoning. The leak began in one family's basement, spread throughout the house and into a neighbor's home. The leak resulted in the carbon monoxide poisoning and death of a 14-year-old girl, who lived in the home where the leak originated. Another seven individuals were treated for CO poisoning, including two women, ages 40 and 19 years old, and two males, ages 20 and 4 years old, who lived with the 14-year-old girl, and a 24-year-old woman and two boys, ages 3 years old and 1 month old, who lived next door. These seven victims were treated for carbon monoxide poisoning and survived the incident [2].

In 2005, three children were taken to the hospital and treated for carbon monoxide poisoning when exhaust fumes from a power generator leaked into the house through a crack in a door for several hours. The children included a 7-year-old boy and two girls, ages 4 and 11 [3]. According to the Consumer Product Safety Commission, the amount of exhaust from one generator is equivalent to that of hundreds of idling cars [4]. The three children were lucky to have been removed from the area and treated early enough that they did not die.

### Carbon Monoxide Facts

The following are some basic facts about carbon monoxide incidents:

- In 2005, January and December were the peak months for non-fire carbon monoxide incidents in which CO was found.
- The peak time of day for reported carbon monoxide incidents is between 6:00 p.m. and 9:59 p.m.
- Overall, 75 percent of non-fire carbon monoxide incidents are reported between the hours of 9:00 a.m. and 10:59 p.m.
- Almost 9 out of every 10 (89 percent) reported non-fire carbon monoxide incidents took place in the home. In contrast, homes accounted for 75 percent of the structure fires reported that year [5]. (Homes include one- or two-family dwellings, manufactured homes, and multifamily dwellings, including apartments, condos, town houses, row houses, and tenements.)
- In 2003, there were an estimated 60,600 unintentional carbon monoxide detector activations in which carbon monoxide was not detected; this includes CO detector malfunctions and false alarms. (Due to the increasingly large size of the national database, false alarms and false calls were not included in the publicly released NFIRS data for 2004 and 2005.)
- In 2003, 46 percent of all CO-related non-fire calls reported to fire departments were carbon monoxide incidents in which carbon monoxide was found. Fifty-four percent of all CO-related non-fire calls reported to fire departments were false alarms, or no CO was found.

### Dangers of CO Exposure

The dangers of CO exposure depend on a number of variables, including the victim's health and activity level. Infants, pregnant women, and people with physical conditions that limit their body's ability to use oxygen (i.e., emphysema, asthma, heart disease) can be more severely affected by lower concentrations of CO than healthy adults would be.

Carbon monoxide poisoning can be confused with flu symptoms, food poisoning, and other illnesses. Some symptoms include shortness of breath, nausea, dizziness, lightheadedness, or headaches. High levels of CO can be fatal, causing death within minutes. Although most CO poisoning happens during a single incident, it is possible to suffer from chronic CO poisoning when a person is exposed to low levels of CO over weeks or months and experiences symptoms over that time.

Even single-incident CO exposures can have long-term health consequences, such as cardiovascular manifestations, neurological dysfunction, or brain damage, which can occur days to weeks after the exposure. In 14 percent to 40 percent of serious initial CO poisonings, the individual exposed still faces the prospect of delayed neurologic dysfunction [6].

According to the Centers for Disease Control and Prevention [7], an estimated 15,200 people were treated annually during 2001–2003 in emergency departments for nonfatal, unintentional, non-fire-related carbon monoxide exposure. During 2001–2002, the CDC estimates 480 people died, on average, each year from unintentional non-fire-related carbon monoxide exposure.

The Consumer Product Safety Commission (CPSC) is a federal regulatory agency that works to reduce the risk of injuries and deaths that result specifically from consumer products. According to the CPSC, 166 unintentional non-fire carbon monoxide poisoning deaths were associated with consumer products on average, annually from 2002–2004 [8]. This represents a 34 percent increase in unintentional non-fire carbon monoxide poisoning deaths from 1999–2000, in which an average of 124 deaths were reported annually [9].

Of the CO non-fire deaths related to consumer products in 2003 and 2004, 47 percent were associated with the use of heating systems, most often gas heating systems. Another 35 percent of the CO deaths were associated with engine-driven tools. The CPSC reports that 73 percent of CO deaths occurred in the home, while deaths in tents, campers, and other temporary shelters accounted for an estimated 14 percent of deaths during 2003–2004.

The CPSC examined carbon monoxide incidents associated specifically with engine-driven generators and other engine-driven tools that occurred between 1990 and 2004. During these 15 years, generators resulted in 264 CO potential exposure deaths and were the leading engine-driven consumer products involved in CO exposure incidents [10].

### NFPA 720 and State Legislation

NFPA 720, *Standard for the Installation of Carbon Monoxide (CO) Detection and Warning Equipment*, is the

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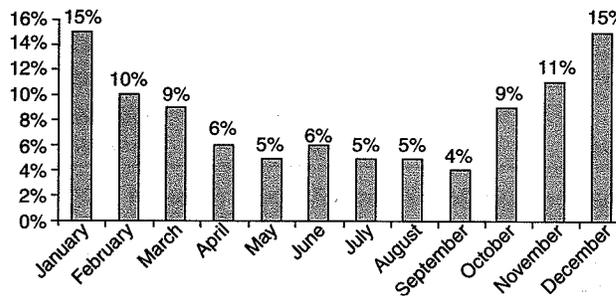
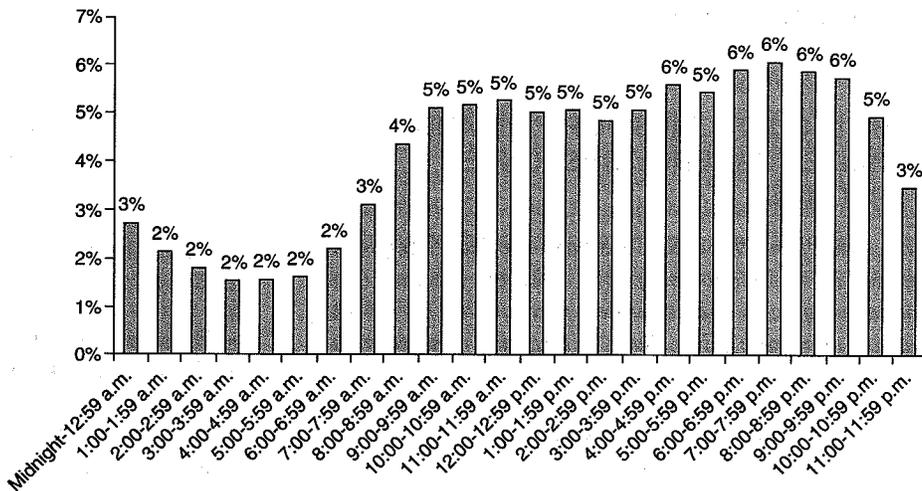
standard for the installation of carbon monoxide (CO) warning equipment in dwelling units [11]. NFPA 720 covers the selection, application, installation, location, testing, and maintenance of carbon monoxide warning equipment within dwelling units that contain fuel-burning appliances or fireplaces, or have attached garages. Beginning with the 2009 edition, the standard also covers nonresidential buildings and structures. The purpose of the standard is to provide a warning of the presence of CO in sufficient time to allow occupants to either escape or take other appropriate action.

NFPA 720 requires a carbon monoxide alarm or detector centrally located outside each separate sleeping area in the immediate vicinity of the bedrooms. Each alarm or detector should be located on the wall, ceiling, or other location as specified in the installation instructions that accompany the unit.

As of 2007, 15 states and more than 40 other authorities having jurisdiction require some form of carbon monoxide detection. Texas, for example, only requires CO detectors in day care and group homes, while Oklahoma only requires detectors in child care facilities. Many states only require carbon monoxide detectors in newly constructed buildings. Of the 15 states that have adopted requirements for carbon monoxide detection, ten require the installation of carbon monoxide detectors in occupancies not covered by the standard, which only applies to dwelling units. The 15 states currently requiring some form of carbon monoxide detection include the following:

- Alaska
- Connecticut
- Florida
- Illinois

**EXHIBIT S3.2** Non-Fire Carbon Monoxide Incidents in Which Carbon Monoxide Was Found, Reported by Responding Fire Departments in 2005, by Alarm Hour. (Source: NFIRS and NFPA Survey)



**EXHIBIT S3.1** Non-Fire Carbon Monoxide Incidents in Which Carbon Monoxide Was Found, Reported by Responding Fire Departments in 2005, by Month. (Source: NFIRS and NFPA Survey)

- Maryland
- Massachusetts
- Minnesota
- New Jersey
- New York
- Oklahoma
- Rhode Island
- Texas
- Utah
- Vermont
- West Virginia

See Exhibits S3.1 and S3.2 and Table S3.1. Note that NFPA's national estimates are based on data from the U.S. Fire Administration's (USFA) National Fire Incident Reporting System (NFIRS) and NFPA's sample-based fire department survey. The NFPA survey collects summary data about U.S. fire department activities. Because NFIRS is not a census, the survey results are used to scale up the details from NFIRS into national estimates.

**TABLE S3.1 Non-Fire Unintentional-Injury Deaths Due to Poisoning by Gases and Vapors**

Year	Total	Gas from Pipeline	Motor Vehicle Exhaust Gas	Other Utility Gas or Carbon Monoxide	Other	Estimated Carbon Monoxide Poisoning Involving Consumer Products
1980	1,242	—	—	—	—	282
1981	1,280	—	—	—	—	311
1982	1,259	72	596	426	165	340
1983	1,251	82	580	414	175	323
1984	1,103	48	511	354	190	275
1985	1,079	49	488	392	150	284
1986	1,009	29	475	341	164	240
1987	900	53	402	288	157	232
1988	873	36	372	314	151	238
1989	921	48	355	353	165	296
1990	748	33	293	289	133	243
1991	736	20	278	316	122	250
1992	633	21	223	281	108	211
1993	660	14	245	290	111	214
1994	685	24	246	307	108	223
1995	611	27	234	272	78	201
1996	638	23	219	283	113	217
1997	576	13	208	251	104	180
1998	546	15	190	254	87	180
1999	597	—	—	—	—	109
2000	631	—	—	—	—	138
2001	656	—	—	—	—	130
2002	691	—	—	—	—	188
2003	690	—	—	—	—	154
2004	629	—	—	—	—	162

Note: Detailed breakdowns were not provided prior to 1982 or after 1998. The last column has estimates from the U.S. Consumer Product Safety Commission.

Source: National Safety Council, *Accident Facts and Injury Facts*, 1981–2007 editions, 1121 Spring Lake Drive, Itasca, IL 60143; <http://www.cdc.gov/nchs>; Matthew V. Hnatov, *Non-fire carbon monoxide deaths associated with the use of consumer products*, U.S. Consumer Product Safety Commission, Bethesda, MD, August 8, 2007, and previous reports in the series; <http://www.nchs.gov>. The national death certificate database, maintained by the U.S. National Center for Health Statistics (NCHS), is coded according to the International Classification of Diseases (ICD), which was substantially revised in 1999. These modifications changed the categories that can be used to analyze trends in deaths involving gases.

## PART II: GUIDELINES FOR FIRE AND OTHER EMERGENCY RESPONSE PERSONNEL

*This guide from the U.S. Consumer Product Safety Commission is intended to help public emergency response personnel act quickly and accurately to a call that may involve carbon monoxide (CO). Such a response can reduce injuries and save lives.*

CO is associated with about 500 unintentional non-fire-related deaths each year. About 60 percent of these deaths are from motor vehicle exhaust, and about 40 percent are associated with consumer products. CO in its pure

form is colorless and odorless; however, other gases that do have an odor often accompany it.

Whether you're part of a fire department or a public emergency response organization, you'll find information here that will help you accomplish the following:

- Determine how much assistance occupants need.
- Ensure your own protection from CO when entering a home.
- Confirm whether a CO hazard exists.
- Make a preliminary assessment of the potential sources of elevated CO.

- Give advice to the resident on how to make the home safe for re-entry.

To use this guide most effectively, follow these steps and refer to the following exhibits later in this supplement:

1. Read the section "What to Know Before You Respond to a CO Incident Call."
2. Become familiar with the guidelines for dispatchers (Exhibit S3.3).
3. Follow the steps in the CO incident reporting form (Exhibit S3.4) and the "CO Measurement Form" (Exhibit S3.6), where you record the readings from your CO meter/measuring equipment.
4. Read the section "CO Levels: Advice to Give, Actions to Take."
5. Fill in the form "Advice for Residents" (Exhibit S3.7), and give a copy of this to occupants.

As you use this guide, feel free to adopt all or part of it for your particular organization or community. If you have suggestions for future editions, contact the U.S. Consumer Product Safety Commission by calling 1-800-638-2772 or visiting [www.cpsc.gov](http://www.cpsc.gov).

### Agency Disclaimer

This guide has been developed for use by public emergency response organizations such as professional and volunteer fire departments, emergency community service units, and other organizations delegated to respond to carbon monoxide (CO) incident calls; it is not directed toward non-emergency organizations that might receive CO incident calls.

These guidelines consist of procedures that emergency response personnel can use to help residents who call and report a suspected CO incident. The procedures are designed to help responders provide for their own safety when answering a call, determine the level of care needed by the residents, make a preliminary assessment of the CO condition in the residence, and determine when it is safe for the occupants to re-enter the home. These procedures can help in finding a *significant* source of CO in the home; in some circumstances, it is possible that other professionals with technical expertise will need to be called to find the cause of hard-to-trace elevated CO levels in the home.

These guidelines assume that the responder has a basic level of familiarity with CO, including how it is generated, how it can become abnormally elevated, how it is distributed through a home, and what the exposure symptoms are. References for background material are cited.

Finally, these guidelines are not a CPSC standard and are not mandatory requirements. CPSC believes that this document contains the basic information needed to pro-

vide a first emergency response to consumers. State and local fire departments and emergency response organizations can choose to adopt all or part of this material to meet their own needs and resources.

### What You Need to Know Before You Respond to a CO Incident Call

- Emergency response procedures for CO incidents are most effective when coordinated with local medical personnel, poison control centers, utilities, and heating and ventilating contractors.
- For your own protection, it is essential to establish a "Safe Entry Procedure" when entering a home where there is a reported CO incident.
- It is important to know what the potential sources of elevated CO are in a home. A list of these sources and a list of background references about CO are provided elsewhere in this document.
- It is important to be familiar with the various types of residential CO alarms and how they work, including the differences among alarm, low-battery, malfunction, and error and warning signals. Manufacturers' product literature provides this information.
- CO incident calls may be made when a CO alarm has sounded or because the occupants suspect possible CO exposure, because of illness or strange odors. A CO alarm signal should never be ignored. CO alarm signals require a different response than smoke alarms. CO alarms are designed to activate at exposures below those at which symptoms occur, while occupants still have time to take action to protect themselves. However, CO levels can build up quickly, so the CO alarm might be responding to a high level. Immediate evacuation is necessary when a CO alarm sounds. CO alarms should not alarm below 30 ppm.
- There have been instances where CO alarms activated and neither a CO elevation nor source could be identified. Changes in the voluntary standard for CO alarms, effective October 1, 1998, have reduced the occurrence of unexplained alarms. If a resident has an alarm manufactured before October 1, 1998, and a CO elevation or CO source cannot be located, the resident should be advised to purchase a new CO alarm. The new alarm should meet one of the following standards:

Canadian Standards Association (CSA) 6.19-01, 2001  
Underwriters Laboratories Inc. (UL) 2034, Second  
Edition, October 1998

International Approval Services (IAS) 6-96, Second  
Edition, June 1, 1998

- Professional CO detection equipment, and training in its use, is essential in finding the source of elevated CO. Use, maintenance, and periodic calibration procedures should be established. Manufacturers of such equipment generally provide recommendations and instructions for maintenance and re-calibration; follow these instructions carefully.
- In most cases where a CO incident is reported, a professional CO monitor that measures room CO concentrations will help you assess the immediate risk. Finding the reason for the CO alarm can be time-consuming and difficult, particularly if the elevated CO levels are the result of a transient condition such as down drafting from an exhaust flue. Heating, ventilating, and air conditioning (HVAC) contractors may be needed to assess conditions in the residence and provide advice to the resident.

### Guidelines for Dispatchers

Dispatchers are the first contact when residents call for help about a CO incident. A dispatcher can use the guidelines in Exhibit S3.3 to decide what kind of help is needed and what type of equipment should be sent to the residence.

### CO Incident Reporting

The CO measurement procedures can help identify the cause of the resident's request for help and can also help determine when it is safe for a resident to re-enter the home.

When you arrive on the scene to investigate a call about CO, follow the steps listed in Exhibit S3.4. Plan to make multiple copies of this form, so you can fill out separate forms for each separate investigation. Be sure to keep a copy of each completed investigation form.

It is important that residents who show symptoms of CO poisoning be examined on the scene by EMS or appropriately trained personnel. If medical treatment is indicated, the residents should be taken to the appropriate medical facility. Residents should not be allowed to drive themselves to a doctor's office or a hospital. Residents should not go back inside until you have inspected the conditions inside the home and authorized re-entry.

Exhibit S3.5 shows sources of and clues to a possible CO problem. Potential sources of CO include automobiles; motorcycles; trucks; golf carts; RVs; gasoline-, propane-, or diesel-fueled appliances; lawn mowers; power generators; furnaces; water heaters; clothes dryers; natural gas or propane refrigerators; ranges; ovens; space heaters; fireplaces; gas logs; wood and coal stoves; charcoal or gas grills; kerosene heaters; wood stoves; and any other equipment or appliance that burns fuel.

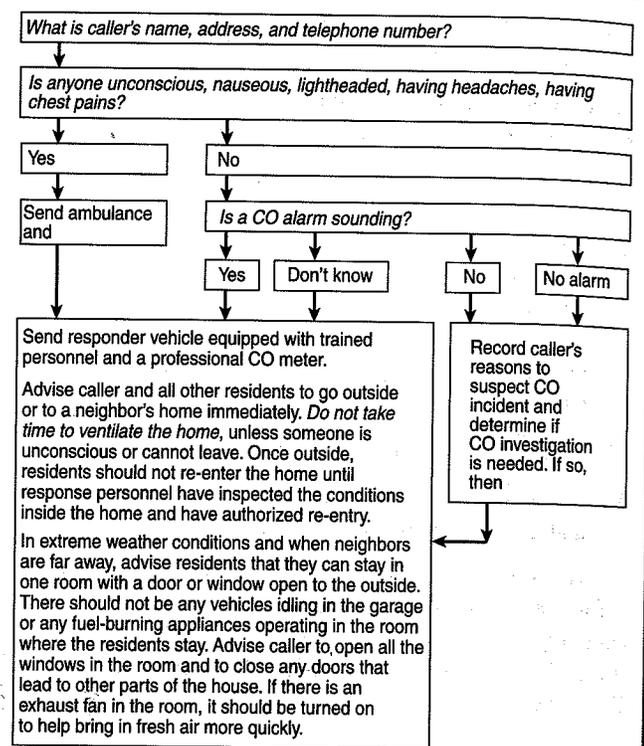


EXHIBIT S3.3 Guidelines for Dispatcher Response.

These potential sources can be improperly installed, used, or maintained, leading to elevated levels of CO. Improper home remodeling can cause CO problems by interfering with combustion air supplies, for example. It is important to note whether you see any indication of this. For example, gasoline generators improperly used indoors and gas ovens improperly used for heating or lined tightly on the bottom with aluminum foil can increase CO emissions and lead to CO buildup in homes.

When taking indoor CO measurements, you should take one set of CO measurements in areas or rooms of the house where there are potential sources of elevated CO that were in operation at the time of the call or were in use in the 24 hours before the call. Record your measurements on the CO measurement form, shown in Exhibit S3.6.

To complete the entire investigation, you will need to take one set of measurements. These measurements will help you assess whether there are elevated levels of CO in the home and what the source(s) of those elevated levels might be.

### CO Levels: Advice to Give, Actions to Take

During the investigation process, residents should be evacuated from the home. After the investigation is

### CO INCIDENT REPORTING FORM

#### STEP 1: Determine the Level of Care Needed by Household Members

**Part A.** If residents are inside the house, go to Part B below. If residents are outside the house, find out the following information:

Are any members of the household feeling ill? \_\_\_\_\_ Yes \_\_\_\_\_ No

Which symptoms are they experiencing?

- \_\_\_\_\_ Headache \_\_\_\_\_ Nausea \_\_\_\_\_ Dizziness \_\_\_\_\_ Confusion \_\_\_\_\_ Shortness of Breath \_\_\_\_\_ Chest Pains  
 \_\_\_\_\_ Other (describe): \_\_\_\_\_

*Note: Cardiac patients are the most susceptible to CO poisoning and may experience chest pains.*

*Note: The symptoms of moderate CO poisoning are similar to those of the flu, and CO poisoning can be misdiagnosed.*

**Part B.** If residents are inside the house, follow local procedures for safe entry before determining the condition of the residents. If no local safe entry procedures for a CO incident exist, take the following steps:

1. Have self-contained breathing apparatus (SCBA) available and ready for use. Follow your jurisdiction's guidelines for using this equipment. If there is any doubt about CO levels, use SCBA.
2. Using your CO meter and following the manufacturer's instructions, take a CO reading outside. Make sure you are standing away from any vehicle exhaust or other source of CO.
3. Record the outside reading on the CO measurement form (Exhibit S3.4). This will be the baseline reading.
4. Before entering the home (standing in the doorway), take a second CO reading.
5. Record this reading on the CO measurement form.
6. Make sure you continue to be properly protected until safe CO levels are attained. Leave windows and doors open or closed — just as you found them — until you begin Step 3 of this investigation.
7. Take all residents outside. Occupants should remain outside until you have inspected conditions inside the home and authorized re-entry.
8. Determine the medical condition of all of the residents by following Part A above. This should be done by appropriately trained EMS/fire fighter personnel.

#### STEP 2: Identify Potential Sources of Elevated CO in the Home and Attached Garage

**Part A.** List the potential sources of elevated CO in the home that were in operation at the time of the call or were in use in the 24 hours before the call. Note their location in the home, and whether they are vented to the outside of the home.

Potential Source	Location	Vented or Unvented
Example: Kerosene Heater	Living Room	X
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

**Part B.** Examine flues, vents, and chimneys for blockage by birds' or other animals' nests or by debris, such as chipped or cracked masonry. Note any loose or disconnected vent or chimney connections, any loose or missing furnace panels, and any debris or soot in the chimney. Advise occupants to have flues, vents, and chimneys professionally serviced if problems are indicated.

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

(NFPA 54HB, 1 of 2)

EXHIBIT S3.4 Procedure for CO Incident Investigations.

(continues)

**Part C.** *If there is an attached garage, answer the following questions:*

- Were any vehicles in the garage in the last 12 hours?     Yes     No  
 Were any vehicles' engines on in the last 12 hours?     Yes     No

**STEP 3: Take Indoor CO Measurements**

**Part A.** *Take indoor measurements by completing the following steps:*

1. If you have not already taken (and recorded) a CO reading outside and at the entry to the home, then return to Step 1, Part B, 1 through 5, and follow those instructions. After taking indoor readings, you will need to subtract the outdoor reading from the indoor reading in order to determine the contribution that indoor sources make to any measured CO indoors. For example, if the outdoor reading is 25 ppm and the indoor reading is 40 ppm, then the contribution from indoor sources is 15 ppm.
2. Close all windows and doors. Turn on the fuel-burning appliances and other CO sources that have been in operation in the past 24 hours and let them reach operating temperature (about 15 minutes). Keep them on during the measurements. Be sure to put pots with water in them on all range-top burners that have been used in the past 24 hours because cold pots on the burner can elevate CO readings.
3. Measure and record indoor CO levels throughout the house. *Important:* Take measurements in the ambient air in the center of each room, standing back approximately 5 feet from any potential CO source. Do *not* take measurements in or near vents or flue pipes.
4. Check for proper draft in a natural draft furnace by using a smoke test. Hold a lit match near the draft hood of each of the appliances that you turned on. Blow the match out. The smoke will be drawn into the hood if there is proper draft.
5. When you have finished taking all measurements and if you measured elevated CO levels, then open all doors and windows of the residence so that the home will be ventilated.

**STEP 4: Evaluate Information**

- A. Consider all of the information gathered in the investigation. Review the CO measurements you recorded.
- B. Consider whether a vehicle was left idling near the home or in an attached garage (even with the garage door open).
- C. Consider whether a portable propane, diesel, or gasoline-powered appliance was in use.
- D. Consider whether any ventilation equipment or exhaust fans were used in the 24 hours before the call.

**STEP 5: Complete the Investigation**

Gather the following information:

Resident's Name \_\_\_\_\_  
 Address \_\_\_\_\_  
 Phone Number \_\_\_\_\_  
 Incident Location (if different from address) \_\_\_\_\_

Type of Residence:     Apartment     Single-family     Townhouse     Duplex  
                                   Commercial establishment     Other (describe): \_\_\_\_\_

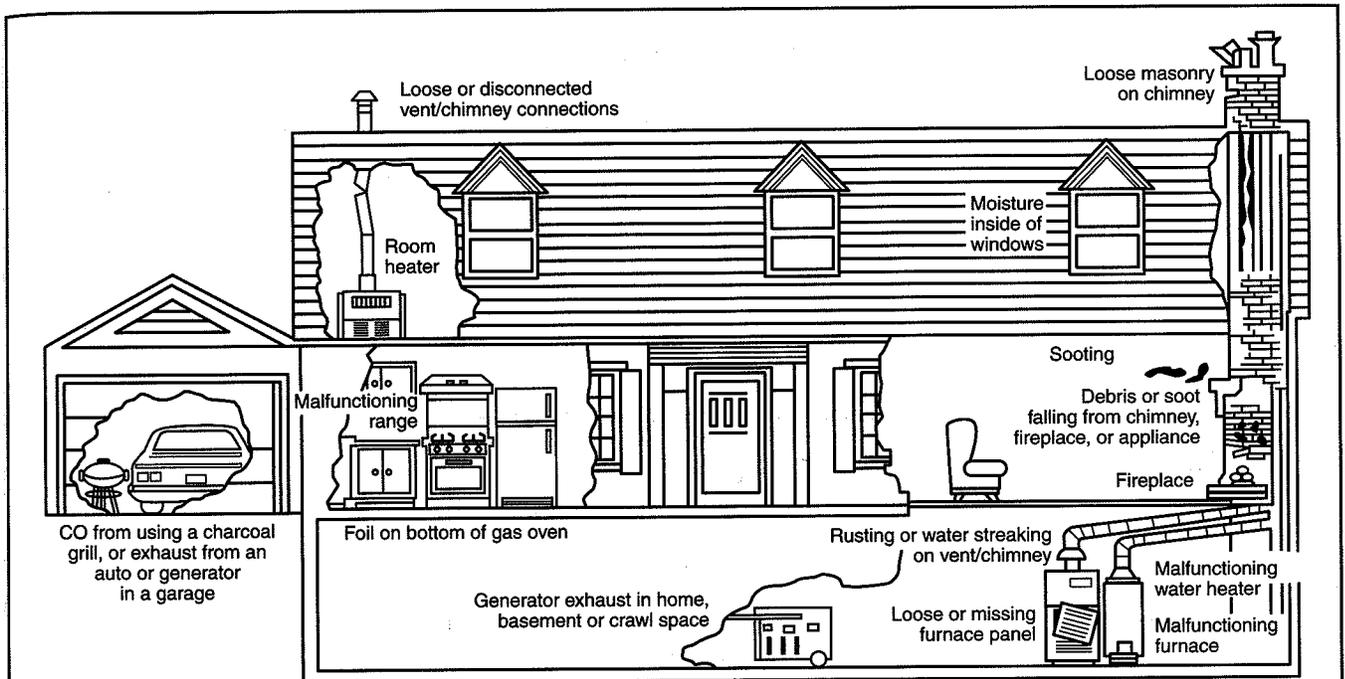
Today's Date \_\_\_\_\_  
 Date/Time of Call \_\_\_\_\_  
 Date/Time Alarm Sounded (if applicable) \_\_\_\_\_

**STEP 6: Advice and Follow-up**

- A. Read the section, "CO Levels: Advice to Give, Actions to Take," elsewhere in this document.
- B. Give residents written advice based on this section and on the information you gathered in your investigation. Use the form in Exhibit S3.5.
- C. Record the advice you gave to the resident:  
 \_\_\_\_\_  
 \_\_\_\_\_

- D. Tell occupants that regular maintenance of fuel-burning appliances is the first line of defense against CO poisoning.
- E. Keep a copy of this report (including the CO measurement form in Exhibit S3.4) for your files.

Your Name (Print): \_\_\_\_\_  
 Your Signature: \_\_\_\_\_



**Carbon monoxide clues you can see...**

- Rusting or water streaking on vent/chimney
- Loose or missing furnace panel
- Sooting
- Debris or soot falling from chimney, fireplace, or appliances
- Loose or disconnected vent/chimney, fireplace, or appliance
- Loose masonry on chimney
- Moisture inside of windows

**Carbon monoxide clues you cannot see...**

- Internal appliance damage or malfunctioning components
  - Improper burner adjustments
  - Hidden blockage or damage in chimneys
- Only a trained service technician can detect hidden problems and correct these conditions!
- CO poisoning symptoms have been experienced when you are home, but they lessen or disappear when you are away from home.

**Warnings...**

- Never leave a car running in a garage even with the garage door open.
- Never run a generator in the home, garage, or crawl space. Opening doors and windows or using fans will NOT prevent CO buildup in the home. When running a generator outdoors, keep it away from open windows and doors.
- Never burn charcoal in homes, tents, vehicles, or garages.
- Never install or service combustion appliances without proper knowledge, skills, and tools.
- Never use a gas range, oven, or dryer for heating.
- Never put foil on the bottom of a gas oven, because it interferes with combustion.
- Never operate an unvented gas-burning appliance in a closed room or in a room in which you are sleeping.

**EXHIBIT S3.5** Sources of and Clues to a Possible CO Problem.

complete, it is time to assess the information you have and provide advice to the residents, including whether they can safely re-enter the home. The final decision on re-entry may need to be made by someone other than the first responder.

The CO levels you measured in various rooms of the residence should have been taken in the center of the room in ambient air, making sure you were about 5 ft away from any appliance. Based on those measurements and your evaluation of the information you gathered in your investigation, identify any areas of the house with measured CO levels of (1) 70 ppm or higher, (2) between 30 ppm and 70 ppm, or (3) less than 30 ppm. Then use the guidelines in

this section to give advice to residents using the form shown in Exhibit S3.7.

**CO Levels: 70 ppm or Higher.** *If the source of these CO levels appears to be a vehicle or an appliance, such as a lawn mower or generator, in a garage*

- Turn off the engine if it is still on.
- If you suspect that an appliance or a generator or a vehicle engine that was idling in a garage several hours earlier is the cause of elevated CO levels, advise the consumer that engines should not be left idling in an attached garage, even with the garage door open.

### CO MEASUREMENT FORM

Record levels of CO found throughout the home. Take measurements in the center of each room under the conditions specified in the CO incident reporting form (Exhibit S3.2).

**Measurements (CO ppm):**

Outdoors (baseline) \_\_\_\_\_ Entrance (doorway) \_\_\_\_\_

Measurements (ppm) with recently used potential CO sources turned on and doors and windows closed:

- Attached Garage \_\_\_\_\_
- Utility Room \_\_\_\_\_
- Den \_\_\_\_\_
- Dining Room \_\_\_\_\_
- Family Room \_\_\_\_\_
- Bedroom 1 \_\_\_\_\_
- Bedroom 2 \_\_\_\_\_
- Bedroom 3 \_\_\_\_\_
- Bedroom 4 \_\_\_\_\_
- Bedroom 5 \_\_\_\_\_
- Other Rooms \_\_\_\_\_

- Basement \_\_\_\_\_
- Recreation Room \_\_\_\_\_
- Living Room \_\_\_\_\_
- Kitchen \_\_\_\_\_
- Powder Room \_\_\_\_\_
- Bathroom 1 \_\_\_\_\_
- Bathroom 2 \_\_\_\_\_
- Bathroom 3 \_\_\_\_\_
- Bathroom 4 \_\_\_\_\_

Draw a diagram of the home showing locations of rooms and possible sources of CO (refer to Exhibit S3.3):

**EXHIBIT S3.6** Form for Recording CO Measurements.

### ADVICE FOR RESIDENTS

Based on my investigation of CO levels in your home, I recommend that the following actions be taken:

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Information provided by: \_\_\_\_\_

Name/Organization/Phone/Date: \_\_\_\_\_

**EXHIBIT S3.7** Form for Advising Residents After a CO Incident Investigation.

*If the source of these CO levels appears to be a permanently installed appliance*

- Turn off the appliance.
- If the fuel supply can be shut off, do so. Where appropriate, contact the fuel supplier and advise it of the possible need to “red tag” the appliance.
- Advise residents that dangerous levels of CO have been detected and that they should not use the appliance until the cause of the elevated CO has been identified and corrected by a qualified technician. The appliance may not need to be repaired or replaced; it is possible that an adjustment to exhaust fans or some other house situation may need attention.

*If the source of these CO levels appears to be a portable appliance*

- Turn off the appliance.
- Advise residents that dangerous levels of CO have been detected and the appliance must be inspected and repaired or replaced before being used again.
- Advise residents that if the appliance passes inspection, but the CO problem recurs, then a qualified contractor or service person should investigate the appliance while it is being operated in the home. This may help identify why elevated CO levels are in the home and what is causing elevated CO levels.

*If you believe that misuse is the cause of CO (for example, using a charcoal grill or a gas oven to heat a home during a power outage)*

- Educate the resident about the causes and dangers of CO and the proper use of appliances.

*If you cannot find an apparent source of elevated levels of CO*

- Follow your jurisdiction’s guidelines or advise the resident to call a heating, ventilating, or air conditioning (HVAC) company immediately to identify and correct the conditions causing the elevated CO levels.
- Advise residents that they can return to the home after it is cleared of CO. When your equipment shows levels of CO below 30 ppm, residents can return to the home. If your equipment shows a CO level below 30 ppm and if a household CO alarm is still sounding, remove the alarm and advise the consumer to replace it as soon as possible.
- Advise residents to have their fuel-burning appliances inspected immediately and maintained once a year by qualified professionals.
- Advise residents to use a CO alarm manufactured to one of the following standards:

Canadian Standards Association (CSA) 6.19-01, 2001  
Underwriters Laboratories Inc. (UL) 2034, Second Edition, October 1998

International Approval Services (IAS) 6-96, Second Edition, June 1, 1998

- Advise all residents to call again if their CO alarm sounds — particularly if they have followed the above recommendations.

**CO Levels: Between 30 ppm and 70 ppm.** *If the source of these CO levels appears to be a vehicle or an appliance, such as a lawn mower or generator, in a garage*

- Turn off the engine if it is still on.
- If you suspect that an appliance or a generator or a vehicle engine that had been idling in a garage several hours earlier is the cause of elevated CO levels, advise the consumer that engines should not be left idling in an attached garage, even with the garage door open.

*If the source of these CO levels appears to be a permanently installed appliance or a portable appliance*

- Turn off the appliance.
- Advise residents that potentially dangerous levels of CO have been detected and that they should not use the appliance until the cause of elevated CO levels has been identified and corrected. Advise residents that a condition in the home may be the cause and that a qualified contractor or serviceperson may need to be in the home while the appliance is in operation to identify and repair the CO source.

*If you believe that misuse is the cause of CO (for example, using a charcoal grill or a gas oven to heat a home during a power outage)*

- Educate the resident about the causes and dangers of CO and about the proper use of appliances.

*If you cannot find an apparent source of elevated levels of CO*

- Follow your jurisdiction's guidelines or advise the resident to call a heating, ventilating, and air-conditioning (HVAC) company immediately.
- Advise residents that they can return to the home after it is cleared of CO. When your equipment shows levels of CO below 30 ppm, residents can return to the home. If your equipment shows a CO level below 30 ppm and a household CO alarm is still sounding, then remove the alarm and advise the consumer to replace it as soon as possible.
- Advise residents to have their fuel-burning appliances inspected immediately and maintained once a year by qualified professionals.
- Advise residents to use a CO alarm manufactured to the requirements of one of the following standards:

Canadian Standards Association (CSA) 6.19-01, 2001  
Underwriters Laboratories Inc. (UL) 2034, Second Edition, October 1998

International Approval Services (IAS) 6-96, Second Edition, June 1, 1998

- Advise residents to call again if their CO alarm sounds — even if they have followed the above recommendations.

**CO Levels: Less Than 30 ppm.** Advise residents that you did not find high levels of CO.

- If the call was the result of a sounding CO alarm, advise the resident to review the manufacturer's instructions about a sounding CO alarm and to contact the manufacturer if necessary.
- If the alarm was manufactured before October 1, 1998, advise residents that they may want to purchase a new alarm that meets the requirements of one of these standards:

Canadian Standards Association (CSA) 6.19-01, 2001  
Underwriters Laboratories Inc. (UL) 2034, Second Edition, October 1998

International Approval Services (IAS) 6-96, Second Edition, June 1, 1998

- Alarms made before that time were subject to nuisance alarming; the new standards reduce the possibility of nuisance alarming. Advise residents that CO alarms have a limited life and that their alarm may need to be replaced. Advise residents never to ignore a sounding CO alarm and to call you again if the alarm activates.

(The following section provides information about why 30 ppm and 70 ppm are used as benchmark levels.)

**A Note About Benchmark CO Levels.** You may have read or heard about standards or recommendations for allowable (or safe) CO levels. Usually, these apply to particular environments, such as outdoors or the workplace. There is no U.S. federal government standard that sets an allowable *residential indoor* level for carbon monoxide; however, there are industry standards for allowable CO emissions from individual indoor appliances, such as furnaces or ovens.

Varying levels of CO exposure may cause varying health effects; there are levels that are not likely to cause adverse health effects in healthy adults, higher exposure levels that can be potentially life-threatening, and levels high enough to cause death. The effects of CO exposure depend on the length of time that a person has been exposed to CO, how high the CO concentration is, how physically active the person is at the time of exposure, and the person's general state of health. When a person breathes in CO, the CO combines with oxygen in the blood to form poisonous carboxyhemoglobin (COHb). The amount of COHb in a person's blood is expressed as a percentage. For example, a person exposed to CO might be described as

having 8 percent COHb. Heavy smokers may have baseline levels of 10 percent COHb.

A 10 percent COHb level is a reference value that is widely regarded by physicians as confirmation of CO poisoning, even if there are no symptoms; when used as an upper limit, it is widely recognized as protecting healthy adults against the harmful effects of CO. At this level, a person generally is still able to take action to alleviate a potential life-threatening CO exposure. This benchmark is built into industry standards for CO alarms; a CO alarm MUST sound at exposures predicted to reach 10 percent COHb in heavily exercising individuals. This will occur at concentrations and times of 70 ppm CO for slightly more than 3 hours, a level of 150 ppm for 50 minutes, or a level of 400 ppm for approximately 15 minutes. At these same exposures, less-active individuals will have less than 10 percent COHb. At levels less than 30 ppm, it is unlikely that adverse health effects will occur in healthy adults. This is a second benchmark level in the industry standards for CO alarms; alarms cannot sound at 30 ppm or less. This helps prevent false or nuisance alarms from temporary "spikes" in CO that may occur when there is an outdoor air

inversion or when an appliance is turned on and used for a relatively short time.

For the reasons described above, CPSC uses two benchmarks in this document as the basis for advice on what actions a resident should take when CO is present in the home. This first is the false alarm resistance level of 30 ppm. The second is 70 ppm, the lowest level that can cause COHb to exceed 10 percent.

The benchmark levels in this document, and the resulting advice, are suggested guidelines and do not constitute a standard. The benchmark levels are conservative in that they recommend action BEFORE potentially life-threatening CO exposure occurs. You may already be using or have come across other published standard operating procedures (SOPs) that use different CO ppm levels as a benchmark. If your jurisdiction has an SOP that works well for your needs and resources, and if the benchmark levels of the SOP, based on your experience and that of medical personnel in your community, adequately provide for the safety of residents, then you may want to continue using that SOP.

### PART III: SIDEWALL VENTED APPLIANCES

The use of sidewall vented appliances in residential construction is becoming prevalent. Sidewall vented appliances, by design, are less likely to introduce carbon monoxide to the indoor atmosphere. However, they are not immune from problems. An incident with a sidewall vented boiler installed in a two-year-old home in Plymouth, Massachusetts, resulted in the tragic death of a young girl. The incident occurred during an unusually windy snowstorm during which the area had extensive electric power failures, which may have been factors. The causes of this incident are still under investigation at the time of this publication.

It is critical that considerations be made for climate and potential changes to landscaping and construction.

Changes that impede the proper operation of the vent can result in appliance shutdown or the production of carbon monoxide. Under certain conditions, such as cold weather, wind, snow accumulation, etc., flue products emitted from a sidewall vent can be drawn into the building through passive openings that exist in most construction. Installers of sidewall vented appliances should always follow code requirements and manufacturers' instructions. Sidewall vent terminations must have proper clearance to grade or decks, windows and doors, combustion and ventilation air openings, regulator vents, etc.

As with all industry codes and standards, improvements are constantly being developed and one should always be aware of the latest changes.

### PART IV: CARBON MONOXIDE INCIDENT INVESTIGATION

Part II of this supplement, "Guidelines for Fire and Other Emergency Response Personnel," is intended to assist public emergency response personnel in fulfilling their duties of rendering medical assistance and public service. Serious carbon monoxide incidents that involve fatalities or serious illness induced by the incident will often be subjected to

detailed investigation. The parties involved in such investigations range from public agencies, representatives on behalf of injured or deceased parties, manufacturers of appliances and other fuel gas equipment, installers of fuel gas equipment, contractors, builders, code officials, and others. The discussion that follows is intended to be referenced in incidents that are suspected of having causal factors relating to fuel gas utilization equipment and systems. This presupposes that the initial broad-based investigation

of evaluation of non-fuel gas utilization carbon monoxide sources has been conducted in a proper and thorough manner.

In addition to the material presented here, two U.S. Consumer Product Safety Commission publications may also be of interest. They are too large to reprint here, but are available from the CPSC web site:

- CO Investigation Guideline
- CO Investigation Guideline – Furnaces

### Fuel Gas Appliance Fundamentals

The *National Fuel Gas Code* is a critical link to the safe and effective utilization of fuel gas appliances. The code requirements intersect with many other appliance, equipment, and building code documents whose aim is to provide safe and effective utilization of fuel gas energy. In the broadest sense, the event represented by a carbon monoxide incident wherein carbon monoxide produced by a fuel gas appliance enters a habitable space is an indication that one or more elements of these codes and standards failed to exist at the time of the incident.

Conceptually, a fuel gas appliance produces only an inconsequential amount of carbon monoxide in its combustion products during proper operation. If the operation of a particular appliance has deteriorated (for whatever reason), a carbon monoxide-related event will still not occur if the combustion products continue to be vented properly from the subject appliance to the outdoors. The investigation of a carbon monoxide incident must therefore evaluate both the operation of specific appliances as well as the ventilation and venting of the building envelope under consideration.

### First Responder Alterations

As is the case with many categories of accident investigations including automobile, fire, industrial, and so on, first responders to a carbon monoxide incident often provide a critical link for understanding the conditions in the habitable space at the time of the event. Part 1 of this supplement provides an indication of possible data that might be obtained by first responders and any subsequent detailed investigation should necessarily inquire as to whether such data is available. First responder data certainly might also include photographs of the building envelope and any combustion appliances.

Another element of first responder activity is the possible alteration to the existing system as a result of necessary or inadvertent actions on the part of first responders. The degree of alteration to systems by initial responders is known to have varied from minor and inadvertent, such as the removal of portable obstructions found covering com-

bustion air intakes, to major modifications even including "troubleshooting" and repair of appliances by service personnel or others. The consequences to the subsequent carbon monoxide investigation of such scene alterations can be significant if no documentation as to the sequence and methodology of the first responders is known.

### Why Now?

Carbon monoxide incidents can commonly involve complex and interacting system and environmental factors. Whatever the combination of causal factors that comes together to produce carbon monoxide in the habitable space, there is always a significant question to be resolved related to the timing of the occurrence. Clearly, significant factors related to possible deterioration or alteration to appliances or venting systems have to be considered if the event occurs with systems that are many years old as compared to a system that has just been installed with service initiated shortly before the incident.

Also fundamental to the question of the timing of a carbon monoxide incident are the characteristics of the incident itself. Broadly speaking (and there is a substantial range of actual incident type), carbon monoxide incidents can commonly be thought of as either long-term chronic exposure to elevated but nonfatal levels of carbon monoxide or shorter-duration acute exposures to high and possibly fatal levels of carbon monoxide. Understanding the fundamental background of a carbon monoxide incident can assist in evaluating the pertinent system elements, which would be important to either type of case.

Common to both categories of incident is the necessity to understand the history of the fuel gas systems involved, including a history of the building envelope. Pertinent portions of the system history can include the timing and details of the initial fuel gas system installation, service information, additions or alterations to the habitable space that would influence the performance of the fuel gas system, such as the addition of walls, partitions, additional combustion appliances, etc., and evaluation as to whether or not any of these changes had an effect at the time of the incident. The changes to the building envelope can be so broad as to include exterior changes to the building that may include alterations to exterior vents or landscaping, which obscures vents in a pre-existing location or otherwise alters or impairs their operation. Accidental environmental alterations, such as obstruction of vents or ventilation by weather or animal activities, must also be considered.

Gas system service calls can also be an indication as to when the system may have been altered or, possibly, when it may last have been known to be operating safely and efficiently. Changes in the system may often be tied to

service records for the system to indicate changes to the appliances or other building envelope alterations.

A significant factor in some carbon monoxide incidents is the influence of adverse weather. Weather effects can produce an aberrant system performance as influenced by extremes of temperature, wind, and precipitation. During the investigation of a carbon monoxide incident, it is understood that various weather conditions may not be reproducible at the time the habitable space is tested for evaluation but the weather data is nonetheless pertinent as an evaluative point for determination of the system performance.

### Incident Scene Investigation

The most effective carbon monoxide incident scene investigation starts well before the physical examination and testing of specific appliances and building systems. As is common and recommended for many types of accident investigation, notification of interested parties, such as those listed at the beginning of this section, can be one of the most useful tools in executing an effective scene investigation. Specifically, the manufacturers of appliances and other fuel gas system components can provide valuable technical input to the scene examination as well as provide an opportunity for the development of a proper test protocol. Similarly, builders, installation contractors, and other persons involved with the appliances and structure may provide valuable information as to the circumstances of the appliance installation and operation and, in many jurisdictions, these parties may have legal rights of notification when they are involved in such an investigation.

A protocol for examination and testing of a building and gas appliance system is extremely useful in providing a thorough and efficient investigation. The most effective investigations benefit when this protocol is made available to participating parties in advance of the joint investigation. Obvious elements during any such investigation include a detailed visual examination of all system components, including the condition of the building envelope. This inspection is commonly expected to include evaluation of the venting systems, combustion air accommodation, and gas pressure regulation system, and a general visual examination of gas utilization equipment without altering the as-found condition.

The testing of fuel gas appliances and the carbon monoxide incident investigation should proceed in a methodical stepwise manner so as to allow documentation of all pertinent data and so as to disclose any operating anomalies that exist or are suspected to exist. Information commonly accepted to be pertinent to such testing includes current weather conditions, gas system delivery pressure, the monitoring of the internal to external building envelope pressure (as influenced by appliance operation, wind ef-

fects, or other factors), combustion performance, thermostatic device operation, and, of course, monitoring of carbon monoxide within the habitable space under examination. Such investigations are undertaken to evaluate the cause of harmful or lethal situations. As such, appropriate personal protection measures must be taken that may vary widely from incident to incident but at the least should monitor carbon monoxide levels for personnel safety during all testing. Other scene safety measures may be deemed necessary by criteria established by responsible and knowledgeable safety officials or consultants associated with the investigation.

### General Considerations

Responsibility for conducting carbon monoxide incident scene investigations may fall to one of several categories of possible parties. These certainly include, at a minimum, public officials, representatives of injured or deceased victims of the incident, property owners, and others. Representatives of broad elements of the gas industry are commonly called upon for direct or indirect assistance for investigation of carbon monoxide incidents. Any individual acting in this capacity must remain aware of the complexity of most carbon monoxide incidents. Ordinary troubleshooting techniques used in appliance servicing are inadequate to properly document and memorialize appliance operation, building envelope behavior, the influence of external factors, such as other solid fuel-burning appliances and fan operations. Participants in the investigation must understand the need to evaluate and document these many contributing factors.

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