Proposed Field Protocol for Gas Range Carbon Monoxide Emissions Testing

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For the
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This document is available at www.karg.com/rangeprotocol.htm

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Table of Contents

Introduction 1
Phase 1: Visual Inspection and Client Education 2
  A. Gas Range Inspection 2
  B. Client Education 4
Phase 2: Measurement of Emissions 5
  A. Safety During the Test Period 5
  B. Emission Testing Equipment 5
  C. Preparation for Burner Testing 6
  D. Range Top Burner Testing 6
  E. Oven Bake Burner Testing 7
  F. Burner or Range Failure 9
  G. Closure of Test Procedure 9
Tools Required for Protocol 9

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Notice:
This protocol and its emission limits are based on an approximation of *Household Cooking Gas Appliances* (ANSI Standard Z21.1) by the American Gas Association. ANSI Standard Z21.1 is a laboratory test conducted by manufacturers of gas ranges, not a field test. Because this protocol is intended for field use, it cannot precisely match the ANSI Standard.

The author of this protocol has attempted to base it on the latest research, practice, and technology. However, the author and the funding organizations cannot accept any responsibility for injury to a field analyst, house occupant, or anyone else caused by the use of this protocol. Any individual or organization using this protocol does so at their or its own risk

This icon indicates a policy decision might be required by program funders.

This icon indicates a maximum level of emissions from a burner. Additional study and field research may result in adjustment of the emission levels of this protocol.

Introduction

The purpose of this protocol is to guide the field analyst through a systematic procedure of gas range testing. This protocol is intended to determine whether a gas range burner(s) is emitting unacceptable levels of carbon monoxide.

The burner limits for this protocol for carbon monoxide emissions are 35 ppm CO, as-measured[1] for range top burners[2] and 800 ppm CO air-free[3] for oven bake burners. Oven broil burners are not required to be tested.

These emission levels are based on field and laboratory research, as well as on consultation with scientists and air quality experts. As more research is conducted in the areas of combustion emissions from gas ranges and assessment of human health risk factors related to CO, these allowable emission levels might change.

This method covers residential grade floor-mounted gas ranges, drop-in range top burners, and built-in ovens only. If drop-in range top burners or built-in ovens are encountered, follow the appropriate sections of this protocol for these appliances. This protocol is not intended for use with 1) outdoor gas grilles; 2) ovens in catalytic cleaning mode; 3) ovens vented into flues or chimneys; or 4) range/ovens with a closely located, down-vented, and operating exhaust fans, e.g., JennAir down-vented exhaust fan.

This protocol is not intended to determine whether gas ranges operate acceptably during misuse, such as using a range for space heating.

Accurately measuring CO emissions in the field is difficult due to the complex nature of combustion and dilution airflow patterns. Use of this protocol can increase the accuracy of measurements to, perhaps, ±30 percent. This means that the protocol will sometimes result in false failures and false passes.

Because there is a broad variety of gas ranges in the field, there is the possibility that range characteristics not addressed in this protocol will be encountered. When problems are discovered that are beyond the scope of this protocol, it is important that the field analyst use his or her good judgment when deciding whether to pass or fail a burner or range.

This protocol has two parts. Phase 1 includes range inspection and client education. Phase 2 includes instrumented emissions testing of the range top and oven burners. Complete Phase 1 before moving on to Phase 2.

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[1] CO as-measured is a part-per-million (ppm) or percentage reading that is *not* adjusted (normalized) with corresponding O_2 or CO_2 readings from the same combustion gas sample.

[2] For the average test, this value is approximately 800 ppm CO air-free allowable emissions from each range top burner.

[3] CO air-free is a CO as-measured reading that has been adjusted (normalized) with corresponding O_2 percentage readings from the same combustion gas sample. CO air-free is usually expressed as a parts-per-million (ppm) value, but it is actually an emission rate, not a percentage.

Phase 1: Visual Inspection and Client Education[4]

A. Gas Range Inspection

1. **Range top inspection:**
    a. Inspect the range top burner area for cleanliness. If the burners or burner area are dirty enough to *adversely impact the combustion process*, inform the client that the range should be cleaned to reduce the possibility of unacceptable emissions. Do not test for CO emissions until the problem is corrected.
    b. Inspect the burners for proper alignment and seating.
    c. All cooking vessel support grates should 1) be in place, 2) fit properly in the burner well, and 3) be in one piece with no broken parts.
    d. If any of the grates are missing or in unsatisfactory condition, the client should not use the affected range burner(s) until the substandard or missing grate is replaced. If a grate(s) cannot be repaired or replaced, the decision whether to replace the range should be made by those funding the program, with appropriate input from the client.
    e. If the range top burners are ignited with a standing pilot light, verify that the pilot flame is present, is about 5/16 in length, and is soft blue in color (not yellow). When properly adjusted, a standing pilot uses about 75 Btuh.
2. **Oven area inspection:**
    a. Inspect the oven for cleanliness. If the burners or oven area are dirty enough to *adversely impact the combustion process*, inform the client that the range should be cleaned to reduce the possibility of unacceptable emissions. Do not test for CO emissions until the problem is corrected.
    b. Check the oven for blockage of the oven-bottom vents. These vent holes must not be blocked by anything in the oven, such as aluminum foil. The vent openings must ***never*** be obstructed because they are an important part of the oven combustion venting system.
    c. Check for air blockage at the bottom of the range and drawer and/or broiler compartment under the oven. Dust, lint, pet hair, rugs, or any other obstruction blocking free airflow to the oven bake burner must be removed.
    d. Check the oven bake-burner spreader plate (burner baffle). Most bake burners (the one at the bottom of the oven compartment) have a flame spreader plate just under the oven compartment bottom and above the bake burner flame (typically, this plate is attached to the oven bottom). Warped or detached spreader plates can result in flame impingement and quenching (cooling) of the gas flame, causing increased production of carbon monoxide. Many spreader plates are intentionally bent into curved or angular shapes, or dimpled, to add strength. Inspect carefully with a flashlight and inspection mirror to determine if the spreader plate has distorted from its original shape or has detached from the oven bottom. Ignite the bake burner to inspect the flame. The flame should not extend beyond the edge of the spreader plate. Also, inspect for carbon buildup on the spreader plate and the oven bottom. Any carbon buildup can be an indication of incomplete combustion caused by flame quenching or a fuel-rich gas mixture.

[4] This phase requires from five to ten minutes of the analyst's time.

   e. If the range also has a broil burner at the top of the oven compartment, check its flame for proper size and color.
   f. Inspect the oven compartment and under the oven compartment for any other defects that could lead to unacceptable CO emissions.
   g. If the oven burner(s) is ignited with a standing pilot light, verify that the pilot flame is present, is about 5/16 in length, and is soft blue in color (not yellow). When properly adjusted, a standing pilot uses about 75 Btuh.
3. **Inspect gas range installation for code compliance.** Refer to the latest edition of the *National Fuel Gas Code* (NFPA 54), section 6.15: Household Cooking Appliances.
4. **Verify that the range is set up for the supply gas.** When a gas range is setup for natural gas but has propane piped to it, dangerous over-firing of the burners results. Although this is not a common occurrence, each range should be checked. Natural gas piped to a range setup for propane is not as hazardous because it results in under-firing.
   a. Gas characteristics:
      i. Propane (LPG) contains 2500 Btu per cubic foot. Gas ranges using propane usually operate at a gas pressure of 7 – 11 inches of water. Because of these characteristics, propane requires a smaller orifice size at each burner and a higher pressure than natural gas.
      ii. Natural gas (methane) contains 1000 Btu per cubic foot. Gas ranges using natural gas usually operate at a gas pressure of 3.5 to 6 inches of water. Because of these characteristics, natural gas requires a larger orifice size than propane at each burner and a lower gas pressure.
   b. If a range is setup for natural gas but has propane piped to it, it will be over-firing, probably creating unacceptable levels of CO. ***A gas range in this condition must not be used until the problem is corrected.*** Symptoms of this problem include noisy flames, yellow flames, large flames rising above the cooking vessel support grates on the range top burners, carbon (smoke) emissions, or unacceptable carbon monoxide emissions.
   c. If a range is setup for propane but has natural gas piped to it, it will be under-firing. In this case, the client might complain of the long period required to boil water or the amount of time required for baking. This condition is usually not hazardous, but it should be corrected.
   d. Methods for verifying supply gas type and range setup:
      i. Client interview
         1. Ask client about the history of the gas range. Is it new? Is it a recently acquired used range? If so, do they know where it was obtained? The client's answers might indicate the gas for which the range was setup at its last location.
         2. Ask client if they have noticed any flame irregularities. Flames too big, yellow, or noisy? Flames very small, cooking or baking taking too long?
      ii. Flame inspection
         1. Range top burner flames should appear normal on the high setting, in size, color, and sound. If the flames appear over-fired or under-fired, it is likely that there is a setup/gas supply mismatch.

iii. Determine gas type piped to gas range
   1. Ask client. Verify by checking for natural gas meter or propane tank and corresponding piping to the appliance.

iv. Determine gas range setup: natural gas or propane
   1. The best way to determine which gas the range is setup to burn is by inspection of orifice sizes or settings, inspection of pressure regulator settings, and measurement of gas pressure. However, because such an inspection is beyond the scope of this protocol, base your appraisal on the performance of the burners, that is, if it appears that all or most of the burner flames are over- or under-firing, assume the range setup does not match the supply gas.

e. ***If it is determined that the range setup gas does not match the supply gas, the client must not use the range until the mismatch is corrected.***

5. **Check for flexible connector**. If the flexible gas connector can be inspected without moving the range, or if the range is moved out for replacement, make sure the flexible connector is 1) not brass, 2) is not a two-piece connector, and 3) has no pre-1973 rings (in some cases, the date can be found on the flare nuts rather than the date rings). Do not move the range for the sole purpose of inspecting the flexible connector; this movement might crack or otherwise damage it.
6. **Check for gas leaks** at the range top burner area, oven area, and any accessible gas lines with an appropriate combustible gas detector. Check for propane leaks below connections (propane settles) and for natural gas leaks above connections (natural gas rises***). If any gas leaks are found, specify repair. Shut off the gas to the appliance and do not proceed with testing until the leak is repaired.***
7. ☞ ***If the gas range fails any of these items above or if the field analyst believes, for any reason beyond the scope of this protocol, that the range burners or the oven bake burner are emitting unacceptable levels of carbon monoxide 1) specify repair of the gas range or 2) specify replacement of the gas range, depending on the character of the problem(s).*** Proceed with Phase 2.

B. Client Education

Educating the client is a very important. Give a copy of *Carbon Monoxide Questions and Answers* to the client (U.S. Consumer Product Safety Commission publication # 466, http://www.cpsc.gov/CPSCPUB/PUBS/466.html), or other appropriate instructional document on the health impact of carbon monoxide. **Always take the time to explain the following to the client:**

1. **The holes in the oven bottom must never be blocked** with aluminum foil or anything else. Blockage of the vent holes can also occur from storing too much in the broiler or drawer area under the bake oven. Blockage of the oven bottom vent holes can result in unacceptable carbon monoxide emissions.
2. **Do not use the range top burners or the oven burner(s) as a space heater**. Use of a gas range for space heating is against the manufacturer's recommendations; gas ranges are not designed for such use.
3. **Install a CO alarm** in the house according to the alarm manufacture's instructions. Make sure the alarm complies with the current UL Standard 2034.

☞ (Whether to provide and install a CO alarm for the client should be determined by those funding the program.)

4. **Have the range checked and tuned once every two years** by a technician with an instrument capable of measuring carbon monoxide. This checkup and tuning should include:
    a. Adherence to this protocol
    b. Testing of range gas pressure
    c. Making all necessary adjustments for the acceptable operation of all burners. The level of carbon monoxide emissions from a burner can only be determined with an instrument that measures CO and O_2; it cannot be determined by visual inspection of the flames.
5. **The oven should be kept clean at all times.** There is evidence that dirty ovens emit more CO than clean ovens.
6. **The flames from gas burners, both natural gas and propane, should burn steadily with a clear, blue flame.** The flame normally makes a slight hissing sound, but it should not sound like a blowtorch. If the flames burn yellow and/or burn loud or irregularly, the gas range should be serviced as soon as possible. Avoid using a bad burner until it is properly adjusted or repaired.

Phase 2: Measurement of Emissions[5]

A. Safety During the Test Period

1. While performing the emissions testing, monitor CO concentrations in the kitchen. Shut down the burner(s), discontinue testing, and open windows and/or doors if indoor air concentrations rise above 35 ppm.
2. Be cautious not to burn hands or other body parts on hot test equipment or the range. Also, be mindful not to damage test equipment by open flames or hot surfaces.
3. Do not damage client's counters, floors, carpeting, or furniture with hot equipment or open flames.
4. This protocol calls for range top burners to "warm up" for at least six minutes before recording emissions. Make sure that the open flame is not left unattended during this burn period. If the analyst wishes to attend to other tasks during the burner warm-up period, ask the client to watch the burners during warm up.

B. Emission Testing Equipment

1. Emission test equipment shall comply with the following:
    a. Digital display capable of measuring CO in 1 - 2 ppm increments with ± 10 percent accuracy at 500 ppm.
    b. Give readings for a range of at least 0 – 2000 ppm CO.
    c. Reach 90 percent of final reading within one minute.
    d. Capability of continuous sampling.

[5] Phase 2 requires as much as 50 minutes of the analyst's time if the analyst attends the range during "warm up" for all five burner tests, or as little as 10 minutes if the analyst works on other tasks during burner warm up and only attends the five burners to record the readings. Do not leave the ignited range top burners unattended (a viable option is to ask the client to attend them while the analyst attends to other auditing tasks). The oven does not require attendance during warm up.

e. Probe/hose assembly for flue gas sampling capable of withstanding high temperatures and the ability to passively, chemically, or mechanically remove water vapor from the combustion emissions.
f. Instrument memory and/or printing capabilities are recommended, but not required.
g. From the same piece of equipment or a separate piece of equipment, must have the capability of measuring percentage of O_2. Measurement of emission gases with the same instrument is preferred over two instruments because of the advantage of synchronicity.[6]

C. Preparation for Burner Testing

1. Always calibrate the emissions measurement instrument according the manufacturer's recommendations*. Before using the instrument, make sure that the most recent calibration is valid* (check for the calibration label on the instrument). If the calibration period has expired, calibrate the instrument before use.
2. Zero the instrument according to the manufacturer's recommendations.
3. Check the range for gas leaks with a combustible gas detector before igniting burners.
4. Read and fully understand all instrument manufacture's instructions before using the instrument.

D. Range Top Burner Testing

1. Remove all objects from the range top.
2. Identify the gas the range uses, either natural or propane.
3. The range top burners are to be tested in order of right rear (RR), left rear (LR), right front (RF), and left front (LF).
4. Test each range top burner with the CO Hot Pot™, model 1.[7] *This protocol with its limit of as-measured CO per burner is based on the use of the CO Hot Pot™, model 1, exactly as designed. The use of any other device or a variation of the CO Hot Pot™, model 1, invalidates this range top burner test procedure.*
    a. Test range top burners before testing oven.
    b. If room air from a fan or open window or door is blowing across the range top burners, ask the client to turn off or redirect the fan, or close the window or door. The natural flow of combustion gases upward from the burner must not be disrupted during the emissions testing process.
    c. Center the CO Hot Pot™ on the burner grate.
    d. Prepare the emission measurement instrument for the test.
    e. Ignite the burner and turn to the highest setting.
    f. Start timing device.
    g. Insert the probe of the emission measurement device into the hole on the side of the CO Hot Pot™ and through the eyebolt. The open end of the probe should be positioned concentrically at the eyebolt.

[6] Use of two instruments, for example, one for measuring CO and another for measuring O_2, can result in out-of-phase readings. The different hose lengths and vacuum pump flow rates from two instruments could mean that CO is read 15 seconds after collection at the probe tip and O_2 is read 30 seconds after collection at the probe tip. This out-of-phase reading can produce less accurate results than synchronized readings from one instrument.
[7] Instructions for making this device are at http://www.karg.com/makehotpot.htm.

h. At six minutes after ignition,[8] watch the instrument carbon monoxide readings for two minutes. Record high and low readings for this period. Average the high and low readings to get the 2-minute average CO_{ppm} (as-measured). Use the printing function on the emissions analyzer, if available.

i. ***The CO_{ppm} at the burner averaged over the two minutes must be 35 ppm or less, as-measured, using the CO Hot Pot™, model 1.***

j. Determine whether the burner passes or fails the limit.

k. Test each of the four range top burners.

E. Oven Bake Burner Testing

1. Test the oven bake burner only.[9] If the oven has a separate broil burner, do not test it.
    a. If room air from a fan or open window or door is blowing across the range top burners, ask the client to turn off or redirect the fan, or close the window or door. The natural flow of combustion gases upward from the oven and out of the oven vent must not be disrupted during the emissions testing process.
    b. Clear the oven of all pots, pans, or other objects.
    c. Clear area below oven of all objects.
    d. Leave oven shelves in place.
    e. If the vent holes on the oven bottom are blocked with foil, catch pans, or anything else, ask the client to remove the blockage.
    f. Prepare the emission measurement instrument for the test.
    g. Ignite the burner, with the temperature setting at 350^{O}F. The oven burner may not ignite immediately; this is normal for some electronic ignition systems. Bake burners with standing pilots usually ignite faster.
    h. Start timing device.
    i. Insert the probe of the emission measurement instrument into the oven vent sleeve at the back of the range top. Make sure the open end of the instrument probe is fully inserted into the oven vent opening at its center. Do not allow dilution air to mix with the sampled combustion by-products. Ensure that grease or other buildup does not inadvertently block the probe tip.
    j. After beginning the oven test, do not open the oven door. If the oven door is opened after the testing period begins, wait at least five minutes or to the end of the fifteen-minute warm up time, whichever is longer, before taking emissions readings.

[8] It is typical for the CO emissions from a range top burner – with the use of the CO Hot Pot™ – to reach a maximum just after ignition, then fall, and finally move to a steady-state condition. Because of this pattern, it is possible to determine if a range top burner will pass or fail *before* the six-minute warm up period called for in the protocol. After field testing of this protocol, we found the time for the range top burner test can be safely shortened and the burner passed if 1) the maximum CO emission just after ignition is less than 35 ppm, as-measured; or 2) if the CO emission level falls to below 35 ppm, as-measured, after the maximum value is reached (it is unlikely that the emission level will again rise to above 35 ppm). Conversely, a range top burner may also be failed before the six-minute warm up if the CO emission level is significantly higher than 35 ppm, say 50 ppm, after the initial maximum is reached and there is no indication that it will fall. In cases where the analyst is uncertain whether the six-minute steady-state level will be below or above 35 ppm, as-measured, the full six-minute warm up time should be respected, followed by the two-minute emissions averaging period specified in section D.4.h., above.

[9] Separate broil burners are not to be tested because 1) they are not used as often as bake burners; 2) when they are used, they are not on as long as bake burners; and 3) not all ovens have separate broil burners.

k. It is not necessary to turn on the emissions measurement instrument at the beginning of the warm up; it may be turned on at a later, but must be ready to take readings after fifteen minutes of oven warm up time.

l. After fifteen minutes of burner warm-up, watch the emission measurement instrument for the minimum and then maximum CO_{ppm} values. The corresponding $CO_{air\text{-}free}$ must be calculated and averaged for these minimum and maximum CO_{ppm} readings. The step-by-step details:
   i. After fifteen minutes of warm up, watch for the *minimum* CO_{ppm} value (not the minimum $CO_{air\text{-}free}$ value).
   ii. Record this *minimum* CO_{ppm} value and the corresponding O_2 percentage (if your instrument automatically calculates $CO_{air\text{-}free}$, record this value at the minimum CO_{ppm} value).
   iii. Continue to watch the instrument until you detect the *next maximum* CO_{ppm} value.
   iv. Record this *maximum* value and the corresponding O_2 percentage (if your instrument automatically calculates $CO_{air\text{-}free}$, record this value at the maximum CO_{ppm} value).
   v. Use the printing function on the emissions analyzer, if available.

m. Calculate the $CO_{air\text{-}free}$ emission rates for the minimum and maximum CO_{ppm} readings from the following equation. Some emissions measurement instruments calculate $CO_{air\text{-}free}$ automatically.[10] If this is the case, this equation need not be used.[11]
   1. For natural gas and propane:

$$CO_{air-free} = \left(\frac{20.9}{20.9 - O_2} \right) x\, CO_{ppm}$$

Where: $CO_{air\text{-}free}$ = carbon monoxide, air-free
CO_{ppm} = as-measured carbon monoxide, ppm
O_2 = oxygen in combustion gas, percentage

n. Average the $CO_{air\text{-}free}$ emission rates for the minimum and maximum CO_{ppm} readings.

o. ***Averaged CO air-free must be 800 ppm or less, averaged from the CO air-free values corresponding to the CO_{ppm} minimum and maximum occurring after fifteen minutes of warm-up, with oven set to 350^{O}F.***

p. Determine whether the burner passes or fails the limit.

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[10] Instruments that calculate $CO_{air\text{-}free}$ automatically do so with an integral computer chip. The instrument reads CO and O_2 and then calculates $CO_{air\text{-}free}$ with the use of Equation 1, above. These instruments will not calculate $CO_{air\text{-}free}$ automatically if the O_2 percentage is high, for example, Bacharach equipment will not calculate $CO_{air\text{-}free}$ if the O_2 percentage is above 16; Testo equipment will not calculate $CO_{air\text{-}free}$ if the O_2 percentage is above 20.

[11] The following equations may be used for natural gas and propane if the analyst has collected carbon monoxide and carbon dioxide readings.

For natural gas: $$CO_{air-free} = \left(\frac{12.2}{CO_2} \right) x\, CO_{ppm}$$

For propane: $$CO_{air-free} = \left(\frac{14}{CO_2} \right) x\, CO_{ppm}$$

Where CO_2 = carbon dioxide in combustion gas, percentage

F. Burner or Range Failure

1. If a failed burner can be adjusted in a way that reduces the CO emissions to below those set by the levels of this protocol, then the range passes the protocol after the field analyst retests the range to ensure that the burner(s) now passes limits of the protocol.
2. If the failed burner(s) cannot be tuned or replaced to pass the protocol levels or the gas range construction does not allow for adjustment or parts replacement, the gas range should be replaced.
3. If the field analyst believes, *for reasons beyond the scope of this protocol*, that a range burner(s) or the oven bake burner are emitting unacceptable levels of carbon monoxide, the range should be repaired or replaced.
    a. If the testing leads to range replacement, use the same shutdown, safety, and replacement procedures that your organization uses in the case of a cracked furnace heat exchanger.
    b. Those funding the program must determine whether to replace the range with program funds.

G. Closure of Test Procedure

1. Pack up test equipment and remove it from house.
2. Return range to condition in which it was found, unless returning it to pre-test condition will create an unacceptable situation (for example, do not put foil back on the oven bottom).

Tools Required for Protocol

- Timing device for timing burner warm-up and test-reading periods
- Combustible gas leak detection instrument.
- CO Hot Pot™, model 1 (Instructions for making this device can be found at http://www.karg.com/makehotpot.htm.)
- Emission measurement instrument(s).
    - Must measure carbon monoxide, as-measured.
    - Must measure carbon dioxide or oxygen as a percentage.
    - Optional – instrument calculation and display of carbon monoxide, air-free, is an advantage, but not necessary.
- Optional – thermometer for measuring temperature of oven at the oven vent. (This might be part of another instrument).
- Flashlight.
- Calculator for determining carbon monoxide, air-free.
- Oven mitten to handle hot CO Hot Pot™ and instrument probe.
- Inspection mirror for inspecting bake oven spreader plate, etc.