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Standard Guide for Field Investigation of Carbon Monoxide Poisoning Incidents[1]

This standard is issued under the fixed designation E2292; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers collection and preservation of information and physical evidence related to incidents involving the poisoning of individuals by carbon monoxide.

1.2 This guide is not intended to address the medical effects of carbon monoxide exposure.

1.3 This guide is not intended to be a guide for investigating carbon monoxide poisoning caused by hostile fires, or contamination in closed air systems or confined spaces. Guidance on the investigation of carbon monoxide poisonings related to fire can be found in NFPA 921.

1.4 This guide is not intended for an investigation where equipment is removed from the incident site and conducted in a more controlled setting.

1.5 This guide is intended to be used by a wide range of investigators, including first responders, appliance technicians and engineers.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E1459 Guide for Physical Evidence Labeling and Related Documentation

E2713 Guide to Forensic Engineering

2.2 *NFPA Standards:*[3]

NFPA 54 National Fuel Gas Code

NFPA 921 Guide for Fire and Explosion Investigations

2.3 *UL Standards:*[4]

UL 2034 Single and Multiple Station Carbon Monoxide Alarms

3. Significance and Use

3.1 This guide is intended for use by individuals who investigate incidents involving carbon monoxide poisoning. If this guide is followed, the cause for the carbon monoxide poisoning incident may be determined, and corrective action may be identified to prevent future incidents.

3.2 When attempting to identify the source of carbon monoxide, consider that it is produced at some level in virtually every fuel-burning engine, boiler, furnace, burner, stove or fire. All carbon-based fuels (for example, gasoline, diesel fuel, natural gas, propane, coal, wood, paper products, plastics) produce carbon monoxide as a result of incomplete combustion. When there is insufficient air for complete combustion, carbon monoxide can become a major product of combustion. In properly-operating combustion equipment, the level of carbon monoxide produced may be as little as a hundred parts per million or less (that is, 0.01 %). However, combustion with insufficient air can produce carbon monoxide concentrations of 10 000 ppm to 100 000 ppm (that is, 1 to 10 %) or higher.

3.3 Be aware of the effects of carbon monoxide on humans and pets. Carbon monoxide acts as a central nervous system depressant. With increasing concentration or time of exposure, or both, carbon monoxide will cause people to feel sleepy or sick, lose consciousness, and die. Carbon monoxide is especially hazardous because it is colorless and odorless, providing no warning of its presence. When inhaled, carbon monoxide binds with hemoglobin in the blood, creating carboxyhemoglobin (COHb). The affinity of carbon monoxide for hemoglobin is approximately 200 times greater than the affinity of

[1] This practice is under the jurisdiction of ASTM Committee E58 on Forensic Engineering and is the direct responsibility of Subcommittee E58.05 on Industrial Processes.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[4] Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, http://www.ul.com.

oxygen for hemoglobin. Therefore, the blood can accumulate dangerous levels of COHb, depriving the body of oxygen.

3.4 Since there is the potential for investigators to become victims of elevated carbon monoxide levels themselves, extreme care should be taken to assure the safety of investigators and anyone else at risk of continuing carbon monoxide exposure. Carbon monoxide monitoring and measurement equipment is required to ensure life safety of those present, as well as to determine the cause of the problem and its solution.

4. Equipment

4.1 The following is a listing of basic measurement equipment that may be useful in diagnosing a carbon monoxide problem and determining the source, cause, and validating corrective actions:

4.1.1 *Electronic Carbon Monoxide Monitor*—A properly calibrated direct reading electronic monitor having a range of 0 to 1000 or 2000 ppm (that is, 0.1 to 0.2 %) is preferred in that its output provides almost instantaneous concentration data, and it therefore has the capability to warn the investigator if carbon monoxide levels are reaching dangerous concentrations. The carbon monoxide monitor may also be used to survey different areas of a building to locate the area of highest concentration, helping to identify the source.

4.1.2 *Carbon Monoxide Alarms (compliant with UL 2034)*—These alarms may be used as warning devices (see Section 5). Alarms with digital readouts should not be used as primary investigative monitors since their range is typically limited to ~100 ppm (that is, 0.01 %).

4.1.3 *Combustion Gas Analyzer*—Because malfunctioning combustion equipment is sometimes found to be the source of excessive carbon monoxide, portable gas analyzers are useful to check the combustion products produced by fuel burning equipment. These instruments indicate carbon monoxide as well as other exhaust gases. Combustion gas analyzers are used to determine whether the combustion equipment is operating within its normal limits for carbon monoxide in the exhaust. A measurement range up to 10 % carbon monoxide (100 000 ppm) may be required.

4.1.4 *Manometer*, or equivalent insturment, capable of determining positive and negative pressures in the combustion air supply, exhaust stack, and inside the living space while fuel burning equipment is operating.

4.1.5 *Ventilation Equipment*—A fan, blower, or similar device should be available to provide air movement in the space around equipment between tests. Monitor the carbon monoxide level in the area before running each test.

4.1.6 *SCBA (self contained breathing apparatus)* may be used if entering a highly contaminated area while conducting tests.

4.1.7 All indicating equipment should be calibrated at least annually or per the manufacturer's recommendations, and checked prior to each use. The equipment may be checked against a standard reference gas. Selection of calibration gas concentrations should reflect both low and high range for gas measurement equipment.

5. Safety

5.1 Entering spaces and testing of equipment suspected of causing carbon monoxide poisoning may yield definitive results that cannot be obtained any other way. Testing of equipment that may have injured individuals; however, is a potentially dangerous undertaking, in that the investigator runs

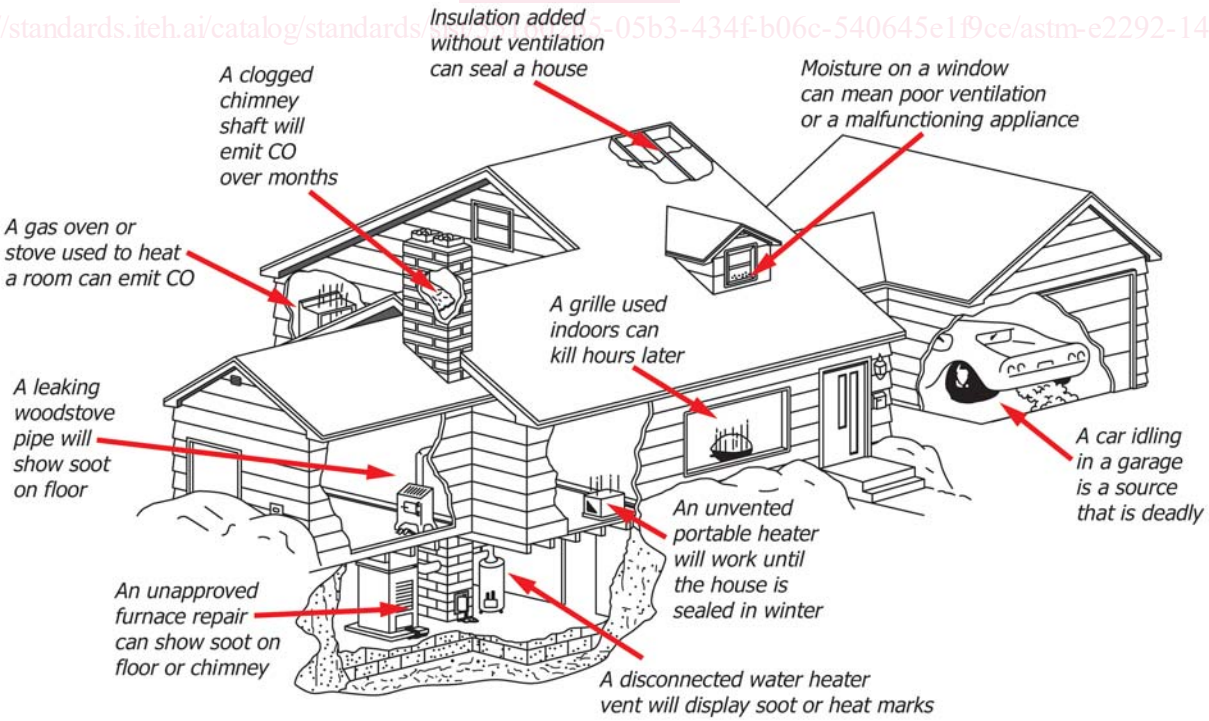

FIG. 1 Common Locations of Carbon Monoxide Build-Up

the risk of becoming exposed to carbon monoxide being produced by improperly functioning equipment.

5.2 Safe testing procedures are of the utmost importance. Before any testing is undertaken, a safety officer should be identified. The safety officer's responsibilities are to protect the safety and health of the investigator and any individuals who may be affected by the testing.

5.3 Stable communications should be assured between the site and emergency service providers.

5.4 Audible carbon monoxide alarms, compliant with UL 2034, may be used as warning devices to warn participants of hazardous conditions. Such alarms are not substitutes for carbon monoxide monitors or analyzers, which provide better accuracy.

5.5 Until its safe operation has been verified, the minimum number of participants should be in the space where a piece of equipment is being tested for carbon monoxide output that the potentially interested parties will agree upon. Those persons inside should remain within sight of the safety officer or another individual capable of rescuing that individual from the space. SCBAs may be used if necessary.

5.6 All testing should be discussed in detail with all individuals involved in the testing, prior to the beginning of any test. A written test protocol may be advisable, as discussed in 6.9 below.

5.7 Permissible levels of carbon monoxide concentration depend on the time of exposure. The U.S. Environmental Protection Agency (EPA) advises a threshold of 50 ppm averaged over 8 hours. Higher concentrations or longer exposures at lower levels, or both, are also hazardous.

6. Procedure

6.1 *Scene Security*—If the carbon monoxide concentration is elevated in the area, the first priority is to evacuate the scene and prevent further injuries or loss of life.

6.1.1 After evacuation, the scene should be secured. If possible, field measurements of carbon monoxide levels in various locations around the scene should be taken.

6.1.2 The fuel supply to the scene should be turned off. This may require the switching off of internal combustion engines, or the closing of valves for gaseous or liquid fuels.

6.2 Notify individuals who have been identified as possibly having an interest in the testing of the time that the tests are going to take place. For additional guidance on notification, see Guide E2713. The advice of legal counsel may be advisable.

6.2.1 Identify any individuals who may have an interest in the outcome of the testing. Such individuals may include the property owner, representatives of the victim(s), equipment manufacturers, equipment service personnel, law enforcement officers, code enforcement officers, and the insurance carrier for any of the parties listed above. Provide each of these individuals a copy of the testing protocol developed for their information and comment.

6.2.2 Keep a record of individuals who have been notified of the proposed testing.

6.2.3 Notification of other interested parties may not be necessary if the investigation is going to be limited to observations that do not change the condition of any of the structures or equipment.

6.3 *Documentary Information*—The following information may be of interest; not all of the information ultimately obtained will be available at the time of the initial field investigation. Nevertheless, the collection process should begin as soon as practical.

6.3.1 Emergency phone line recordings and medical records, particularly those that describe the blood gas analysis of the victims.

6.3.2 Obtain statements as early as possible from all individuals associated with the incident.

6.3.2.1 Determination of whether the occupants (including small animals) exhibited prior signs of carbon monoxide exposure; for example, flu like symptoms.

6.3.2.2 First responders' test protocols and data.

6.3.2.3 First responders' actions to correct defects or remove carbon monoxide sources.

6.3.3 Weather data prior to and at the time of the incident; wind speed and direction, temperature, precipitation (snow, rain).

6.3.4 Altitude of the site if over 2000 feet; see NFPA 54 regarding high altitude installations.

6.3.5 Maintenance/service records for any fuel burning equipment, including maintenance contracts.

6.3.6 Equipment manuals or other related information regarding operation, service, maintenance, and input ratings.

6.3.7 Activities prior to the incident that may have affected the fuel sources, fuel burning equipment or ventilation of combustion products.

6.3.8 Information about the status of carbon monoxide alarms and monitoring systems.

6.3.9 Layout of the rooms and their dimensions.

6.4 Identify all fuel-burning equipment in the site. Determine when and how often the equipment operates.

6.4.1 Fuel gas burning equipment is operated on natural gas or propane. This equipment includes boilers, furnaces, water heaters, dryers, forklifts, gas fireplaces, stoves, ovens, etc. This equipment may be vented to the outside or unvented (discharging combustion products to the living or working space).

6.4.2 Liquid burning equipment is operated on gasoline, diesel, kerosene or fuel oil. This equipment includes internal combustion engines, kerosene heaters and fuel oil burning furnaces. The equipment is usually unvented if it is portable and vented if it is stationary.

6.4.3 Solid burning equipment includes wood stoves, fireplaces and pellet stoves. These are usually stationary and vented. If applicable, note position of fireplace dampers (open or closed) as well as door and window positions.

6.5 Identify all ventilation equipment, not associated with fuel burning equipment. This equipment includes power vents for bathrooms or gas ranges, electric dryers, and heat recovery ventilators.

6.6 Determine and document the condition of the equipment at the time of the incident.

6.6.1 Determine the condition of the flues on ventilated equipment. Look for sooting that would indicate incomplete combustion. Look for corrosion that might permit the recirculation of combustion products as combustion air.

6.6.2 If the equipment includes a heat exchanger, determine whether there is a crack or break that might permit combustion products being introduced into the living/working space.

6.6.3 Measure the pressure to fuel gas appliances during operation, as well as the regulated pressure within those appliances.

6.6.4 If the equipment is convertible (for example, natural gas to propane), determine whether it is properly configured and adjusted.

6.6.5 If the altitude is above 2000 feet above sea level, determine whether the equipment is adjusted in accordance with the appliance instructions or NFPA 54.

6.6.6 Establish the condition of valves and/or switches. Systems within an appliance may be tested individually or in combination with the overall function of the appliance.

6.7 Determine the source of fuel, combustion air, and ventilation of each piece of equipment.

6.7.1 Determine whether any of the equipment is located in an enclosure that can be defined as a "confined space." Confined spaces are defined in NFPA 54 as, "a space whose volume is less than fifty cubic feet per 1000 BTU per hour (4.8 m^3 per kW) of the aggregate input of all appliances installed in that space."

6.7.2 Determine whether the equipment has an adequate supply of air for combustion and ventilation as specified in NFPA 54, Chapter 9.

6.7.2.1 Where combustion air is obtained directly from the outdoors, determine whether openings comply with NFPA 54; including reduction due to louvers, grills and screens.

6.7.2.2 Where combustion air is mechanically supplied, determine whether openings comply with NFPA 54.

6.7.2.3 Determine whether there is a separation between the return air and combustion air supply in HVAC installations in accordance with NFPA 54.

6.7.2.4 Document whether safety switches such as spill switched have been bypassed or tampered with.

6.8 Determine whether the equipment, if venting is required, is vented to safely carry the products of combustion outside, as required by NFPA 54, Chapter 12, and relevant building codes.

6.8.1 Determine whether any temporary obstruction of the equipment ventilation, including obstructions of the return vents, have been moved. Verify that this has not changed since the incident (for example, melting snow or remedial measures taken by emergency responders).

6.9 *Planning the Test*—Develop a plan for safely testing the potential sources of carbon monoxide at the scene. This planning will involve preparation of a written protocol for tests to be carried out.

6.9.1 A written protocol should be prepared for each investigation and tailored to the particular incident.

6.9.2 This plan will typically include turning on suspected equipment and observing and recording its performance 'as found' using the carbon monoxide measurement devices described in Section 4. In addition to testing equipment "as found" it may also be desirable to test the equipment in accordance with the appropriate appliance standard.

6.9.2.1 A basic protocol may be derived from that described in Appendix X2 for first responders.

6.9.2.2 The suggested basic protocol in Appendix X2 does not address the impact of misuse, whereas the forensic protocol may address the impact of that misuse; and, a steady state carbon monoxide level will require time to attain a particular level from a cold start.

6.9.2.3 The protocol may include operation of the multiple fuel burning items (for example, a furnace in combination with a fireplace) or in combination with other power vents, or both, as well as door/window positions determined in 6.5.

6.9.2.4 More detailed protocols would include a flue gas analysis for individual appliances or the impact of negative pressures on an appliance's performance, or both.

6.9.2.5 The protocol may include operation of the equipment before and after removing the defects determined above.

6.9.3 Identify the individuals who will be conducting the tests and the safety officer.

6.10 Operate each piece of equipment per the protocol; with changes as agreed to by the attending parties.

7. Collection of Physical Evidence

7.1 Once all parties to the investigation are satisfied that sufficient testing has been accomplished on site, items of physical evidence pertinent to the matter may be secured for future examination or testing.

7.2 Label according to Practice E1459.

7.3 Frequently, the device that is identified as having produced the carbon monoxide can be restored to a safe operating condition, and left in place after the condition that led to the poisoning event has been sufficiently documented. If left in place, a qualified appliance technician should make repairs and take responsibility for safe operation of the equipment.

8. Report

8.1 The report of test results should include the following information:

8.1.1 Location of test,

8.1.2 Names of those present, and

8.1.3 The test results.

8.2 The format of the report should be appropriate for inclusion in a separate final opinion report, if necessary.

9. Keywords

9.1 carbon monoxide; CO; combustion; monoxide; poisoning