Combustion Appliance Testing WHY, HOW, WHEN?

Get over your resistance to learning how to test—it can save lives and your business.

by A. Tamasin Sterner

All people and animals are at risk for CO (carbon monoxide) poisoning. Infants and people with chronic heart disease, anemia, or respiratory problems are more susceptible to its effects. Each year, according to the Centers for Disease Control and Prevention, more than 400 Americans die from CO poisoning, more than 20,000 visit the emergency room for CO poisoning, and more than 4,000 are hospitalized for CO poisoning. Fatalities are highest among Americans 65 years of age and older.

The seriousness of the issue is highlighted by the news of a civil lawsuit filed on August 11, 2010, stemming from the CO poisoning of a family of four in Aspen, Colorado. According to a recent report in the *Aspen Daily News*, the lawsuit claims five preventable causes that led to the poisoning, including disconnected exhaust piping and fresh-air intake vents, defective design of the boiler unit itself, improper installation of the ventilation system, and the absence of CO detectors in the house.

"Examples like these are the precise reason why we have standards," says Larry Zarker, CEO of BPI (Building Performance Institute). "Anything less can result in tragedy for families and adverse consequences for contractors, manufacturers, program managers, and anyone and everyone connected with the project, however distantly." (BPI knows of no one involved in the case who has any affiliation with BPI.)

There can be many problems with combustion equipment in existing homes, especially if the homes are older, the equipment is older, and there isn't money to maintain or replace the combustion appliances or the distribution systems. Technicians who work in existing homes, especially low-income homes, must be able to test houses and combustion appliances properly, in order to ensure that everything is safe. Unfortunately, energy raters who work in new homes are not required to test appliances for safety.

My company, Pure Energy, based in Lancaster, Pennsylvania, is known primarily for performing quality assurance and quality control inspections of work performed in existing low-income homes on behalf of utility retrofit and weatherization programs. These programs run many diagnostic tests, including an entire litany of combustion equipment and combustion appliance zone (CAZ) tests. But Pure Energy's quality control inspectors find gas leaks or unacceptable levels of CO in about half of the homes in which they perform comprehensive final inspections.

Why is that? Many home performance professionals and weatherization technicians are confused about why, when, and how to test combustion appliances and the combustion appliance zone to ensure safe living conditions for families. If you read this article, you will:

- learn why it is important to be sure that combustion appliances are safe to use, before and after weatherization;
- learn about each type of test; and
- learn how to perform each test efficiently and safely.

Easy or Not, You Must Test

Look at the two photos on the next page. It is easy for most technicians to see that there are signs of flame rollout in the first photo and a disconnected flue in the second photo. Flame rollout means that the fire leaves the place where the fire should remain and comes out of the unit. This is dangerous because combustible materials may be close to the flame. A disconnected flue pipe is a problem because the fumes from the burnt fuel might not be going up the chimney. If these fumes come into the room, and if they contain CO, and if the level of CO is high enough for a long enough period of time people or pets can be poisoned (see "What Is CO?"). There are other by-products of combustion, including moisture, that can cause structural and health problems if they don't all go up the chimney. However, this article deals primarily with BPI test procedures, which don't include action levels for by-products other than CO.

Because some combustion appliance problems can't be seen, they are not easy to diagnose, and tests must be performed to find them. For example, by using tracer smoke, a technician can tell if an appliance drafts properly. However, the technician can't tell if the draft is strong enough unless he or she checks draft


PURE ENERGY

Signs of flame rollout.


PURE ENERGY

Signs of spillage.


PURE ENERGY

Disconnected flue pipe.

pressure and compares it to a chart of acceptable minimum draft pressure ranges.

The combustion appliances we are most concerned with are those that were not designed to turn themselves off if a problem is detected. These appliances also rely on nature to make them draft properly. The best scenario is to eliminate all older, inefficient, natural-draft combustion appliances and replace them with high-efficiency, direct-vent appliances, where exhaust gases are vented to the outside and combustion air is brought in from the outside through a separate vent, so the occupants are in control of the house and its systems instead of being controlled by the systems. But until this can happen, we must ensure safe operation when weatherizing homes. We are mostly concerned with fuel-burning water heaters, and space-heating systems that are not 90%+ efficient and direct vent, but there are always exceptions. Most new systems won't fire if there is a problem with the flue, but older systems will still fire. And if they are making CO, the CO in the flue gases can leak into the living area.

Some programs require energy auditors and field technicians to be BPI certified. Combustion-testing procedures are prominent in BPI standards. Home Performance with Energy Star requires combustion testing. Appliances need to be checked for safe operation if the home has been weatherized. Some electric conservation and efficiency programs are beginning to air seal homes with combustion appliances to reduce cooling load. The purpose of air sealing and some insulation is to reduce the air exchange across the thermal boundary. If the home has a fossil-fuel heating or water-heating system, the reduced air exchange may change the way the combustion appliances work.

BPI standards require testing before and after the work is done. "Test in and test out" is a familiar motto for those who test according to BPI standards.

When fuels don't burn fully, CO can be formed. This is our main concern. Carbon monoxide can enter the house if the chimney is blocked or the flue is disconnected, or because exhaust fans in the house are pulling air down the chimney. In

What is CO?

- CO is a product of incomplete combustion of a fuel.
- It is very dangerous for humans and animals, because it prevents the absorption of oxygen into the bloodstream.
- CO is expressed in parts per million (ppm).

Sources of CO

- Fuel-burning furnaces, boilers, and water heaters
- Fuel-burning space heaters
- Fireplaces
- Gas ranges and ovens
- Vehicles
- Tobacco smoke

Characteristics of CO

- Odorless
- Colorless
- Tasteless
- Mixes well in air
- Does not stratify
- Follows airflow in a structure
- Poisonous

How much CO is too much CO?

- 35 ppm NIOSH permissible exposure limit: 8 hours
- 200 ppm NIOSH ceiling: 15 minutes
- 200 ppm Slight headache within 2 to 3 hours
- 400 ppm Headache within 1 to 2 hours
- 800 ppm Sickness and twitching of limbs within 1 to 2 hours; unconsciousness within 2 hours
- 1,600 ppm Headache within 20 minutes; death within 2 hours
- 3,200 ppm Death within 30 minutes
- 6,400 ppm Death within 10 to 15 minutes
- 12,800 ppm Death within 1 to 3 minutes


PURE ENERGY

Flue pipe doesn't reach the chimney, so flue gasses can't leave the building.

Some problems are obvious. Some are not. With proper training and equipment, a technician can identify dangerous conditions that otherwise might go undetected. These valuable skills can save lives.

addition, a depressurized CAZ can cause flame rollout and gas leaks can cause explosions. The technician must test for all of these potential problems.

The tests are designed to answer the following questions:

- Is there CO in the ambient air? In the CAZ? In the flues? In the gas oven? If so, how much? Is it too much?
- Are there any gas leaks in the gas lines or valves or joints?
- Do the fumes go out the chimney or the flue quickly? Do any fumes come back into the room? When the water heater or furnace or boiler fires up, do flames come out of the unit?
- When the CAZ is depressurized the most by exhaust fans or clothes dryers in the house, do the appliances still draft adequately?
- Is the pressure in the flue with reference to the CAZ strong enough to ensure that the appliance drafts?

Some tests are always performed, regardless of the type or age of the appliance. These include testing for gas leaks, testing for CO in the ambient air, checking for flame rollout, and testing for CO levels in the exhaust. Be aware—sometimes you will find a CO level in the flue gases that is higher than BPI action levels, but manufacturers may allow higher CO levels if the appliance is power vented (other terms are fan assisted and forced draft).

All the combustion safety tests must be performed if there are any natural-draft combustion appliances in the house, and if air sealing or insulation is done. These appliances are most likely to fail to draft properly in a worst-case CAZ depressurization scenario. If you don't know what worst-case CAZ depressurization means, you are not alone! Read on.

Worst-Case CAZ Depressurization

When bathroom fans, vented kitchen range hoods, or vented dryers are on and venting, they are pumping air out of the house. New air has to come from somewhere to replace what is being pumped out. If windows are closed, and the building envelope and interstitial cavities have been sealed, that new air is likely to enter the house through the chimney and the flues. If the water heater or furnace comes on when air is coming down the flue, the flue gases will enter the house. This is bad. This sort of negative pressure imbalance can also happen when ducts are leaky or sealed, and when interior doors are opened or closed.

So the technician must put the house under worst-case conditions—that is, under conditions the occupants might happen to create that might cause a problem with the combustion appliances. This means that the technician tries to configure the house systems and door positions in such a way as to cause the highest depressurization on the CAZ, because that is when a combustion appliance may not vent properly. The technician must keep checking the pressure in the area where the combustion appliances are located until he or she finds the worst-case configuration. Some doors may be open and others closed—every house is different. There are typical configurations, but the only way to know what is worst-case for a particular house is to measure the CAZ pressure with reference to the outside until the biggest negative number—representing the pressure difference between the CAZ and the outside—is reached. That is worst-case depressurization.

If the appliance drafts strongly enough when the house is under worst-case depressurization, the appliance will probably operate safely. However, all the tests must be done at the end of each workday during weatherization, in order to be sure that the house remains safe.

The BPI action levels specify what is safe and what is not safe. There are action levels for the amount of CO that is permissible in flue gases; for the minimum draft pressure that is acceptable in the flue pipes with reference to the CAZ; and for the maximum negative pressure that is acceptable in the CAZ. And there are rules for what to do if any of these levels is exceeded or not met (depending on the test). For a link to BPI's Combustion Safety Test Action Level Tables, see "For More Information" below.

A natural-draft furnace works by gravity. In this type of furnace, assuming there is enough difference in temperature between the air outside and inside the flue, the buoyancy of warm-air flue. In an induced-draft furnace, there is a fan just inside or outside the wall where the vent exits the home that forces flue gases through the flue. This fan creates negative pressure in the flue. In a forced-draft furnace, a fan in the combustion appliance forces combustion gases through the flue to the outside of the home using positive pressure. A condensing furnace, both direct- and indirect-vent pulls some heat out of the exhaust gases before they are expelled from the house, making them more efficient. Condensing furnaces use fans to create a positive pressure in the flue. (Note that appliances with positive pressure in their vent connectors require airtight vent connectors.)

Negative pressure in the flue means that the gases are being sucked out. Positive pressure in the flue means the gases are being pushed out. Don't confuse pressure with flow. We want the flue gases to leave the building (flow to the outside). Sometimes this happens when the flue gases are pushed out (positive pressure in the flue with reference to the CAZ), and sometimes this happens when the flue gases are sucked out by nature (negative pressure in the flue with reference to the CAZ). It is important to know how the appliance is supposed to work before deciding that the pressure in the flue is wrong.

If a test fails before the house is air sealed or insulated, follow the BPI Combustion Safety Test Procedure For Vented Appliances. Depending on the problem found and the action level, no air sealing should be done until the problem is fixed. If a test fails after the house is air sealed or insulated, follow procedure—fix the problem. Follow the directions on the action levels charts.

Proper testing is essential—these tests can be a matter of life and death! A little knowledge can be dangerous. All of the appropriate tests need to be done thoroughly, done in the proper order, and reported on a form. The form should be signed and dated. There should be a set of test results that were done before work was performed, and another set of test results that were done at the end of each workday, when the air leakage rates may have been reduced.

Why Does Pure Energy Find So Many Problems?

Why does Pure Energy find so many gas leaks in the houses it inspects? Why do we find so many high CO levels? It's possible that no one ever performed the tests. We believe some technicians don't know how to test properly, or they test too quickly and miss gas leaks at pipe joints. We also believe some technicians don't perform all the tests, or perform them in the correct order. It is also possible that some technicians don't know how to use their tools properly, or that they have not maintained their equipment adequately, so the tests are invalid. And we believe some technicians don't know how to interpret their test results. Why do we believe these things? Because we have struggled with some testing procedures, and we know how hard it can be to learn the whys, hows, whens, and whats of combustion testing!

So here we want to share skills we've learned—to help technicians multitask successfully. Our suggestions follow.

Organize your office, self, vehicle

- Have your data-collection forms prepped.
- Make sure you have combustion analyzer printer paper and data-collection forms.
- Is the equipment charged? Need batteries?
- Does the customer know how to prepare for your visit?

Before your appointment

- Order tools and parts if necessary.
- Have the oxygen or CO sensors in your combustion analyzer expired? If they have, your tests aren't valid.
- Not having one tool will shut you down, so check to be sure you have all the tools, equipment, and supplies you will need.

In your vehicle

- Do you have all the supplies you need, such as chemical smoke, high-temperature flue tape, and plugs to fill the test holes?
- Is your vehicle organized enough so you can find your tools and supplies?
- Is everything accessible and secure?

At the customer's home

- Can you get to the CAZ and all other areas?
- Can you get to the water heater and furnace?
- Take the tools and equipment to the CAZ as you are unloading.
- Turn the water heater down and the furnace off if conditions allow; mark settings.
- Remember to return the water heater and furnace to prior settings. **TIP:** leave your truck keys here as a reminder!

REMEMBER: The house is a system, and everything in it is part of this system. The water heater and furnace or boiler may never have been tested for adequate draft pressure or CO before your visit. It is very likely the systems have never been tested with the CAZ under the worst-case scenario, as described above. You may be the first to fully test. Be safe. Do it right.

A. Tamasin Sterner *is the founder and owner of Pure Energy, a Lancaster, Pennsylvania–based company. She has been in the energy auditing and weatherization field since 1980, working in Washington, Pennsylvania, New Jersey, Delaware, Ohio, and Montana. Recently, Pure Energy, in partnership with Larry Armanda of Therma-View Infrared and Energy Consultants, opened a training center on a ranch in Montana, and created a mobile teaching and testing lab in Pennsylvania.*

>> For more information:

The author can be reached at tsterner@PureEnergyAudits.com.

To learn more about her company, Pure Energy, go to www.PureEnergyAudits.com.

To learn more about Pure Energy's training opportunities go to www.PureEnergyCenter.org.

For more on BPI CO testing standards, including CO action levels, go to www.bpi.org.

For the report on the lawsuit cited at the beginning of this article, see www.aspendaily-news.com/section/home/141957.

This article is part of a series sponsored by Home Performance with ENERGY STAR, jointly managed by the U.S. Department of Energy and Environmental Protection Agency. The opinions, views and ideas expressed within this article are those of the author and do not necessarily reflect the official policy or position of any agency of the U.S. government.