Combustion Appliance Testing

Train the Trainer

Key Terminology

Action levels

Air-free CO content

Ambient

As-measured CO content

Atmospheric

Backdrafting

Baffle

Barometric damper

British Thermal Unit (BTU)

B-vent

Carbon Dioxide (CO_2)

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)

Indoor Air Quality (IAQ)

Induced draft furnace

Inspection mirror

Manometer

Minimum Ventilation Requirement (MVR)

Natural draft

Natural gas

National Fire Protection Association's Standard for the Implementation of Oil-Burning Equipment (NFPA 31)

National Fire Protection Association's National Fuel Gas Code (NFPA 54)

National Fire Protection Association's Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances (NFPA 211)

Over-fired

Oxidation

Parts per million (ppm)

Pascals (Pa)

Primary air

Propane (liquefied petroleum gas, or LPG)

Secondary air

Smoke tester

Spillage

Steady-state efficiency

Sulfur Dioxide (SO_2)

Under-fired

U.S. DOE Hot Climate Initiative

Vent

Worst case Combustion Appliance Zone (CAZ) testing

Section Transition

Learning Objectives (Slide #2)

By attending this session, participants will:

- Learn the basic principles of combustion, distribution, and venting.
- Be able to recognize safety-related problems.
- Learn the basics of diagnostic combustion appliance testing.
- Become familiar with the test procedures for vented and non-vented appliances.
- Understand the relationship between combustion safety problems and poorly designed or non-code-compliant vent systems.
- Understand worst case combustion appliance zone (CAZ) testing.

Why Test Combustion Appliances? (Slide #3)

- We test to assure:
  - Health and safety.
  - Building integrity.
  - Comfort.
  - Energy efficiency.
- Combustion appliances are inherently dangerous if allowed to deteriorate or operate unsafely. They can quickly create deadly indoor air and/or cause a fire.

Each House Is a System (Slide #4)

- The house is a system. Changes to one aspect of the house, like the air barrier, cause changes in other aspects of the house, like ***indoor air quality (IAQ)*** and moisture movement.
- When we air seal and insulate, we change how the house operates.
- Our biggest responsibility as weatherization technicians is to ensure the safety of our clients. Every home should be tested and inspected for safety before heading home every evening in case there are potentially lethal conditions.
- Dangerous conditions can arise quickly when a home with combustion appliances is air sealed before pressure imbalances have been addressed.

House as a System (Slide #5)

Making the house tighter can:

- Make existing problems worse.
- Create new problems – Moisture and gas leaks that might not have been problems when the home was leaky will become new problems if they aren't addressed before sealing the home.

Some existing and new problems can be lethal:

- Gas leaks.
- ***Carbon monoxide (CO)***.
- ***Backdrafting***.
- Moisture and mold.

Most of the potentially lethal problems involve combustion appliances like the furnace or water heater.

Q: What do you think happens to IAQ if there's no exhaust fan in the bathroom and we seal the house up super tight?

A: We probably cause moisture issues in that house.

Q: Given the dangers to IAQ, is it possible to seal a house up too tight? Should installers leave the house leaky so there will be adequate fresh air?

A: Leaving a home leaky does not ensure adequate ventilation all the time. There may be forces that prohibit airflow, or the source of incoming air may be a musty attic or crawl space. The air might not be so fresh. Seal tight, ventilate right.

Combustion Basics (Slide #6)

This illustration shows how fuel and air mix on a gas cooking appliance.

When air combines with heat (a spark), ***oxidation*** (burning) occurs. Both ***primary*** and ***secondary air*** is necessary to ensure complete combustion.

- Primary air is air mixed with fuel before combustion, as shown on the right.
- Secondary air is additional air surrounding the flame, as shown on the left.

Excess air is air beyond what is needed for combustion. It is released along with the rest of the ***combustion byproducts.***

The Combustion Triangle (Slide #7)

- Fuel (hydrocarbon) and oxygen (O_2) must mix with heat for combustion to occur.

Triangle of Combustion Products (Slide #8)

- Water and ***carbon dioxide (CO_2)*** are the two major byproducts of combustion.

Complete Combustion (Slide #9)

- Complete combustion occurs when all the fuel is burned with sufficient oxygen to produce carbon dioxide and water vapor:
  Fuel + oxygen + heat = heat + water + carbon dioxide
- Byproducts of combustion are *heat + water + carbon dioxide + excess air + trace compounds* (CO, carbon, ***sulfur dioxide (SO_2)***, etc.).
- Combustion byproducts must be:
  - Vented in the case of a furnace or water heater, or
  - Assured to be within safe limits in unvented gas space heaters or gas cook stoves.

Carbon Monoxide from Incomplete Combustion (Slide #10)

- Carbon monoxide is created when the ratio of fuel to oxygen is either too high to permit the complete formation of CO_2 or the temperature is too low to permit complete burning. This is caused by:
  - Too much fuel for the amount of oxygen, or
  - Not enough oxygen for the amount of fuel, or
  - Not enough heat (***flame impingement***).

Unvented Space Heaters (Slide #11)

- Unvented space heaters release all of their combustion byproducts into the home. In addition to CO_2 and water vapor, CO compounds, excess air, and SO_2 will be present.

  Q. How much water do you think is produced in the combustion process?

  A. About 1 gallon per 100,000 BTUs.

  Q. How many gallons of water per hour does a 25,000 BTU/hr appliance produce?

  A. One-quarter gallon (1 quart) per hour.

  Q. What do you think happens to all that water vapor on a cold winter day?

  A. It condenses on windows and/or it is carried by air currents into the attic or wall cavities, where it may condense on cold surfaces and cause mold.

Visual Assessment – Space Heaters (Slide #12)

WPN 08-4: Space Heater Policy

- No Weatherization work is allowed where unvented gas or a liquid fuel space heater is the primary heat source.
- The policy strongly encourages removal such heaters and replacing them with ***vented***, code-compliant heating systems before weatherization.
- It shall not have an input rating in excess of 40,000 BTU per hour.
- ***Minimum ventilation requirement (MVR)*** guidelines apply.
- Weatherization Assistance Program (WAP) funds may be used to replace only a primary heating system with a vented, code-compliant system. They may not be used to replace unvented space heaters left in the home as secondary units.
- A space heater in a mobile home must be vented to the outside.

Combustion, Distribution, and Venting (Slide #13)

This illustration shows the fundamental process of a heating system, including combustion, heat exchange, warm air distribution, and chimney venting.

Combustion generates sufficient heat to allow exhaust gases to rise safely up the chimney.

What to Test – Diagnostics (Slide #14)

What do we test on combustion appliances?

- Fuel leaks.
- Fuel input rate.
- Sufficient combustion air.
- Worst case draft.
- Carbon monoxide.
- **Combustion efficiency**.
  - Diagnostic test procedures go well beyond visual inspections and are necessary to prove combustion safety and efficiency. Specialized diagnostic tools such as ***manometers*** and ***combustion analyzers*** are used for this purpose.

Testing Equipment – Criteria (Slide #15)

Combustion analyzers should be able to measure:

- Flue gas O_2 content.
- Flue gas temperature.
- ***Ambient*** temperature (temperature of the air surrounding the combustion appliance).
- Flue gas CO.
- Combustion efficiency.
- Flue gas CO_2 content.
- Flue gas ***air-free*** or ***as-measured CO content***.
  - A combustion analyzer measures flue gas samples to determine the safety and efficiency of the combustion process.
  - Oxygen or carbon dioxide content and flue gas temperature are measured to determine ***steady-state efficiency*** (also known as combustion efficiency). Steady-state efficiency is the percentage of heat captured by fluids such as air, water, or steam.
  - "Air free" refers to the level of CO not diluted with oxygen. There is always some excess oxygen or air in combustion byproducts. Air-free values can be extrapolated mathematically if the level of oxygen is known. Many newer models of combustion analyzers show air-free values.
  - "As measured" refers to a sample of CO that includes oxygen. As-measured values will always be lower than air-free samples.

Show and tell: combustion analyzer

Selected Testing Equipment (Slide #16)

Photos of selected test equipment.

- ***Draft gauge*** – for testing chimney draft.
- ***Smoke tester*** – for measuring the amount of smoke produced by an oil burner.
- ***Inspection mirror*** – for looking into constricted spaces.
- ***Digital probe thermometer*** – for testing temperature rise and fan operating temperatures.

  Show and tell: selected testing equipment.

Testing Equipment (Slide #17)

- Most modern combustion analyzers have printing capability, providing you with hard copy documentation.

  Show and tell: analyzer's printing capability.

Fuel Leak Testing #1 (Slide #18)

Use a calibrated gas leak detector to locate fuel leaks.

- To calibrate the instrument, adjust the dial until you hear a slow but steady clicking sound. Run the probe along the pipes and fittings. If the instrument detects a gas leak, the intervals will shorten and the clicks will rise to a shrill, continuous sound.

Fuel Leak Testing #2 (Slide #19)

- Test all joints, valves, and fittings.
  - ***Natural gas*** is lighter than air, so test above joints, fittings, and pipes.
  - ***Propane (liquefied petroleum gas, or LPG)***, is heavier than air, so test below the connections.
- Use soap bubbles to confirm a leak. Check the entire area with the leak detector before using soap bubbles, since they will set off the fuel leak detector.

Fuel Leak Testing #3 (Slide #20)

- Use a gas leak detector for gas and propane.
- Do a visual inspection and a sniff test to detect fuel oil leaks.

Measuring Input Rate (Slide #21)

- Turn on only the unit to be measured. Other units should be off.
- At the gas meter, time one revolution of the smallest dial and compare to a calibration chart.
- Any discrepancy in the rated input should be within 10% of the input rating.
  - If an appliance such as a furnace is ***over-fired*** or ***under-fired*** beyond its input rating in BTU per hour, the unit could produce higher than acceptable levels of CO. This is because the ratio of fuel to oxygen is too high or too low to permit complete combustion.
  - One British thermal unit (BTU) is the amount of energy it takes to heat one pound of water 1ºF.
  - Clock the gas meter to determine how close the actual input is to the rated input of the appliance.
  - Clock only one appliance at a time. If the actual fuel input varies from the rated input on the furnace nameplate by more than ± 10% (± 5% for 90+ condensing units), refer the unit to a HVAC technician who can inspect the unit and adjust the gas pressure to acceptable levels (3.5 ***inches of water column (IWC)*** for natural gas and 11 IWC for propane).

Refer to the calibration chart on page 3 of the "Combustion Appliance Safety & Efficiency Testing Tech Brief" handout.

Combustion Air (Slide #22)

- The ***National Fire Protection Association's National Fuel Gas Code (NFPA 54)*** states that combustion air must be provided for any combustion zone where the collective fuel input exceeds 1,000 BTU per 50 cubic feet.
- Make-up air can be provided from outdoors or from other zones of the building.
  - ***Natural draft*** heating systems (often referred to as ***atmospheric*** heating systems) require combustion air from the room where the appliance is located. If the room is too small to provide adequate combustion air, the chimney may not ***draft*** properly. Draft is a measurement used to determine how well a chimney is exhausting combustion gases.
  - An easy test is to open a window. If the draft increases, combustion air is most likely needed.

Do a classroom exercise to calculate the volume in cubic feet required for a 120,000 BTU furnace. See lesson plan.

Filter Replacement (Slide #23)

Replace the furnace filter and educate the client.

- Air filters are often so clogged that airflow is drastically reduced. This restriction may cause ***heat exchangers*** to overheat and fail over time.
- Clients need to understand that a dirty filter can affect their comfort and reduce the life of the furnace.

Cook Stove Testing (Slide #24)

Why test gas cook stoves?

- CO kills.
- People sometimes use them as a heat source, and elevated levels of CO are common.
- Knowledge encourages action.
  - Gas- and propane-fired cook stoves release combustion byproducts into the air. They must be tested and repaired if CO exceeds suggested ***action levels***:
    - Gas furnace, boiler, or water heater – 100 ***parts per million*** (***ppm)***, as measured.
    - Unvented gas space heater – 200 ppm, air free.
    - Oil-fired furnace, boiler, or water heater – 100 ppm, as measured.
    - Gas cook stove: range-top burner – 25 ppm, as measured.
    - Gas cook stove: oven – 100 ppm, as measured.

Gas Cook Stove Testing – Stove Top (Slide #25)

Photo on left:

- Test each range-top burner for CO. Hold the probe 6” above the flame and measure the CO content in ambient air.

Photo on right:

- A portable flue section concentrates combustion byproducts for an accurate CO measurement.
  - Calibrate or “zero” the instrument in outside air before testing.
  - To protect yourself and the client, continually monitor CO in the ambient air. If CO exceeds 20 ppm as measured, stop the test immediately.
  - Remedial action is required if CO levels from the burners exceed 25 ppm as measured.

Gas Cook Stove Testing – Oven (Slide #26)

Photo on left:

- Prepare the oven for the test by removing stored items, aluminum foil, etc.

Photo on right:

- Insert the probe of the analyzer into the oven vent and read the CO content after the oven has warmed.
  - Calibrate or “zero” the instrument in outside air before testing.
  - To protect yourself and the client, continually monitor CO in the ambient air. If CO exceeds 25 ppm as measured, stop the test immediately.
  - Remedial action is required if CO levels exceed 100 ppm as measured.

Furnace Testing Protocol (Slide #27)

Photo: Oil furnace with a single-wall flue graduated to a double-wall flue to maintain ***clearance*** to combustibles.

Note the test hole where samples of flue gases will be taken and draft measured.
Furnaces must be tested to assess:

- Safety (fuel leaks, clearances, etc.).
- Flue gas temperatures.
- Oxygen and carbon dioxide.
- Carbon monoxide.
- Draft.
- Condition of the heat exchanger.

Heat Exchanger Leakage Testing (Slide #28)

Test methods:

- Look for flame-damaged areas on the heat exchanger.
- Look for rust on the burner ports.
- Measure flue gas concentration before and after the blower starts. There should be no more than 1% oxygen change when the blower starts.
- Observe change in draft, CO, or flame when the blower turns on.
- Look for flame-damaged areas on the heat exchanger.
  - Combustion byproducts and conditioned house air should never mix.
  - Use both visual checks and a combustion analyzer to assess the condition of the heat exchanger.
  - If there are flame-damaged areas, a cracked heat exchanger is the likely cause and the exchanger or the furnace must be replaced.

Chimney and Vent Connectors (Slide #29)

- Natural draft appliances rely on the buoyancy and temperature of combustion gases to vent them up the chimney. As combustion gases escape, they are replaced by the air around the appliance.
- Note the intentional openings, the ***draft diverter*** and ***draft hood***, where ***dilution air*** from the room mixes with the flue gases. They help maintain a consistent draft and counter the effects of wind. If the movement of flue gases is reversed, they will spill out through these openings.

Venting Systems (Slide #30)

A venting system should:

- Carry all combustion byproducts to the outdoors.
- Establish draft quickly.
- Be properly sized with minimal restrictions.
- Be durable (corrosion resistant).
- Not overheat surrounding materials.
- Have adequate make-up air.

Open Returns (Slide #31)

- Photo of a dangerous combination of a disconnected draft hood and open return register on the furnace return air plenum.

  Q. Why is this a problem?

  A. Flue gases spill into the CAZ and are drawn into the conditioned house air by the ***furnace blower*** *through the open return air register. Open returns in the CAZ should always be sealed.*

Chimneys and Vents (Slide #32)

Photo of vent and chimney connection

- The vent connects the combustion appliance to a vertical masonry or metal chimney, and is also referred to in the heating trade as a smoke pipe.

  Q. Anything wrong with this picture?

  A. The excessive elbows on the large vent to the furnace are restricting the flow of flue gases.

What's Wrong with This Picture? (Slide #33)

Photo of a grossly misaligned vent system.

Q. What's not compliant here?

A. The improperly sloped hot water tank flue. Vents need to be sloped upward to take advantage of the natural buoyancy of hot flue gases.

Q. Do you think there's a chance that the hot water tank will draft properly?

A. No way.

Chimney Specifications (Slide #34)

- According to the ***National Fire Protection Association's Standard for the Implementation of Oil-Burning Equipment (NFPA 31)***, chimneys must be at least 2 feet higher than any portion of the building within 10 feet. ***B-vent*** height may be less with a UL-listed cap.

  Q. What's wrong with the chimney in the picture on the right?

  A. It may not draft properly and is not code compliant. It should be raised so that it is at least 2 feet higher than any roof surface within 10 feet.

Chimneys and Vents #1 (Slide #35)

Chimneys and vents should:

- Be connected and unblocked.
- Have no holes or cracks.
- Have a sound liner.
- Rise at least 1⁄4" per linear foot in the direction of the outlet.
- Extend at least 3' above the highest point at which they pass through the roof.
- Be the appropriate type and size for the combustion appliances.
- Be at least the same diameter as the exhaust port of the combustion appliance.
  - NFPA 31, NFPA 54, and the ***National Fire Protection Association's Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances (NFPA 211)*** should be reviewed to ensure that the vent and chimney are properly installed.

Chimneys and Vents #2 (Slide #36)

- Chimneys and vents must not be blocked and there must be no holes in the chimney or vent.

Chimneys and Vents #3 (Slide #37)

Photo of improper slope and a hole in the vent connector.

Q. What's the proper slope for a vent connector?

A. Vents should have an upward slope of at least 1⁄4" per linear foot in the direction of the outlet.

Chimneys and Vents #4 (Slide #38)

Photo of a non-compliant reduced vent connector and one with a hole in the vent connector.

- Vents must the appropriate type and size for the combustion appliance and be at least the same diameter as the exhaust port.

  Q. If the hot water tank is producing 100 ppm of CO, do you think all of that CO will find its way to the chimney?

  A. No way.

Water Heaters (Slide #39)

Photo on left:

- Burn marks above the burner compartment show evidence of ***flame roll-out***.
- Evidence of flame roll-out as pictured on the left indicates that ignition of the appliance is delayed, causing a sudden mini-explosion of unburned natural gas in the burner compartment at the bottom of the tank.

Photo on right:

- ***Spillage*** of flue gases or insufficient draft is often a result of an improper installation such as this.

  Q. What are some reasons for this?

  A: Obstruction in the flue running up through the center of the tank, improper mix of fuel and oxygen, and/or dirty burner ports.

  Q. Let's say the hot water tank pictured on the right was found to have a spillage problem. Based on what you see in the picture, what might be the reason for this?

  A. Improper slope of the vent to the chimney.

Chimney Liner (Slide #40)

- An oversized chimney will have a hard time heating up enough to allow adequate draft. An appliance served by an oversized chimney may have spillage and backdrafting problems.
- A good example of this is when a water heater remains tied to a chimney after a high-efficiency, direct-vent heating system replaces the furnace that used the chimney. The chimney is no longer needed for the new furnace and the hot water tank remains, orphaned at the oversized chimney.
- A stainless steel liner should be installed to narrow the chimney serving the water heater. Refer to NFPA 54 for proper type and size.

  Show a sample of the chimney liner and cap.

Worst Case Combustion Safety Testing (Slide #41)

- ***CAZ testing*** determines if combustion appliances will vent under ***worst case*** conditions and protect the occupant from the hazards of ***draft reversal***.
- Under worst case conditions, conduct:
    - *Spillage test.*
    - *Draft test.*
    - *CO test.*
- Perform these tests during the audit and at the end of each work day.
- Conduct these tests for vented systems only!
- Ambient CO levels should be monitored in the CAZ during worst case testing, especially if ***depressurization*** of the combustion zone exceeds -5 ***pascals (Pa)*** during house depressurization testing. If ambient CO levels in the combustion zone exceed 20 ppm, the draft test should cease for safety. The combustion zone should be ventilated before testing and repair of CO problems resumes.
- Deactivate combustion appliances until the hazard is fixed.

Setting Up Worst Case Conditions (Slide #42)

- Record the outdoor temperature.
- Check and clean the dryer lint filter and vent. Replace or clean the furnace filter if needed.
- Deactivate all combustion appliances.
- Close all exterior doors and windows.
- Open interior doors containing exhaust fans.
- Close all other interior doors.

Conducting a Worst Case Test (Slide #43)

- Measure the pressure difference of the CAZ with respect to the outdoors using a manometer. This is the baseline pressure that should be subtracted from all other CAZ readings.
- Operate all exhaust devices (including the dryer and air handler).
- Measure the pressure difference of the CAZ with respect to the outdoors.
- Open and close interior doors (including the door to the CAZ) to induce the greatest CAZ depressurization. Check interior doors using a smoke puffer. If smoke enters the room from the main body of the house, open the interior door. If air from the room blows smoke back into the main body of the house, close the interior door.
- Conduct CO, spillage, and draft tests under worst case conditions. Start with the weakest drafting appliance first. If the draft in the combustion appliance vent is less negative than minimum draft, the vented combustion appliance is susceptible to extended periods of pressure-induced spillage and/or backdrafting when exhaust devices are in operation.
    - Draft is a measurable pressure difference caused by combustion byproducts exhausting through a chimney flue as influenced by the temperature difference and the height of the flue. Draft for a natural draft appliance such as a furnace or water heater should be a negative value such as -0.02 IWC or its metric equivalent, -5 Pa.
- Repeat for all other vented appliances.
- Return exhaust fans and combustion appliances to normal settings.

If a house is available, conduct these tests with students during a field trip.

Test for Spillage (Slide #44)

Photo of a smoke-generating device to test for spillage

- There should be no spillage after 1 minute of furnace operation.

Spillage, Draft, and CO (Slide #45)

- Spillage – Test at vent openings, i.e., dilution air openings or ***barometric damper,*** with smoke. Dilution air is room air that mixes with flue gases. Its purpose is to assist and maintain a consistent draft and counter the effects of wind.
- Draft – Test in the vent connection between the last opening in the vent connection and the chimney.
    - Oil burners – Test over fire in the combustion chamber.
- CO – Test at appliance breech, between the appliance and the first opening in the vent connect or directly above the heat exchanger.
    - Condensing gas appliances – Test at vent termination.

CO, Draft, and Steady-State Efficiency (Slide #46)

Test for CO at each burner exhaust port of a natural draft furnace.

- Start the heating unit. Allow it to reach "steady state," a condition that exists when the stack temperature stops rising more than 2ºF in 1 minute as measured by the probe of a combustion analyzer.
- Insert the probe into the heat exchanger ports of a natural draft furnace, taking a complete set of readings in each port.
- In all cases, test CO in undiluted flue gases before they enter the dilution air inlet (draft hood). Test in each burner port.
- Test for draft above the draft hood or draft diverter. A draft hood or draft diverter is an intentional opening in the vent system serving a natural draft appliance (i.e., furnace or water heater). This is where dilution air is drawn from the surrounding room to mix with the flue gases in the chimney. *See slide #29*
- For an 80+ efficiency ***induced draft furnace***, test for CO and draft in the vent above the inducer fan.
- Measure the steady-state efficiency in the flue gases. It is calculated by the combustion analyzer based on the levels of CO_2 or O_2 and the flue gas temperature.

CO and Draft Test Locations #1 (Slide #47)

- For a 90+ efficiency ***condensing furnace***, test for CO at the vent termination. A draft test is not required for a condensing furnace because it operates on positive pressure in the flue.
- For a floor furnace, test for draft downstream of the draft diverter and CO at the burner exhaust port.

CO and Draft Test Locations #2 (Slide #48)

- For a fuel oil furnace, test for CO and draft before the barometric damper. The barometric damper on an oil-fired system consists of a short section of vent and a counterweighted gate. The gate is balanced and adjustable to allow dilution air from the house to mix with exhaust gases going up the chimney. It maintains a consistent draft and counters the effects of wind.
- Measure the combustion efficiency and perform a smoke test. As measured with a smoke tester, the level of smoke in a flue gas sample of an oil furnace indicates how efficiently the burner is operating. Improper fuel-to-air ratio will result in high smoke.

Testing Water Heaters #1 (Slide #49)

- Insert the combustion analyzer probe down into the water heater before the draft hood and take CO readings on both sides of the ***baffle*** in the center of the flue inside the water tank. The baffle retards the flow of hot flue gases to facilitate the transfer of that heat to the water jacket surrounding the flue.
- Test for draft above the draft hood.
- Ambient CO levels should be monitored in the living space and the CAZ to ensure the safety of agency staff, weatherization contractors, and occupants.
- Remember to calibrate the combustion analyzer outside and measure outdoor baseline CO levels before the test to ensure the accuracy of CO readings.
- If ambient CO levels exceed 9 ppm in the house, the combustion appliance zone should be ventilated before further testing and repair of the CO problem.

Testing Water Heaters #2 (Slide #50)

Photo on left:

- Test for CO directly into the breech of the unit on both sides of the baffle that runs up through the center of the tank.

Photo on right:

- At start up, time the spillage. Then test the draft above the draft hood. Spillage should cease after 1 minute of water heater operation.

Minimum Acceptable Draft (Slide #51)

- This chart shows minimum acceptable drafts at various outdoor temperatures. The suggested minimum drafts account for the effect of temperature difference on draft. For example, draft on a gas-fired furnace is not as strong on an 80° day as on a 20° day.
- In most instances, chimney and vent problems are due to spillage or inadequate draft.
- Standards for draft are based on fuel type, appliance type, and outdoor temperature.
- Draft can be measured in IWC or Pa.
- This chart of minimum acceptable draft for combustion appliances suggests values based on industry and weatherization standards, cited in the ***U.S. DOE Hot Climate Initiative*** document, “Combustion Appliance Safety and Efficiency Testing.”

Carbon Monoxide Action Levels (Slide #52)

- This chart of suggested CO action levels is based on industry and weatherization standards, cited in "Combustion Appliance Safety and Efficiency Testing."
- When CO exceeds acceptable action levels, perform the following tests, adjustments, or fixes:
    - Verify that the vent system is allowing sufficient draft.
    - Verify that the gas pressure is within the acceptable range by measuring the gas pressure or clocking the gas meter (natural gas only).
    - Adjust the primary and/or secondary air on gas burners or clean burners.
- If these steps do not reduce CO to acceptable levels, refer the client to a heating technician who can replace the appliance as a health and safety measure.

Combustion Safety Problems – Fixes (Slide #53)

Solve excessive depressurization or inadequate draft by specifying an appropriate combination of the following measures:

- Repair chimney obstructions, disconnections, or leaks.
- Resize the vent, connector, or liner.
- Install a metal chimney liner and/or a wind-rated chimney cap.
- Seal leaks in the return ducts of the CAZ.
- Balance supply and return air by adding new returns or passive return air openings to the main body of the house.
- Reduce the capacity of large exhaust fans.
- Provide make-up air for dryers and exhaust fans.
- Provide a combustion air inlet to the CAZ.

Summary (Slide #54)

- Understanding the basic principles of combustion, distribution, and venting will enable technicians to recognize safety-related problems.
- Health and safety issues related to combustion equipment are among the most important aspects of weatherization.
- Combustion safety problems are often related to poorly designed or non-code-compliant vent systems.
- Worst case CAZ testing should be done as a safety test-out procedure if work has been done on combustion appliance systems or the building envelope.