Consulting, Resource, Education, Training, and Support Services for Home Inspectors
"A candle loses no light when it lights another candle."

FUEL GAS AND FUEL OIL COMBUSTION BY- PRODUCTS AND VENTING

Part of an inspection of vented fuel gas-fired or fuel oil-fired appliances includes inspecting for combustion by-product backdrafting, leakage, and spillage. Backdrafting, leakage, and spillage can occur at:

- **Openings into combustion chambers**
- **Draft hoods/diverters and at connections of vents to vent collars**
- **Improperly assembled and/or secured vent section joints and at improper terminations of vent systems**
- **Damaged areas of draft hoods**
- **Damaged areas anywhere along the developed length of the appliance vent/chimney**

The causes of and contributing factors which lead to combustion by-product backdrafting, leakage, and spillage are numerous and may include:

- **Insufficient combustion air**
- **Negative air pressure in the building, room, or compartment in which the appliance is located**
- **Obstructed or damaged draft hoods/diverters**
- **Obstructed or damaged heat exchangers; obstructed flue gas vents/chimneys**
- **Damaged flue gas venting system components**
- **Improper termination of flue gas venting systems**
- **Improper assembly, sizing, insulation, or installation of flue gas venting systems**
- **Excessively long flue gas vents**
- **Combustion by-product flow restriction caused by too may changes in direction in the vent**

The single greatest potential hazard associated with combustion by-product backdrafting, leakage, and spillage is the production of CO (carbon monoxide) and its introduction into the interior environment where it can result in both occupant exposure and CO poisoning of occupants. CO poisoning is silent and insidious because CO is odorless, colorless, and tasteless. Just one molecule of CO for every 1999 air molecules can result in a lethal mixture. This is 500 parts per million - not very much.

CO typically enters the bloodstream through the lungs. Once in the bloodstream, CO attaches to the blood's *hemoglobin*, the protein coloring matter in blood that gives it its red color and which transports oxygen. When this occurs it decreases the total oxygen carrying capacity of the blood – in effect, starving the various tissues and their cells of oxygen. By attaching to the blood's hemoglobin, CO effectively makes a portion of the hemoglobin unusable for binding with oxygen. As if that were not bad enough, CO also binds with hemoglobin more avidly than does oxygen. This, in turn, makes it more difficult for oxygen to be released to the body's tissues resulting in *asphyxia* – oxygen starvation. Because hemoglobin has about a 250 times greater affinity for CO than it does for oxygen, it takes much longer for the body to get rid of CO. In other words, hemoglobin doesn't just prefer CO to oxygen; it wants to hang on to CO once it binds to it.

The most common initial symptoms of CO poisoning are **headache**, **dizziness**, **weakness**, **nausea**, **vomiting**, **chest pain**, and **confusion**. High levels can result in loss of consciousness and death. If CO poisoning is not suspected as a cause of many of these symptoms, it can be difficult to diagnose since the symptoms mimic other illnesses such as flu. Individuals who are asleep or intoxicated can die from CO poisoning before ever waking or experiencing any symptoms.

As with other aspects of a home inspection, inspection for combustion by-product backdrafting, leakage, and spillage from vented fuel gas and fuel oil-fired appliances is a primarily visual examination of the visible, safely accessible, and readily accessible portions of fuel gas and fuel oil-fired appliances and their related venting system components. While inspectors may choose to use specialized combustion by-product detection equipment or special tools in the course of conducting a home inspection, they are not required to do so (watch for an upcoming ***ProSpex*** article *Specialized Equipment and Tools - Raising Expectations and Liability* in the "FREE Articles" area of the ***ProSpex*** website.

In order for fuel gases and fuel oil to burn at maximum efficiency, they must be provided with combustion air which contains enough oxygen to permit complete combustion. Whether combustion air sources are from the interior of the building in which appliances are located or from the exterior, all fuel gas and fuel oil-fired appliances require some source of combustion air and all combustion air ultimately comes from the exterior of a home. In many older homes there may be no dedicated sources of combustion air because such homes were not constructed as tightly as homes built today. In such older homes air infiltration provided sufficient combustion air. However, because of today's higher energy costs, it is not uncommon for older homes to have been modified to reduce air infiltration without consideration being given to the effect that this may have on the combustion air supply for gas and fuel oil-fired appliances.

This makes inspection for visible conditions that are consistent with combustion by-product backdrafting, leakage and spillage, for conditions that could increase the potential for combustion by-product backdrafting, leakage and spillage, and for combustion air sources extremely important in all homes.

For the purposes of this discussion, we will assume a conventionally aspirated (not forced or induced draft), atmospheric burner and conventionally vented gas-fired appliance such as a tank type water heater or an older, gas-fired, conventionally aspirated, atmospheric burner furnace or boiler. We will also assume that the appliance is located somewhere in the interior of the home and that it takes its combustion air from the interior of the home. Combustion by-products proceed along a path from their point of initial creation at the appliance burner and combustion chamber; past a heat exchanging surface; through a draft hood, draft diverter, or barometric damper (remember, we're assuming a conventionally aspirated unit); into the vent connector; into the vent; and are finally discharged to the outside atmosphere at the downstream termination of the vent on the exterior of the home.

The purpose of draft hoods, draft diverters, and barometric dampers on conventionally aspirated combustion by-product venting systems is to ensure that a constant low draft condition is maintained in the combustion chamber. By doing so, draft hoods, draft diverters, and barometric dampers contribute to the stability of the air supply for the combustion process. They also reduce the potential for both excessive chimney draft (updrafts) and downdrafts that have the potential to extinguish burners and pilot flames.

The combustion by-products pass into the draft hood or diverter or past the barometric damper at around 500° F where they are mixed with cooler room air (dilution air) and the temperature of the combustion by-products drops to around 300 -350° F. At this temperature the combustion by-products are still warm enough to rise up the vent by their own buoyancy and to prevent the acidic water vapor in the combustion by-products from condensing out and running down the inside of the vent and into the appliance causing corrosion damage to both.

When there is sufficient combustion air, the by-products of combustion are carbon dioxide (CO_2), nitrogen (N), water (H_2O), very small amounts of carbon monoxide (CO), particulates, occasionally very small amounts of sulfur (S) [depending on the specific chemical composition of the fuel], and, last but not least, heat – which what the fuel is burned for in the first place.

If the appliance is equipped with a properly designed, assembled, installed, and maintained venting system, these combustion by-products (except for a portion of the heat) are conveyed from the appliance to the outside atmosphere through the appliance vent (also referred to as a flue, smokestack, or exhaust). Water heaters, furnaces, and boilers all have components which transfer some of the heat of combustion to air, water, or some other heat-retention/storage or heat-transfer medium.

If there is insufficient combustion air, the burner will be starved and the fuel will not burn efficiently. When his happens, as the appliance continues to operate, the combustion process will produce soot, higher levels of CO, and less heat. If the appliance combustion by-product vent is intact, properly assembled, and properly installed, it will continue to convey the combustion by-products to the outside atmosphere. However, the soot that's produced as a result of incomplete combustion can build up on the inside surfaces of burners, combustion chambers, heat exchangers, draft hoods, and vents.

This soot build-up reduces the cross sectional area of heat exchangers and vents and can eventually block them off completely. I have observed heat exchangers with so much soot build-up on the opposing walls of the exchanger chambers that the soot met in the center of the chambers almost completely blocking the passage of combustion by-products through the exchanger to the vent. This occurred because the primary air shutters for the burners were completely closed and very little combustion air was being fed into the fuel gas to mix with it before it was ignited.

Even slight restrictions inside a vent can reduce the ability of combustion by-products to move through the vent and can cause them to spill out at the draft hood or at the appliance vestibule area into the interior space where the appliance is located. Combustion by-product spillage dilutes the interior air with CO and other components of combustion resulting in a reduction of the percentage of available oxygen in the combustion air. The reduction of available oxygen now starves the burner and, the more the burner is starved, the more inefficient the combustion process becomes resulting in the production of more soot and CO. Now the CO production cycle begins – more CO leads to more inefficient combustion leads which to more soot build-up and even higher levels of CO which leads to more soot build-up and… the picture should be clear.

In addition to heat exchanger and venting system blockage, incomplete combustion can result in damage to the vent. Since the appliance in this example is conventionally aspirated (not an induced draft or a forced draft appliance), it will typically have a galvanized (zinc-plated) steel metal vent. Incomplete combustion produces less heat and produces nitrogen dioxide (NO_2) and water vapor which combine to produce nitric acid (HNO_3). Nitric acid is aggressive toward steel, zinc, paint, human tissue, and silver among other things. Its effects on silver can be seen in the tarnish on silver plated items in homes with gas-fired cooking appliances. When less heat is produced, the potential for this acidic water vapor component of the combustion by-products to condense out of the combustion by-products increases. It will react with and corrode the inside surface of the metal components such as heat exchangers, vent hoods, vent connectors, and vents.

As if it were not bad enough to have elevated levels of nitric acid in the combustion by-products, consider that, because incomplete combustion produces less heat, the combustion by-products will not be as buoyant. That is, they will not be as light in weight compared to the ambient air as they would be

if there was complete combustion. Therefore, they will not rise through the vent as rapidly. This means that the corrosive components in the combustion by-products will remain in the vent longer and can do more damage to the vent.

If the corrosive components of the combustion by-products corrode through the sheet metal of the vent or through the walls of a heat exchanger, the combustion by-products can vent or leak directly into the interior of the home. Now, there is another source of CO and other combustion by-products and further reduction of oxygen for combustion. Again, the CO cycle is initiated and/or accelerated.

Add to this a vent connector that has too little slope, a cold outside temperature that can cause temporary cold air blockage in the vent when the appliance isn't operating and no heat is moving through the vent, and components which contribute to depressurizing the house such as a properly vented clothes dryer in the house, a couple of bathroom exhaust fans, a solid fuel appliance (fireplace or wood stove), and an exterior vented kitchen exhaust fan. Any of these, alone or in combination, can contribute to further starving the gas-fired appliance of combustion air and to the potential for CO poisoning of the home's occupants.

While this example may represent a kind of worst-case scenario, it serves to point out some of the ways combustion by-products from fuel gas and fuel oil-fired appliances can find their way into the interior of a home. As an inspector, you are certainly going to examine all of the visible, safely accessible, and readily accessible portions of the vent connector and the vent for proper materials, proper assembly, proper support, proper minimum slope, clearance to combustible materials, proper termination, and a storm cap. Good! But you are not done yet. You want to determine the source(s) of combustion air and you want to check for backdrafting of combustion by-products.

Corrosion and/or scorching on the exterior surface or paint of a draft hood or holes through draft hoods, draft diverters, and vents are common signs that combustion by-product spillage or backdrafting have occurred. Make sure that all gas-fired appliance burners are off. Then, turn on the bath fans, the kitchen exhaust fan (if it vents to the exterior), and the clothes dryer. Now, go to all of the gas-fired appliance controls and energize the appliances so that their burners ignite. Wait about sixty seconds and then place your mirror next to each appliance's draft hood or diverter. If your mirror fogs up, that is an indication that combustion by-products are spilling out of the vent system and into the house air at the appliance. Place your hand near the draft hood or diverter, if you feel moist air flowing out of the hood or diverter, you have spillage.

If you can use your mirror and flashlight to view the interior of metal vent connectors or vents and you see a white, almost chalky substance on the interior surfaces, you are seeing nitric acid corrosion of the sheet metal of the vents. Excessive or atypical rust and corrosion on the interior and/or exterior surfaces of a furnace, boiler, or water heater draft hood are signs of improper venting and of combustion by-product spillage or backdrafting.

It is not difficult. All that are necessary are your hand and a mirror and a flashlight, both tools that all inspectors should carry. Remember to turn off the exhaust fans and clothes dryer and to set the gas-fired appliance controls back to their original settings after you have completed your examination for spillage and backdrafting.

Be sure to carefully examine the portions of the vent in the attic and above the roof line whenever possible regardless of whether the appliance is venting through a conventional vent or through a masonry chimney. Inspect the condition of the vent above the roof line and its storm cap. If the vent connector vents into a masonry chimney, remember to look for a cleanout below the point where the vent connector enters the chimney. Open the cleanout and use your flashlight and mirror to examine the interior of the chimney for deterioration, any liner, obstructions or interior damage, and to determine if the vent connector extends past the interior surface of the flue. If more than one appliance vents into the chimney, be sure to determine that the vents are offset and don't enter the chimney at the same level and that smaller vents always connect to the chimney above (downstream of) larger vents.

Gas or oil-fired appliances venting into an unlined masonry chimney should be flagged in the written inspection report as a condition for which immediate action is recommended. The moisture in the combustion by-products will eventually cause deterioration of both any mortar lining and masonry joint mortar. This will result in weakening of and damage to the chimney structure as well as in the potential for leakage of combustion by-products into the interior of the house.

Finally, multiple gas-fired appliances can share a common vent and multiple oil-fired appliances can share a common vent as long as the common vents for both meets certain criteria pertaining to the minimum cross sectional area of the common vent and the points at which the appliance vent connectors join the common vent, but neither gas-fired or fuel oil-fired appliances can share a common vent with the other or with a solid fuel appliance.

NO MIXING OF GAS-FIRED APPLIANCE VENTS WITH FUEL OIL-FIRED APPLIANCE VENTS

NO MIXING OF SOLID FUEL APPLIANCE VENTS WITH OTHER SOLID FUEL APPLIANCE VENTS

NO MIXING OF EITHER GAS-FIRED APPLIANCE VENTS OR VENTS OR FUEL OIL-FIRED APPLIANCE VENTS WITH SOILD FUEL APPLIANCE VENTS VENTS!

Each solid fuel appliance is to have its own separate vent or flue –multiple solid fuel appliances should never vent into a common vent or flue. If large enough, a single chimney structure can contain multiple flues/vents for solid fuel, gas-fired, and oil-fired appliances. However, while multiple gas-fired appliances can share a common vent and multiple oil-fired appliances can also share a common vent, appliances which burn different fuels cannot be vented in common and multiple solid fuel appliances cannot share a common vent or flue.

Additional information can be found in *Code Check* and *Code Check Mechanical*.

If you want to make a recommendation regarding the installation of a CO detector in homes with gas or oil-fired appliances, you may want to consider placing such a recommendation as an elective modification.

Other Sources of CO Poisoning

There are other potential sources of CO poisoning that should be considered and evaluated in the course of conducting a home inspection – these are gas-fired clothes dryers and vehicle garages. Be sure to inspect the vent and vent terminal of gas-fired clothes dryers for proper materials, damage, proper installation and termination, proper assembly, and for obstructions. Screws or other mechanical fastening devices that can project into the interior of any clothes dryer vent should not be used to secure sections of the vent. Such fasteners can trap lint resulting in the obstruction of the vent, combustion by-product spillage, overheating of the dryer, and an increased potential for both CO production and fire. Cloth and plastic type duct tape are also inappropriate for securing dryer vent sections at their joint connections. Such tapes are not designed to be subjected to the high temperatures generated in a dryer vent. These tapes and their adhesives will quickly become dry and brittle and will fail resulting in the potential for dryer exhaust leakage and separation of vent sections at joints. The hot dryer exhaust will also reduce the combustion temperature of these tapes through a process known as “pyrolysis.” Dryer vent section joints should be secured using an appropriate, adhesive-backed metal tape or other approved methods and materials.

Flexible plastic clothes dryer vents should not be used with any types of clothes dryers because they are vulnerable to physical damage. Clothes dryer lint is extremely flammable and a tear in a flexible plastic vent can create a lint build-up behind and inside of any dryer, gas or electric. This can increase the potential for ignition of the accumulated lint. In addition, in the case of a gas-fired clothes dryer, the vent is conveying the combustion by-products of the burning gas to the exterior. A damaged vent can

permit those by-products to leak or spill into the interior of the home resulting in the production of and exposure of occupants to CO.

> **NOTE:** For additional information regarding clothes dryer exhaust vent systems see *Clothes Dryer Venting* in the "FREE Articles" section of the ***ProSpex*** website at: www.prospex.us.
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> For additional information regarding on offset clothes dryer transition ducts go to www.applianceaccessories.com.
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> On the menu on left side of the page place your cursor on "Laundry" and when a drop down menu appears immediately to the right of "Laundry," move your cursor to "Dryer Venting" and double click. This site provides a lot of information and photos of specialized offset transition ducts.

The installation of self-closing devices on doors between attached garages and interiors of homes serves to help maintain the fire separation between attached garages and the interior of homes as well as reducing the potential for gas and oil-fired appliance combustion by-products and vehicle exhaust fumes to enter the home.

Several years ago in a northeastern Colorado town an entire family, three children and both parents, died from CO poisoning when one of the children started a car in a closed garage and went back to bed. His parents had been allowing him to start the car on cold mornings so they would have a warm car for their ride to school. Unfortunately, on this particular morning, their son had awakened earlier than usual, before anyone else was awake. After he started the car, he failed to close the door between the garage and the house and he went back to bed. When the children didn't show up for school, the father didn't show up at work, and no one answered the telephone, someone went to the home and found the entire family dead in their beds and the car still running. This should plainly illustrate why currently, in many states, the installation of CO detectors is required when a home is sold and why discussing the installation and location of CO detectors, the installation of self-closing devices on doors between garages and the interior of homes, and documenting breaches such as pet doors, holes, or other damage to walls, ceilings, and doors between attached garages and the interior of homes is an important part of a home inspection.

Regarding inspection of self-closing devices on doors between attached garages and the interior of homes, if they are in place, they should be evaluated for proper operation. If a self-closing device is damaged, not operating properly, or if there are clear indications that such a device has been installed but is no longer present, it should be noted in the written report.