THE HOUSE AS A SYSTEM:
Combustion Safety

"If you only get one thing right, make it combustion safety."
— Richard Kadulski, 9/97 Solplan Review

"Only sealed combustion, power vented, induced draft or direct vented combustion appliances should be used for space conditioning and domestic hot water."
— Joe Lstiburek, Builders' Guide: Cold Climates

A crisis is when you can't say "let's forget the whole thing."
— Murphy's Laws

By Steve Andrews

A typical new home along the Colorado Front Range comes with an array of gas-fired combustion appliances. The usual suspects include furnace, water heater and fireplace. Gas cook-tops and ovens are also commonplace, and gas dryers are certainly not rare.

Each new home's combustion appliances are assumed to be safe. HVAC contractors know the rules and follow numerous key installation guidelines. Code officials inspect for supply lines and exhaust flues that meet run-rise specifications laid out in mechanical codes. But findings around the state indicate that exhaust systems rarely are tested for performance and safety.

Fortunately, the consequences of lack of performance testing are rarely catastrophic. Properly equipped, tuned and vented gas water heaters and furnaces don't produce carbon monoxide (CO). The numbers below show that the worst consequence, an unintentional CO poisoning, is quite rare.

But from a systems perspective, there is some negative synergy operating here, resulting in less-than-safe residential combustion systems. First, pressure imbalances caused by leaky ductwork in today's new homes are the norm. Second, because today's homes are tighter, the pressure imbalances are exacerbated. Third, a gradual increase in the number of appliances that exhaust air from home-fans, dryers and fireplaces-contribute to higher pressure imbalances. Fourth, the greater the pressure imbalance in a home, the greater the likelihood that atmospherically-vented combustion appliances will backdraft and spill the byproducts of combustion back into the home. Finally, recent measurements indicate that unvented combustion appliances, such as gas ovens, are prone to dumping carbon monoxide into the home during the first 20 minutes of operation.

Combine these systems problems with big outdoor winds, or with other unexplained circumstances sometimes called "acts of God," and you have the potential for a tragic situation that begs for your attention.

National and Colorado numbers

Figures from the American Lung Association, the Consumer Products Safety Commission and others indicate that, during 1998, roughly 7,700 people were treated in hospital emergency rooms for CO poisoning unrelated to vehicles or fires. Furthermore, nearly 600 people die annually from unintentional carbon

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monoxide exposure related to residential combustion appliances. Fireplaces are the number one culprit, with heating equipment second.

In Colorado, approximately 115 people died between 1988 and 1996 due to unintentional exposure to carbon monoxide.

According to a variety of sources, the number of people sickened by CO from residential combustion appliances, both in Colorado and nationwide, is suspected to be much higher because the cause is often not correctly identified by the medical profession.

National news

Occasionally, the national media will widely publicize a particularly tragic CO poisoning. Such a high-profile case of carbon monoxide poisoning occurred on May 7, 2000. In that particular situation, six people died in a Mineola, N.Y., residence. Dr. Andrei Kranz's 2-year-old daughter, nanny, parents and two elderly guests died of CO poisoning.

According to reports in the trade press, the cause of the problem was leaking ductwork that depressurized the combustion zone, thus backdrafting the furnace. The fact that the two combustion air ducts were accidentally blocked off may have contributed to the problem. Sadly, this was clearly a case where an uninformed homeowner made things worse by not responding to a carbon monoxide alarm; in fact, he disabled the alarm because it was going off so frequently he thought it was malfunctioning.

The day after the Kranz family tragedy, Hal Ketofsky's family of four awoke to the beeping of the CO alarm in their New Jersey home. Fire officials found the alarm reading 330 parts per million (9 ppm is deemed safe for indoor exposure). Measurements in the basement furnace room were even higher: 400 ppm. The officials reportedly said that "death would have been certain if the family had slept through the night." (The full story is archived at www.achrnews.com.)

Colorado cases

During 1999, a Denver-area policeman and his family of four were taken to the emergency room twice within 10 days for treatment of CO poisoning. The culprit? Backdrafting and spillage of combustion byproducts into the 8-year-old home, probably caused by major winds. The solution: replacement of the atmospheric water heater and furnace with sealed combustion appliances.

Several years ago, a Fort Collins couple and their three children were nearly overcome by carbon monoxide in their home. The husband awoke when he heard his wife's body hit the kitchen floor, where he found her unconscious. He hauled everyone outside and called the fire department. All were eventually taken to the hospital. The lead fire official said this case was among the most serious he had seen, but he stated, "At this time of year, I suspect that there are one or two calls a day" regarding carbon monoxide problems.

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Back in early 1998, a Fort Collins Utilities employee installed a CO alarm in his 1988 home's basement. Two years later, a high wind drove combustion byproducts down into the home at a rate of over 600 ppm; the beeping alarm was barely audible above the howling wind. Later, after changing the vent cap on his flue, the employee installed two more CO alarms. He still lives in the same home, but knowing the statistic that about one-third of CO alarms don't work — usually because of dead batteries-he checks the status of the alarms frequently and changes batteries — every six months.

A technician working in a new 200-unit Fort Collins apartment project encountered heat spilling into one apartment from its water heater flue. He called Rob DeKieffer (Boulder Design Alliance) to investigate. The key finding: leaky supply ductwork blowing air outside the home (into either a crawlspace or attic) created enough negative pressure inside the conditioned space that just closing one supply register would backdraft the water heater. Within 48 hours, CO alarms were being installed in each unit; the next likely step — replacement of all 200 water heaters with draft-induced models.

Key points from Fort Collins

The housing performance study conducted by Fort Collins Utilities will be released during the first quarter of this year. This study reports findings from the most detailed and well-documented field work of its kind ever performed in Colorado. According to principal study author Doug Swartz, an energy services engineer with FCU, the report's most important single observation is as follows:

"Combustion safety problems observed in the testing sample were infrequent but significant. Yet nothing in the way homes are built provides confidence about combustion safety."

Other key points from the 40-home sub-sample tested with detailed building diagnostics:

• The appliances in several homes produced unsafe levels of carbon monoxide. Carbon monoxide can be

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produced by excessive gas pressure, oversized gas orifices, a restricted air supply, recirculation of exhaust gases to the burner, restricted flues and dirty burners.

• Basement depressurization was high enough to potentially back-draft atmospheric combustion in more than one-third of the homes tested. The danger level is -5 pascals of negative pressure (pascals are a very small unit of air pressure); the worst home tested at -17 pascals of negative pressure.

• Positive drafts in the water heater flue were measured, and in one-third of the homes, the positive flue draft was at or below +5 pascals. Thus in these homes, a negative pressure in the basement of -5 pascals (or worse) can cause spillage of combustion gases whenever the positive draft in the flue is less than +5 pascals.

• During the tests, two water heaters and four fireplaces — all atmospherically vented appliances — spilled combustion products into the home. In one home, the homeowner had repeatedly complained to the builder about odors in the house whenever the fireplace operated. After two callbacks to try to fix the problem, nothing improved, leaving the homeowner unsatisfied with the fireplace and very unhappy with the builder.

• There is typically no effective ventilation for gas ovens, as 10 of the 11 homes with gas ovens were equipped with non-venting, charcoal recirculating fans. Testing of four of these gas stoves showed that each was generating carbon monoxide — between 300 and 1,100 ppm — after five minutes of operation. Several kept-generating CO after 15 minutes of operation, though at significantly lower levels of CO. (Two other randomly tested ovens were also spilling between 800 and 1,600 ppm of CO about 5 minutes after startup.)

• Tests conducted with combustion air ducts open and closed showed that these code-required ducts to the outdoors have little impact on basement depressurization — the key safety risk to safe operation of combustion appliances. For example, closing the combustion air ducts reduced the basement pressure by an average of just -1 pascal; that means that opening them up (+1) does not provide

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nearly enough to offset the negative pressure caused by leaking return-air ducts (often -5) within the basement.

• The code does not address depressurization associated with operating a forced-air heating and cooling system. Code assumes that installation of combustion air ducts will provide some pressure relief in basements. Note that in five homes of the 80-home sample, the homeowner had sealed off the combustion air ducts to prevent cold air drafts. The 1997 Fort Collins energy code now requires warning labels on their combustion air ducts (something like "there are possible health hazards from sealing off those ducts"); none of the five pairs of sealed-off combustion air ducts were equipped with warning labels.

• No one — builders, HVAC installer or building inspectors — typically checks combustion safety before turning a new home over to its buyer. About 15 percent of the furnaces in Fort Collins produced enough CO — between 25 and 50 ppm — to require adjustment. One furnace was generating more than 2,000 ppm; due to this very incomplete combustion process, that furnace's flue had corroded sufficiently after two years that light banging against the metal caused material to fall down inside the flue chamber-a cause for alarm.

Swartz summarized his discussion about combustion safety and atmospherically vented appliances as follows: "All evidence suggests that combustion safety in many homes is on the 'hairy edge,' and that small changes in weather, operating conditions, or the home itself could readily cause venting problems.... In most cases the system works pretty well. Sometimes it doesn't. It appears more luck than planning that there aren't more problems. An analogy is Russian roulette. It's an appropriate comparison, because both can kill if you're unlucky."

The safest solution

There is only one relatively sure-fire solution, and it is listed at the top of this story. As written by Joe Lstiburek in EEBA's Builders' Guide: Cold Climates, "Only sealed-combustion, power-vented, induced-draft or direct-vented combustion appliances should be used for space conditioning and domestic hot water." Add direct-vent fireplaces to this list. And either eliminate gas ovens from the home or provide exhaust ventilation above the unit.

McStain Enterprises is the first production builder along the Front Range to implement this strategy (see this issue's "Energy Waves" column). Their challenge is to try to figure a way to lower the impact of the associated price increase on their bottom line.

Other strategies

When atmospheric-draft combustion appliances are installed, follow as many of these recommended procedures as possible:

• Install two CO alarms — one in the primary combustion zone and the other near the bedrooms. (CO alarms were found in 25 percent of the Fort Collins

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80-home testing sample.)

- Establish CO standards and then have all combustion appliances tested for CO in the exhaust gases.
- Test the drafting of all combustion appliances under both normal operating and worst-case conditions (i.e., all exhaust fans and dryer operating).
- Reduce the possibility for negative pressure in combustion zones by carefully sealing ductwork in all locations; for sealant, use either mastic (prescriptive) or the Aeroseal system (performance-tested for tightness).
- Similar to the Fort Collins code, install warning labels on combustion air ducts, such as: "Leave these open at all times; sealing them could lead to life-threatening problems with the operation of your furnace and water heater."
- Do not install hook-ups for gas or electric dryers in the same air zone where the water heater or fireplace is located.

Two potential problems

One frequently recommended strategy is to isolate the combustion appliances in their own utility room. However, locating such a room in a basement means the room will be extremely difficult and very expensive to isolate from the basement zone.

Locating these appliances within a garage is potentially harmful to the appliances, due to contaminants in the garage air used for combustion. Furthermore, any ductwork leaks within a smaller furnace room, compared to an open basement, will potentially exacerbate pre-existing back-drafting and spillage problems caused by negative pressure.

A second concern is the problems that exhaust fans cause. Exhaust fans are increasingly recommended as a means of providing background ventilation in order to improve indoor air quality. Yet when atmospherically vented gas appliances are present, exhaust can become part of the problem, not part of the solution.

New direction

Based on a series of four seminars presented in December 2000 to code officials and builders about the Fort Collins findings, several code jurisdic-

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tions are in the early stages of considering draft-induced water heaters. Their concern here is, rightfully, health and safety, not energy efficiency. In fact, improving energy efficiency is hardly a factor in the switch away from atmospherically vented water heaters.

Steve Andrews, a Denver-based energy consultant, freelance writer and board member of the Energy Efficient Building Association, is the primary author. Dave Schrock (Comfort Air Distributing, Inc.) and Rich Moore (Sun Power, Inc.) contributed and reviewed. A considerable amount of material in this study comes from the draft Fort Collins report. Some material from each article in this series comes from EEBA's Builder's Guide: Cold Climate (www.eeba.org).