# Combustion Appliances

# Weatherization Energy Auditor Single Family

Learning Objectives

By attending this session, participants will be able to:

* Explain the basic principles of combustion, distribution, and venting and be able to recognize safety-related problems.
* Describe the health and safety issues related to combustion equipment.
* List the basic steps of visual and diagnostic combustion appliance safety and efficiency inspection.
* Cite test procedures for vented and non-vented appliances.
* Understand the relationship between combustion safety problems and poorly designed or non-code-compliant vent systems.
* Describe worstcase combustion appliance zone testing.

Key Terminology

Action levels

Air-free CO content

Ambient

As-measured CO content

Atmospheric

Backdraft

Baffle

Barometric damper

British thermal unit (BTU)

B-vent

Carbon dioxide (CO2)

Carbon monoxide (CO)

Clearance

Combustion analyzer

Combustion appliance zone (CAZ)

Combustion byproducts

Combustion efficiency

Condensing furnace

Depressurization

Digital probe thermometer

Dilution air

Draft

Draft diverter

Draft gauge

Draft hood

Draft reversal

Excess air

Flame impingement

Flame roll-out

Furnace blower

Heat exchanger

Inches of water column (IWC)

Induced draft furnace

Inspection mirror

Manometer

Natural gas

NFPA 31

NFPA 54

NFPA 211

Over-fired

Oxidation

Parts per million (ppm)

Pascals (Pa)

Primary air

Propane (Liquefied Petroleum Gas, or LPG)

Secondary air

Smoke tester

Spillage

Standard Work Specifications, for Single-Family Energy Upgrades

Steady-state efficiency

Sulfur dioxide (SO2)

Under-fired

U.S. DOE Hot Climate Initiative

Worst case combustion appliance zone (CAZ) testing

Supplemental Materials

Handouts & Resources

“Boiler Basics: Part 1 - Combustion Air and Drafting.” *WxTV*. Montana Weatherization Training Center. <www.wxtvonline.org>.

“Boiler Basics: Part 2 - Clean, Test, and Tune.” *WxTV*. Montana Weatherization Training Center. <www.wxtvonline.org>.

“Boiler Basics: Part 3 - External Components.” *WxTV*. Montana Weatherization Training Center. <www.wxtvonline.org>.

CO Probe Locations Illustration.

Combustion Analysis Quick Sheet.

DeKieffer, Rob. “Combustion Safety Checks: How Not to Kill Your Clients.” *Home Energy* March/Apr. 1995. <www.homeenergy.org>.

“Gas Furnace Basics: Part 1 - Initial Assessment.” *WxTV*. Montana Weatherization Training Center. <www.wxtvonline.org>.

“Gas Furnace Basics: Part 2 - Testing the Unit.” *WxTV*. Montana Weatherization Training Center. <www.wxtvonline.org>.

“Gas Furnace Basics: Part 3 - Troubleshooting High CO.” *WxTV*. Montana Weatherization Training Center. <www.wxtvonline.org>.

“Gas Furnace Basics: Part 4 - Cleaning and Final Assessment.” *WxTV*. Montana Weatherization Training Center. <www.wxtvonline.org>.

“Heating Basics: A Tour of 9 Systems.” *WxTV*. Montana Weatherization Training Center. <www.wxtvonline.org>.

Indiana Community Action Association. “INCAP Daily Safety Test-Out Procedure Checklist.” June 2005. <www.incap.org>.

Karg, Rick. “CO Testing for the Real World.” *Home Energy* Jan/Feb 2002. <www.homeenergy.org>.

Kilcoyne, Scott, and Bill Van der Meer. “Confined Space Combustion Appliance Zones and the Code.” Weatherization Training Center Technical Update 1.6 (October 2005). Weatherization Training Center at Pennsylvania College of Technology. <www.pct.edu>.

MacPhaul, David and Christy Etter. “HVAC System Design for Humid Climates.” WBDG.org.National Institute of Building Sciences. <www.wbdg.org>.

Moffatt, Sebastian. “Backdrafting Causes and Cures.” Home Energy May/June 1991: 30-35. <[www.homeenergy.org](http://www.homeenergy.org)>.

National Fire Protection Agency. “Combustion Clearance Tables.” <www.nfpa.org>.

National Fire Protection Agency. NFPA 211: *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances,* especially Table 2-2.1, “Chimney Selection Chart.” (Applicable sections)

National Fire Protection Agency. NFPA 31: *Standard for the Installation of Oil-Burning Equipment.* (Applicable sections)

National Fire Protection Agency. “NFPA54: National Fuel Gas Code.” <www.nfpa.org>.

National Fire Protection Agency. “Table 13.1: Type B Double-Wall Gas Ventilation Table” from the NFPA54: National Fuel Gas Code. <www.nfpa.org>.CO Probe Locations Illustration

U.S. Department of Energy. EERE. “Combustion Equipment Fact Sheet.” Oct. 2000.

U.S. Department of Energy. Hot Climate Initiative. Combustion Appliance Safety & Efficiency Testing.

U.S. Department of Energy. Weatherization Assistance Program. “Furnace Replacement Video.” 2009. <www.waptac.org>.

U.S. Department of Energy. Weatherization Assistance Program. WPN 11-6 Health and Safety Guidance. <www.waptac.org>.

U.S. Department of Energy. Weatherization Assistance Program. Midwest Regional Field Office. *Midwest Weatherization Best Practices Field Guide* May 2007: 37-56. <www.karg.com>.

U.S. Department of Labor. Occupational Safety and Health Administration. “Carbon Monoxide Fact Sheet.” OSHA <www.osha.gov>.

U.S. Department of Labor. Occupational Safety and Health Administration. “Carbon Monoxide Poisoning QuickCardTM.” OSHA 3282 – 2005. <www.osha.gov>.

U.S. Environmental Protection Agency. “Carbon Monoxide Fact Sheet.” Oct. 1996. <www.epa.gov>.

Worst Case CAZ Depressurization, Step-by-Step Handout.

Online Platform Lessons

Use these online interactive training modules as prerequisites before students attend the course or as in-class computer lab sessions. To access the lesson, users must first create an account at [www.nterlearning.org](http://www.nterlearning.org).

a- 2.5 Furnace Inspection

a- 2.6 Water Heater Inspection

a- 2.8 Gas Leak Detection

a- 4.1 Combustion Safety Testing – Gas Range

c- 4.1 Daily CAZ Testing

c- 4.2 Combustion Safety Testing: Water Heater and Furnace/Boiler

c- 10.1 Identifying Heating Equipment

c- 10.2 Identifying Hot Water Systems

c- 10.3 Identifying Combustion Exhaust

Relevant Standard Work Specifications

1.105.1 – Heating & Cooling Equipment – Safe Work Practices, Combustion Worker Safety

1.201 – Combustion Safety Testing - General

1.202 – Unvented Space Heaters

1.203 – Vented Gas Appliances

1.299 – Combustion Safety Training, Additional Resources

4.1001.3 – General Preparation, Fireplace Chimney and Combustion Flue Vents

5.3002.2 – Equipment Installation, Heating and Cooling Controls

5.3003.1 – Equipment Maintenance, Testing and Repair, Data Plate Verification

5.3003.2 – Equipment Maintenance, Testing and Repair, Combustion Analysis of Oil-Fired Appliances

5.3101 – Hydronic Heating, Design

5.3103 – Hydronic Heating, Equipment Maintenance, Testing and Repair

Classroom Props & Activities

**Combustion appliances:** Set up used appliances so you can perform diagnostic tests on them. Non-operating appliances can be used to identify components and physical problems.

* Vented and unvented space heater
* Atmospheric furnace
* Atmospheric water heater
* Gas cook stove

**Vent materials:**

* Type B vent
* Type B-W vent
* Type L vent
* Single-wall galvanized vent
* PVC schedule 40 pipe
* Stainless steel chimney liner and cap

**Tools:**

* Mirror and flashlight
* Gas leak detector and soap solution
* Combustion analyzer
* CO detector
* Draft gauge
* Smoke tester (oil)
* Digital manometer and hose
* Digital probe thermometer

Note: Demonstrate diagnostic tests with the most up-to-date equipment possible.

**Miscellaneous:**

* Dirty filter and blower
* Oil burner
* Barometric damper (oil)
* Thermostat

**Class Overview**

* Use the presentation, discussion, and handouts to introduce students to the key elements of assessing combustion appliances.
  + Principles of combustion, heat exchange, and venting
  + Safety and other problems related to combustion appliances
    - Electrical checks
    - Gas leak detection
    - Clearance to combustibles
    - Clocking gas meters
    - Vent specifications
  + Visual and diagnostic checks on furnaces and water heaters
    - Standards and specifications
    - Worst case combustion appliance zone testing
    - Minimum draft
    - CO action levels
  + Mitigation of CO and venting problems
* Introduce the concepts of combustion safety with the classroom presentation. Refer to the DOE “Combustion Appliance Safety & Efficiency Testing” document when discussing proper testing locations for CO, efficiency, draft, and clearance to combustibles on various appliances. Break up the presentation by demonstrating various combustion inspection tools.

**Combustion appliances for inspection and testing**—Point out the various components of the appliances and have students name them. In groups, have students inspect wiring and fans, look for cracked or corroded heat exchangers, and identify proper vent materials. Test for fuel leaks, safety shut-off, draft, free oxygen (combustion air), CO, cracked heat exchangers, and combustion efficiency.

**Combustion analyzer** – Run through the various functions of a combustion analyzer.

**Gas leak detection** – Demonstrate the sensitivity of the gas leak detector by drawing a thick line on a piece of paper with a permanent marker, then show how the detector alarms as it approaches the line.

**Combustion air** – Calculate the required volume in a combustion appliance zone to provide sufficient combustion air for a furnace and water heater totaling 120,000 BTU per hour input. Fifty cubic feet of volume must be provided for every 1,000 BTU per hour of appliance input.

* BTU input: 120,000 ÷ 1,000 = 120
* 120 x 50 = 6,000 cubic feet

**Gas input rating demonstration** – If possible, bring the students to the building’s gas meter. Using a calibration card or table and timer, have a pair of students determine the gas consumption of the building. Discuss the procedure for testing the fuel input of appliances at client homes.

**Vent materials** – When discussing vent pipes materials, refer to NFPA 211 code requirements. Pass around or display samples of various vent pipes.

**Worst case combustion safety testing** – Conduct this test with the class in conjunction with a field trip to a real house or test house within a lab. Perform the combustion safety tests as described in slides 33-38. This test will only apply to vented systems. The test house should also have operating exhaust devices such as a dryer and spot source bathroom and/or kitchen exhaust fans. These may be operated to show their impact on the vent systems. A forced air system would be a benefit because these systems have the potential to create significant pressure differences, which can affect the removal of flue gases by the existing vent system.