121 Furnaces and Boilers

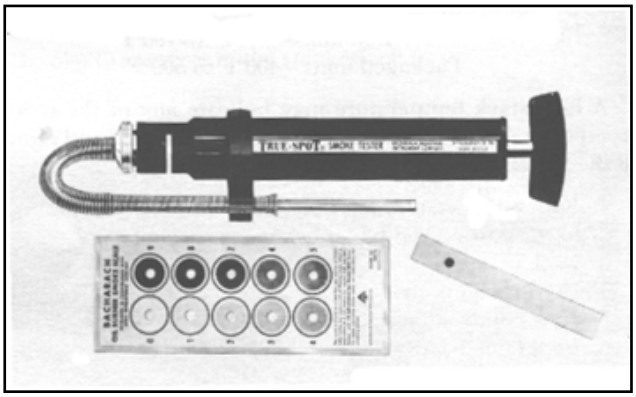
Best Practices Recommendations:

- A combustion efficiency test should be performed for an adequate appraisal of the operation and efficiency of the heating system.
- The following tests should also be conducted to help assess existing condition of heating system.
    - CO test,
    - Draft test under worst-case draft conditions,
    - Gas leak test (gas-fired systems),
    - Temperature rise (forced-air furnaces), and
    - Clocking the meter (gas-fired systems).

1211 Smoke Testing

A combustion smoke test should be performed on all oil-fired heating systems *before* a steady-state efficiency test is done. This smoke test is not required on natural gas- or propane-fired systems.

If the measured smoke reading of the combustion emissions is 2 or less, the steady-state efficiency test may be performed. If the smoke test shows a reading higher than 2, the system must be cleaned and tuned before a steady-state efficiency test is performed.



Bacharach True Spot® Smoke Test kit used for oil-fired systems only

This standardized smoke test measures the amount of carbon in the flue gases by pulling a measured amount of these combustion gases through a special filter paper. The smoke dot on the filter paper is then matched with one of ten smoke density samples numbered from 0 to 9 on a sample card.

The most common device for measuring smoke on an oil-fired system is the Bacharach True-Spot® Smoke Test Kit. This is a pump-type device with a slot for filter paper. While the burner is operating and when the system has reached steady-state (stable flue gas temperature), insert the probe for the calibrated pump into a hole in the breech of the vent connector and then manually operate the pump according to the instructions to pull combustion gases through the filter paper. Match the smoke spot on the filter paper with one of the ten choices on the sample smoke card.

1212 Combustion Efficiency Testing

A combustion efficiency test should be performed by the assessor or a heating system specialist for an adequate appraisal of the operation and efficiency of the heating system. This test must always be performed during steady-state conditions. This means that the burner must be operating and the flue gas in the vent connector must reach a stable temperature. If the burner stops firing during a steady-state efficiency test, the test must be aborted and started again.

12121 Information Needed for Test

To determine the steady-state efficiency of a heating system, the net stack temperature and the amount of excess air in the flue gas must be measured.

The net stack temperature is the temperature of the combustion supply air (room temperature) subtracted from the temperature of the combustion gases in the vent connector. Older combustion analyzers measure the gross stack temperature. The combustion supply air, which is usually the room air temperature of the space in which the heating appliance is located, must be subtracted from the gross stack temperature to find the net stack temperature.

The Testo 325 combustion analyzer measures steady-state efficiency and carbon monoxide emissions

Newer digital combustion analyzers automatically subtract room air temperature from stack temperature for their calculation of efficiency. Make sure that the room temperature is recorded by the analyzer so that it calculates the efficiency correctly. The lower the net stack temperature, the higher the efficiency of the heating system.

In order to determine the amount of excess air is in the combustion gases, the oxygen (O_2) or carbon dioxide (CO_2) percentage in the combustion gas is measured. Digital combustion analyzers always read O_2 with an oxygen sensing cell. These newer digital units are sometimes referred to as dry-type analyzers. The older wet-type analyzers determine the percentage of CO_2 in the flue gas by pumping the combustion gases through a special liquid (potassium hydroxide) that absorbs CO_2. As the CO_2 is absorbed the volume of the liquid increases.

12122 Where to Test

The temperature and O_2 or CO_2 must always be measured before any room air is allowed to dilute the combustion gases. For a gas boiler, the measurements must be taken before the draft hood or draft diverter. For some older gas-fired boilers,

room dilution air enters through an opening in the underside of the vent connector at the point it connects to the heating unit. For these older systems, the temperature and O_2 or CO_2 readings are taken by inserting the instrument probe into the vent connector opening (drilling a hole is not necessary) and holding the probe in a position that will not be affected by room dilution air.

For an atmospheric gas furnace, the readings must be taken just before the emissions are diluted by room air at the draft diverter.

For oil-fired units, the readings must be taken at the breech before the barometric damper.

12123 Conducting the Test

With the heating unit operating, insert the sampling probe of a combustion analyzer into the appropriate location of the vent system. Measure the temperature of the flue gases to determine when steady-state condition is reached. This will be when the flue gas temperature stabilizes (steady-state condition).

The Bacharach Fyrite Pro combustion analyzer measures steady-state efficiency and carbon monoxide emissions

Measure and record the net stack temperature (room temperature subtracted from steady-state stack temperature) and O_2 or CO_2. Determine whether the readings are within the acceptable limits listed in Table 121-1, "Acceptable Combustion Test Analysis Values".

If the burner shuts down while conducting the test, start the test again. Turning up the thermostat so that the burner runs longer may be helpful. Other temporary adjustments will ensure that the burner runs for longer periods, but it is important to follow state program recommendations when making such adjustments.

Return the thermostat(s) and other modified controls to their original settings when the test is complete.

Always be aware of health and safety during combustion testing. If any of the following conditions are present during an efficiency test, shut down the heating system and take remedial action:

- If significant draft reversal occurs, filling the combustion appliance zone with combustion gases.
- If ambient carbon monoxide levels reach 10 ppm.
- Flame rollout.

- Hazardous heat exchanger defects.
- Obvious electrical or system control problems.
- Any other hazardous malfunction of the heating unit or distribution system.

Acceptable Combustion Test Analysis Values
Table 121-1

Heating Unit Type	*Oxygen (O_2)*	*Carbon Dioxide (CO_2)*	*Net Stack Temp.*	*Smoke Test*
Gas				
Atmospheric	4 - 9%	Natural 9.6 - 6.8% LPG 11.2 - 7.8%	300-600º F	NA
Fan-assisted	4 - 9%	Natural 9.6 - 6.8% LPG 11.2 - 7.8%	300-480º F	NA
Condensing	See man. Info.	See man. Info.	See man. Info.	NA
Standard Power Burner	4 - 9%	Natural 9.6 - 6.8% LPG 11.2 - 7.8%	300-650º F	NA
Oil (No. 1 & 2)				
Oil gun burner	4 - 9%	12.5 - 8.8%	325-600º F	2 or less
Flame Retention Burner	4 - 7%	12.5 - 10.3%	325-600º F	2 or less

1213 Carbon Monoxide Test

With the heating unit operating and in steady-state condition, insert the sampling probe into the appropriate spot in the vent system (before any room dilution air has entered the vent system). The CO test is always done in the same vent system location as the steady-state efficiency test.

Measure and record the amount of carbon monoxide in the flue gas, either as-measured or air-free. The measured CO emissions level must be equal to or less than that listed in Table 121-2. If cleaning and tuning does not adequately lower the CO emissions, consider replacement of the heating unit (see Section 223, “Heating System Replacement”, for other criteria related to replacing existing heating appliances).

The best time to measure for CO emissions is during worst-case conditions. Please refer to Section 123 for more information.

Carbon Monoxide (CO) Action Levels and Allowable Levels
Table 121 -2

Appliance	*Allowable CO Level*	*Comments*
Gas Furnace / Boiler	100 ppm / 200 ppm	as-measured / air-free
Oil Furnace / Boiler	100 ppm	as-measured

1214 Draft Testing

All heating system units should be tested for draft at the time of the efficiency test, during a cleaning and tuning, and under worst-case conditions (see Section 123, "Worst-Case Draft Testing"). Exceptions to this requirement include:

- Condensing furnaces and boilers.
- Direct-vent, sealed combustion appliances.
- Heating units with vent connectors under positive pressure.

Under all conditions, including worst-case, heating units must demonstrate a minimum draft strength corresponding to the values in Tables 121-3 and 121-4. Notice that typical oil-fired units have two draft values – overfire and breech. In addition, notice that draft readings for oil-fired units are not dependent on outdoor temperature – as atmospheric gas-fired units are – because the barometric damper on oil units automatically adjusts for differences in temperature.

Draft readings are often taken at a different location in the vent connector than combustion efficiency or carbon monoxide readings. Make sure that the draft reading is always taken at the proper location.

Atmospheric Gas Appliances Only
Acceptable Draft Test Readings for Various Outdoor Temperature Ranges
Table 121-3

ºF	<20	20-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

Power Oil Burners
Acceptable Draft Readings Overfire and at Breech
Table 121-4

Draft Reading Location	**Acceptable Draft**
Overfire Draft	-0.01 to -0.02 inches or -2.5 to -5 Pascals
Vent Connector or Breech	-0.04 to -0.06 inches or -10 to -15 Pascals

1215 Gas Leak Testing

Gas leak testing should be done for all natural gas and propane appliance lines and connections. Because propane is heavier than air and natural gas is lighter than air, hold the combustible gas detector probe just below a propane gas line and just above a natural gas line. All identified gas leaks should be referred to appropriate persons for repair or replacement.

1216 Temperature Rise

The temperature rise of a furnace distribution system should be measured before and then after any significant heating unit or distribution system repairs or modifications.

The measured temperature rise should be between 40^{o} and 70^{o}F or within the manufacturer's specified range. The specified temperature rise is almost always included on a nameplate on the furnace.

If the temperature rise is too high, it could be due to:

- Low air handler fan speed or broken fan belt.
- Obstruction in the return or supply ductwork, including a dirty filter.
- Inadequate or restricted return ductwork.
- Overfired burner.
- Dirty or defective blower.

If the temperature rise is too low, it could be due to:

- Air handler fan speed is too high.
- Excessive duct leakage.
- Underfired burner.

With the heating unit and blower operating, measure the temperature in a duct within 12 inches of the supply and return plenums. In a mobile home, measure the supply temperature at the supply register closest to the furnace.

If the temperature rise is out of range, take action to correct the cause.

1217 Clocking the Gas Meter

Clock the gas meter to measure gas input. Ensure that other gas appliances (water heater, dryer, range) do not fire when clocking the meter. Refer to table 121-5 for input rates based on clocking the gas meter. Use the following formula if the gas meter does not have a ½ ft^3 or 1 ft^3 dial:

1,000 Btuh = (dial type * 3600)/time for revolution

For example, a there is a 2 ft^3 dial on the gas meter and it takes 50 seconds to make one revolution. The metered gas input is 144,000 Btuh.

1,000 Btuh = (2 x 3600)/50 seconds = 144

Clocking the Gas Meter

Table 121-5

Using a watch, measure the number of seconds for either the ½ ft^3 or the 1 ft^3 to make one complete revolution. Read the corresponding input rate in 1,000 of Btus/ft^3.

Seconds for One Revolution on the Dial	½ ft^3	1 ft^3	Seconds for One Revolution on the Dial	½ ft^3	1 ft^3
10	180	360	40	45	90
11	164	327	41	44	88
12	150	300	42	43	84
13	138	277	43	42	84
14	129	257	44	41	82
15	120	240	45	40	80
16	112	225	46	39	78
17	106	212	47	38	77
18	100	200	48	37	75
19	95	189	49	37	73
20	90	180	50	36	72
21	86	171	51	35	71
22	82	164	52	35	69
23	78	157	53	34	68
24	75	150	54	33	67
25	72	144	55	33	65
26	69	138	56	32	64
27	67	133	57	32	63
28	64	129	58	31	62
29	62	124	59	30	61
30	60	120	60	30	60
31	58	116	62	29	58
32	56	113	64	29	56
33	55	109	66	29	54
34	53	106	68	28	53
35	51	100	70	26	51
36	50	100	72	25	50
37	49	97	74	24	48
38	47	95	76	24	47
39	46	92	78	23	46

122 Water Heaters

Best Practice Recommendations:

- The following tests should be conducted to help assess existing condition of water heaters.
  - Draft test under worst-case draft conditions,
  - CO test, and
  - Gas leak test (gas-fired systems).

1221 Draft Test

The draft test on a gas- or oil-fired water heater must be measured through a hole drilled in the vent connector. For an atmospheric gas-fired unit, drill a hole between the draft hood and the chimney, and in a straight vertical section, if possible. For an oil-fired water heater, drill the appropriately sized hole before the barometric damper and at least six inches away from the water heater unit.

After the water heater has been operating for at least two minutes, insert the probe of the draft device into the hole to the center of the vent connector. Under all conditions, including worst-case, water heaters must demonstrate a minimum draft strength corresponding to the values in Tables 122-1 and 122-2. Notice that draft readings for oil-fired units are not dependent on outdoor temperature – as atmospheric gas-fired units are – because the barometric damper on oil units automatically adjusts for differences in temperature.

Atmospheric Gas Appliances Only
Acceptable Draft Test Readings for Various Outdoor Temperature Ranges
Table 122-1

ºF	<20	21-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

Power Oil Burner Water Heaters
Acceptable Draft Readings at Breech
Table 122-2

Draft Reading Location	**Acceptable Draft**
Vent Connector	-0.04 to -0.06 inches or -10 to -15 Pascals

1222 Carbon Monoxide Test

With the water heating unit operating for at least two minutes, insert the sampling probe into the appropriate spot in the vent system (before any room dilution air has entered the vent system). For an atmospheric gas-fired unit, the probe must be inserted into the

opening in the draft hood to sample the combustion gases before they are diluted by room air. Readings need to be taken on each side of the vent baffle that divides the integral vent into two sections.

On an oil-fired water heater, check for CO levels at the same hole used to check the draft.

Measure and record the amount of carbon monoxide in the flue gas, either as-measured or air-free. The measured CO level must be equal to or less than that listed in Table 122-3. If cleaning and tuning does not adequately lower the CO emissions, consider replacement of the water heating appliance. See section 2243 for other criteria relating to water heater replacement.

The best time to measure for CO emissions is during worst-case conditions. Please refer to Section 123 for more information.

Carbon Monoxide (CO) Action Levels and Allowable Levels
Table 122-3

Appliance	*Allowable CO Level*	*Comments*
Gas Water Heater	100 ppm / 200 ppm	as-measured / air-free
Oil Water Heater	100 ppm	as-measured

1223 Gas Leak Testing

Gas leak testing should be done for all natural gas and propane appliance lines and connections. Because propane is heavier than air and natural gas is lighter than air, hold the combustible gas detector probe just below a propane gas line and just above a natural gas line. All identified gas leaks should be referred to appropriate persons for repair or replacement.

Bacharach Leakator® – 10 combustible gas detector

123 Worst-Case Draft Testing

Best Practice Recommendations:

- A worst-case draft test should be performed near the end of each work day in appropriate dwellings.
- The worst-case draft test should include:
  - Determination of the worst-case condition in the dwelling.
  - Testing each vented combustion appliance for spillage under worst-case conditions.
  - Testing each vented combustion appliance for adequate draft under worst-case conditions.
- Any appliance that fails the worst-case test before or after all weatherization work is completed should be made non-operational until the hazardous condition is corrected.

1231 Introduction

The purpose of worst-case draft testing is to ensure the proper venting of vented combustion devices in a dwelling. Additionally, carbon monoxide (CO) emissions are measured to ensure they are within acceptable levels.

There are two parts to this important test. For the first part, the assessor establishes the worst-case condition for the Combustion Appliance Zone (CAZ), in other words, finds the greatest magnitude of negative pressure in the CAZ under which the combustion appliances might have to operate. For the second part, the assessor checks for spillage, measures the draft, and determines the level of CO emissions while the dwelling is in worst-case condition.

If a house contains more than one CAZ, a worst-case draft test must be performed for each area. Additionally, if more than one vented combustion appliance is located in a CAZ, each must be tested for safe operation under worst-case conditions.

At the end of each weatherization work day and after the completion of ALL weatherization work, a worst-case draft test must be performed by an assessor or crew foreman. The results must be documented in the job file.

Obvious evidence of drafting failure

If any vented combustion appliance fails the test under worst-case conditions, actions must be taken to correct the cause (see section 12355, “Solutions to Draft Failure or High

CO under Worst-Case Conditions"). After correction, another worst-case draft test must be performed.

1232 Appliances and Dwellings Requiring Worst-Case Draft Testing

Worst-case draft testing should be performed on the following appliance types as specified:[8]

- All Category I gas appliances, both natural draft and fan-assisted, should be tested for spillage, draft, and carbon monoxide emissions.
- All vented oil-fired appliances should be tested for spillage, draft, and carbon monoxide emissions.
- All Category III and IV, sidewall-vented but **NOT** direct-vent/sealed combustion should be tested for CO, but not for spillage or draft. It is recommended that the test for CO emissions be done at the outdoor vent termination.
- All mobile home furnaces should be tested for CO, but not for spillage or draft. It is recommended that the test for CO emissions be done at the outdoor vent termination.

Table 123-1 lists the worst-case conditions testing recommended for various appliance types.

Worst-Case Conditions Testing for Various Vented Combustion Appliances
Table 123-1

Combustion Appliance Type	*Tests Under Worst-Case Conditions*		
	Spillage Test (at 2 minutes)	*Draft Test* (at 5 minutes)	*CO Emissions Test* As-measured CO ≤ 100 ppm (at 5 minutes)
Gas-fired, Category I, natural draft and fan-assisted	yes	yes	yes
Oil-fired with typical power burner	yes	yes	yes
Gas-fired, Category III & IV, side wall vented, but not direct-vent/sealed combustion	no	no	yes
Mobile home furnaces	no	no	yes

Worst-case draft testing must be done in all dwellings. The following are *exceptions* to this requirement:

- If the house or mobile home is all-electric with no vented combustion appliances, woodstoves or fireplaces.
- If the dwelling has a boiler and/or an atmospheric water heater ***and*** has no exhaust equipment, including clothes dryers, vented bath and kitchen fans, vented central vacuum systems, fireplaces, woodstoves, etc.

[8] For a definition of vent categories, please refer to the *National Fuel Gas Code* (NFPA 54), Chapter 3, "Definitions", "Vented appliance, Category I, II, III, and IV".

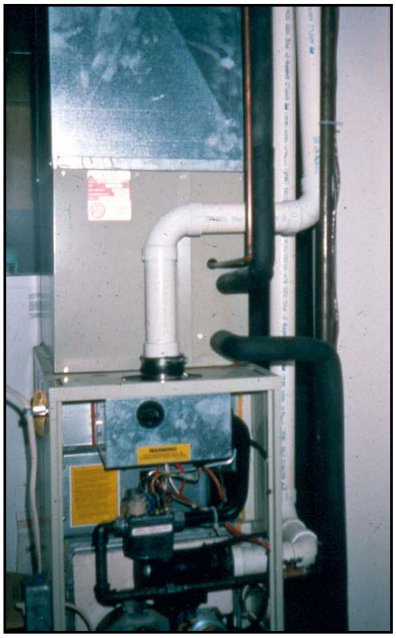
- If the only vented appliances in the dwelling are direct-vent/sealed combustion appliances.
- If the CAZ is located outside of the thermal boundary, such as in a mobile home water heater closet or a garage
- In multi-family buildings with no combustion appliances.

1233 Testing Before Job Completion

In order to ensure that clients are not exposed to the hazards of venting problems between the beginning and completion of the weatherization work, a worst-case draft test should be performed at the end of each work day.

If any combustion appliances fail the worst-case draft test, remedial action must be taken before the work crew leaves the job site for the day. This action might include:

- Correcting the cause of the draft failure or high CO emissions.
- Shutting down the appliance(s) failing the test. This might not always be an option, for example, turning off a heating system during the winter months. Some weatherization programs loan portable electric heaters to clients if heating systems must be temporarily shut down for safety reasons.
- Inform the client of the draft hazard and tell them not to use the appliance until the problem is eliminated by the weatherization organization.



This direct-vent, sealed combustion gas furnace does not require worst-case draft testing

All test results from each day must be documented in the job file.

Caution: Never use the DTL nor the worst-case test threshold values as a substitute for the final worst-case draft test.

1234 Testing After Job Completion

All other diagnostic testing and weatherization work must be completed before the final worst-case draft test is performed. It is particularly important to perform the Duct-Induced Room Pressures Test and correct related problems. Refer to Section 1142 for instructions.

1235 Test Procedure

"Worst-case" is defined as the configuration of the house that results in the greatest negative pressure in the combustion appliance zone (CAZ). Consideration must be given to:

- The types and locations of the heating systems.

- The location and CFM rating of all exhausting equipment (bath fans, dryers, kitchen exhaust devices, etc.).
- The location of wood stoves, fireplaces, and water heaters.
- The volume of the area where the combustion devices are located.
- The location of forced-air system supply registers and return grilles.

12351 Procedure Setup

1. For the final worst-case draft test, duct-induced room pressure testing and adjusting should have been completed Refer to Section 1142 for this test.
2. Place the building in the wintertime condition with all windows and exterior doors closed. If the blower door is set-up, make sure the fan is closed off.
3. Measure and record the outdoor temperature.
4. Deactivate all combustion appliances by turning them off or setting the control to "pilot." Try to test the appliances with a cool vent system, if possible.
5. Close all operable vents (for example, a fireplace damper).
6. If there is a furnace, replace or clean the filter if it is dirty.
7. Check and clean the lint filter in the dryer.
8. If there are any supply registers in the CAZ, close them.
9. Set up the digital manometer and pressure hoses so that the pressure differential of the CAZ with reference to the outdoors can be easily measured. If the CAZ is in a basement, run a pressure hose to the outdoors through a window or door, and then close the window or door as tightly as possible without totally closing off airflow through the hose. Use masking tape to seal the opening and the meeting rail. Brake lining tubing is also works well as it resists "pinching".
10. With the interior doors in the conditioned area open, the CAZ door open, and all combustion appliances and exhaust devices off, record the baseline pressure in the CAZ. This is the pressure in the CAZ resulting from stack-effect air leakage. Generally, the colder the outdoor temperature the greater the magnitude of this baseline value. Record the baseline pressure (**P1**).

12352 Determining Worst-Case Conditions

1. Turn on all exhaust devices (except a whole-house exhaust fan). Close all interior doors except those for rooms that contain an exhaust fan, but no supply register. If you are not sure whether to close a door or leave it open, close the door and use smoke to determine which way the air is flowing under the door. If smoke is sucked into the room, leave the door open. If smoke blows out of the room, leave the door closed. Record the pressure in the CAZ (**P2**). The pressure created in the CAZ from the operation of these exhaust devices is the difference between P1 and the baseline pressure, or P2 - P1.

Note: If there is a whole-house exhaust fan, it is important to inform the client that operating this fan with the house closed up could be very hazardous.

2. If the house contains a furnace, activate the blower. Record the pressure reading in the CAZ with reference to the outdoors (**P3**). The CAZ pressure resulting from the operation of the exhaust devices *and* the air handler is the difference between P3 and the baseline pressure, or P3 - P1.

Caution: If the only way to activate the blower is to fire the furnace, extreme caution must be used due to the potential for combustion backdrafting or flame rollout. Try to activate the furnace blower without firing the furnace burner. If this is not possible, measure ambient carbon monoxide levels in the CAZ during the test. If ambient CO levels exceed 10 ppm, abort the worst-case draft test and take corrective action.

3. Close the door to the CAZ (this is usually the basement door). If closing this door results in greater depressurization in the CAZ with reference to the outdoors (for example, closing the door changes the pressure from -2 to -4), leave this door closed and record the pressure (**P4**). Leave door open if closing it decreases the depressurization (for example, closing the door changes the pressure from -4 to -3). If the CAZ door is left open, this pressure should be the same as **P3**.

Stand-alone gas water heaters are the most likely appliance to suffer draft reversal

4. Review the results of the testing and determine the dwelling configuration resulting in the greatest negative pressure in the CAZ with reference to the outdoors. Record the worst-case depressurization and its corresponding mechanical systems/doors configuration. This is the configuration – worst-case – to use when checking for adequate draft and CO emissions from each combustion appliance.
5. If there are other Combustion Appliance Zones in the dwelling, find the worst-case configuration for each. Record all data in the job file.

12353 Multiple Combustion Appliance Zones, One with Fireplace

In some cases, it is best to simulate the draft from a fireplace in a dwelling that has multiple combustion appliance zones and one of the zones includes a fireplace used by the client.

Use the blower door to simulate 300 CFM drawn by a typical working fireplace. To do so, place the "B" ring in the Minneapolis Blower Door, Model 3, and increase the fan pressure to 26 Pascals. **Note that this is fan pressure, not house pressure.** Alter the above procedure – Section 12352 – by turning on the blower door (the fireplace simulator) just after activating all the exhaust appliances, but just before activation a furnace air handler, if there is one. Otherwise, proceed with the sequence of the test as instructed in Section 12352.

12354 Verifying Proper Appliance Operation under Worst-Case Conditions

1. For personal safety, measure CO in the ambient air while appliances are being tested for proper venting.
2. Under these worst-case conditions in each CAZ, fire the combustion appliance with the lowest Btu input first to determine if the appliance is drafting properly.
    a. There should be no spillage of flue gases after two minutes of combustion. If there is spillage after two minutes, the appliance fails the test.
    b. After five minutes of combustion, the draft should meet or exceed the values in Table 123-2 or Table 123-3. If the values in the appropriate table are not met, the appliance fails the test.
    c. After five minutes of combustion, measure CO emissions in the vent. Make certain the emissions are measured *before* dilution air enters the vent. As-measured CO should be 100 ppm or less. If CO emissions are higher, the appliance fails the test.
3. Fire all remaining appliances, one at a time, in order of input rating (smaller to larger), testing each one for spillage at two minutes and draft and CO emissions after five minutes or more.
    a. If the appliances vent into the same chimney flue or vent connector, test each one individually.
    b. If the appliances vent into different chimney flues or vents, test with each successive unit running, that is, when firing up the next appliance, allow the previous one to operate. In the case of a water heater, retest the water heater with the other larger Btu input appliances operating.
4. If the dwelling has other combustion appliance zones, repeat the sequence of activating exhaust equipment, door closure, furnace blower activation, recording pressure readings, etc.
5. When all worst-case draft testing has been completed, turn off all exhaust equipment and return doors and combustion appliances to their previous operational settings.

Category I Appliances, Natural and Fan-Assisted Acceptable Draft Test Readings for Various Outdoor Temperature Ranges Table 123-2					
ºF	<20	20-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

Power Oil Burners Acceptable Draft Readings at Breech Table 123-3	
Draft Reading Location	***Acceptable Draft***
Vent Connector or Breech	-0.04 to -0.06 or -10 to -15 Pascals

12355 Solutions to Draft Failure or High CO under Worst-Case Conditions

If spillage is a problem or if a draft measurement is unacceptable, correct the problem by one of the following methods:

a. Check for blockage in the vent system and, if found, correct the problem;
b. Check vent system for leaks, including missing or loose cleanout doors or open or cracked mortar joints. Seal vent system as appropriate. Lining a chimney may solve this problem (refer to Section 225).
c. Properly seal return duct leakage in the CAZ.
d. Increase the CAZ air volume by connecting the CAZ to other areas within the conditioned volume of the dwelling (see NFPA 54, NFPA 31);
e. Increase the CAZ air volume by connecting the CAZ to the outdoors (see NFPA 54, NFPA 31, or NFPA 211).
f. Install a manufacturers' outdoor air kit for the failed appliances. This is an option with a number of oil-fired furnaces, boilers, and water heaters.
g. Install fan to supply air to pressurize the CAZ. It is best to link the controls of such a make-up air fan to the operation of the combustion appliance(s) in the CAZ.
h. For high CO emissions, clean and tune the appliance and test for CO emissions again. Replace appliance if high CO emissions are not correctable.

124 Gas Range Testing

Best Practices Recommendations:

- The following should be completed in dwellings with gas ranges.
  - Inspect the gas range top burners and oven burners for proper maintenance and operation.
  - Measure the range top burners for CO emission levels (as-measured).
  - Measure the oven bake burner for CO emission levels (air-free).
  - Educate the client about gas range use and maintenance.

1241 Introduction

Gas ranges pose a difficult problem for the assessor and the weatherization agency. First, of all the combustion appliances in the field, gas ranges present the greatest challenge for the accurate measurement of carbon monoxide emissions. No other combustion appliance in a dwelling is interacted with as much by clients, making it very difficult to accurately simulate client use during field measurement of CO emissions. In addition, unlike any other combustion appliance in the house, the oven bake burner turns on and off during CO emissions testing, forcing the assessor to be very aware of the cycle during CO emissions testing.

Kitchen range, four top burners, one oven bake burner

Second, the preferred method of measuring CO emissions from gas oven bake burners requires equipment that measures air-free carbon monoxide. This electronic equipment must be able to measure carbon monoxide ppm and oxygen percentage.[9] In addition, it is important that the assessor understands that CO is measured in two different ways, "air-free" and "as-measured".[10]

Third, if gas range problems are discovered by an assessor, it might be difficult or impossible to find a qualified technician to repair the appliance.

Use this list to help establish program priorities for protecting clients from any hazard caused by a gas range. The list starts with the most important and ends with the least important.

[9] *Two major manufacturers of the equipment that measures air-free CO are TESTO and Bacharach.*

[10] Please refer to *Air-Free Carbon Monoxide Emissions from Gas Ranges: Analysis and Suggested Field Procedure,* R. Karg, 1998 for an explanation of as-measured and air-free measurement of carbon monoxide. This document is available at www.karg.com/PDF files/COairfree.PDF.

- Install at least one CO alarm in a house that has a working gas range (see section 243, “Carbon Monoxide Alarms”). Make sure this alarm is not closer than five feet to the range.
- Inspect the range as instructed below.
- Educate the client about gas range use. See Section 1244, “Client Education”.
- Ensure that your CO test equipment is operating properly and has been calibrated according to the manufacturer’s recommendations.
- Test the oven for CO emissions. Field research has demonstrated that ovens are more likely to be high emitters of CO than range top burners.
- Test range top burners.

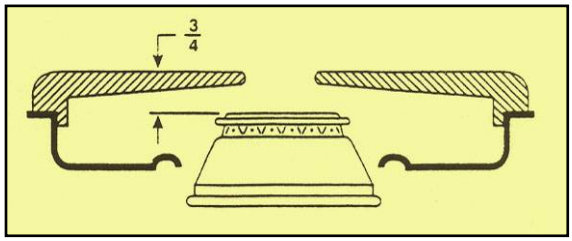
1242 Inspection

12421 General

- Inspect gas range installation for compliance with NFPA 54, the National Fuel Gas Code.
- Check for a flexible gas line 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 not brass, is not a two-piece connector, and 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.
- 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.
- Check the unit for a pressure regulator. If no regulator is present, check the nameplate for the suggested gas pressure. Measure the gas pressure that is being delivered when the oven is operating. Adjust the gas pressure if necessary.

12422 Range Top Inspection

- Inspect the burners for proper alignment and seating.
- All cooking vessel support grates should be in place, fit properly, and be in one piece.
- 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.

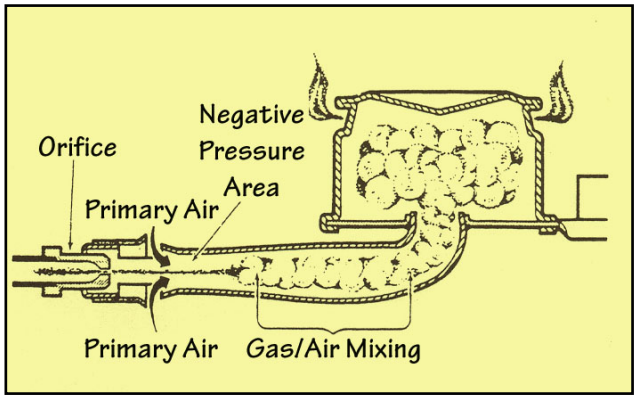


Top of burner should be at least ¾ inch below top of grate

- 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).
- Ignite each burner for at least 30 seconds to inspect its flame for color and noise.
  - The flames should have sharp blue edges with orange specks rising through the flames (dust particles). Make sure there is no significant yellow at the upper tips of the flames.
  - You should be able to hear the gas/flame flow in a quiet kitchen. The sound should not be loud or irregular.

12423 Oven Area Inspection

- 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.
- 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.



Typical range burner operation

- 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.

- If the range also has a broil burner at the top of the oven compartment, check its flame for proper size and color.
- 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.

1243 Measurement of Emissions

12431 Safety During Testing

While testing, if indoor air CO concentrations rise above 20 ppm, shut down the burner(s), discontinue testing and open windows and/or doors.

12432 Range Top Burner Emissions Testing[11]

Test the range top burners after all other appliances have been tested for CO emissions, but before the oven is tested. Test the range top burners as-measured, that is, without adjustment for oxygen content. To test the range top burners:

- Remove all pots and foil from the burners.
- Turn all burners on high and allow them to warm up for at least four minutes.
- Measure the emissions 6 inches above each burner with an open flame.
- Take action based on the table 124-1.

Action Levels for Range Top Burners

Table 124-1

As Measured CO PPM	Measuring Time	Action
< 25 PPM	After 4 minutes of operation	Should be cleaned by client to prevent possible CO problems.
25 to 50 PPM	After 4 minutes of operation	Have appliance serviced.
> 50 PPM	After 4 minutes of operation	Appliance should not be used until either repaired or replaced.

12433 Oven Bake Burner Emissions Testing[12]

Test gas ovens after all other appliances have been tested for CO emissions, including the range top burners. If the oven has a broil burner at the oven ceiling, do not test it for emissions. Only test bake burners located under the floor of the oven. Gas oven bake burners must be tested air-free, that is, with adjustment for oxygen content. To test the over bake burner:

- Remove any items stored in the oven or in the drawer or broiler under the oven compartment. Remove any foil or other extraneous material from the oven floor.

[11] This test method is based on the Wisconsin Weatherization test protocol.
[12] This test method is based on the Wisconsin Weatherization test protocol.