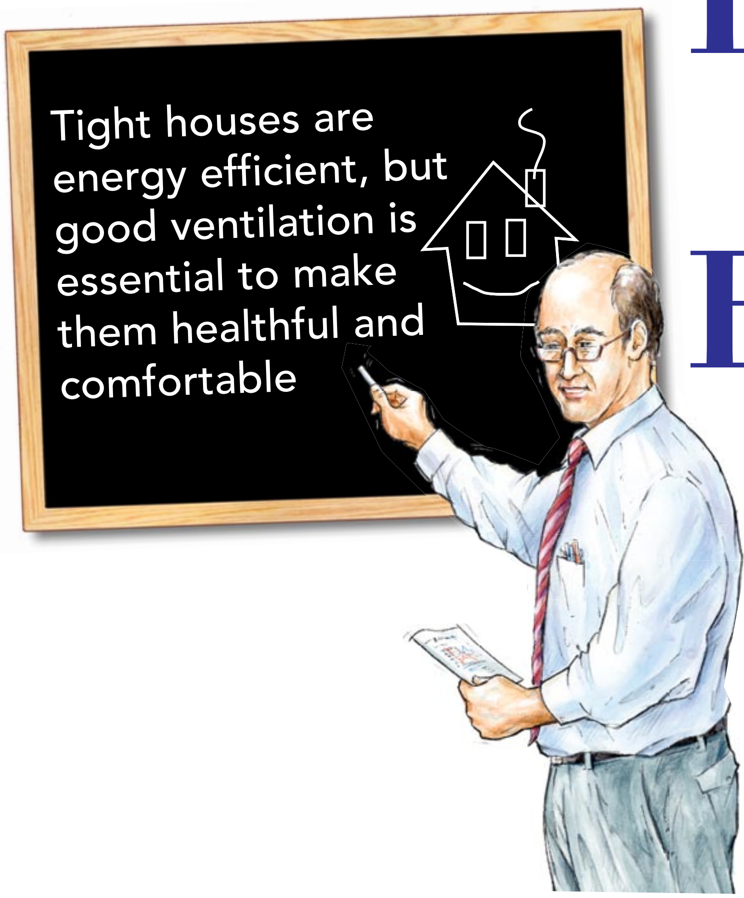


Houses Need to Breathe… Right?

BY MAX H. SHERMAN

I hear it all the time: "Houses are too tight." "Houses didn't used to make people sick." These assertions seem well founded: The most serious chronic illness of American children is asthma, and the Environmental Protection Agency lists poor indoor-air quality among its top five environmental threats. Are tight houses poisoning us?

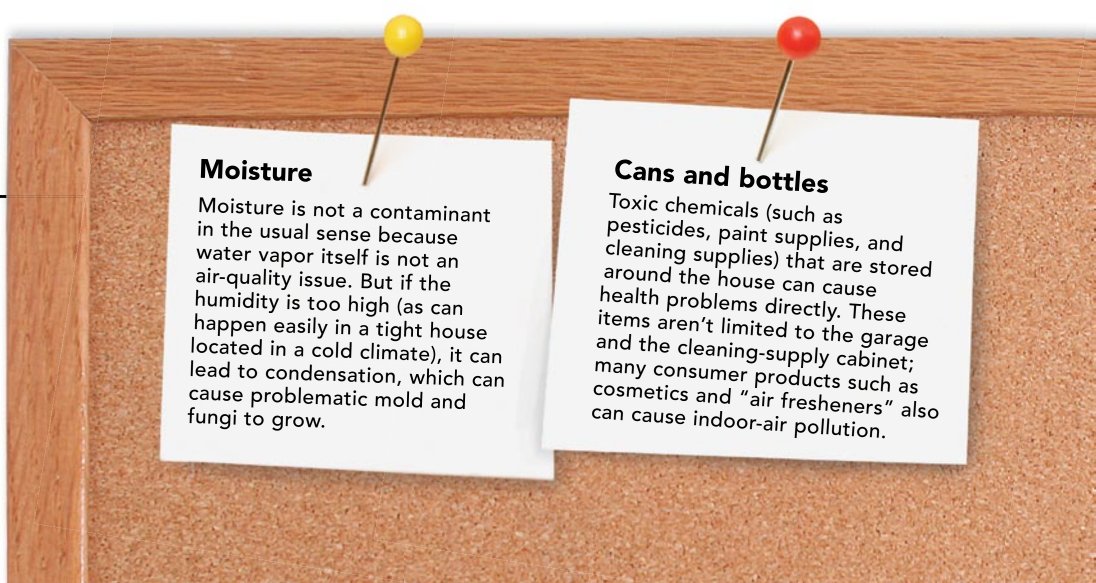
There's no disputing the cause-and-effect relationship between tight houses and indoor-air pollution. In theory, the solution is simple: If you build tight, you must ventilate right. In practice, though, ventilating right is complicated and controversial. In 2003, I chaired an American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) committee that passed the country's first residential ventilation standard, which gives builders and designers guidelines for providing good indoor air while keeping utility costs low (see p. 69).

Ventilation is manifold in house systems

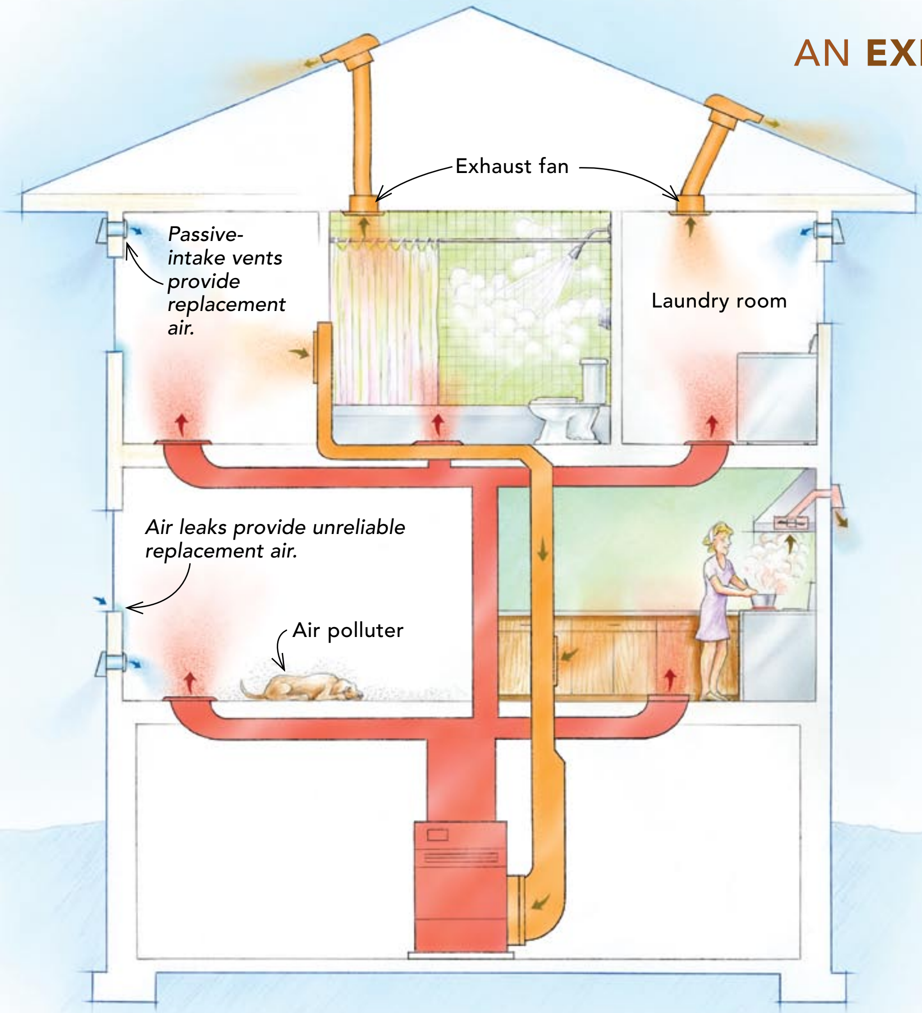
Before I go farther, let me define *ventilation*. The word *ventilate* comes from the Latin *ventuilare*, and it means to expose to the wind. Although this may sound like some creep in a raincoat, the real story is more complex. *Ventilation* is used many ways when describing how a house works: There's crawlspace ventilation (often bad), ventilated siding assemblies (good), and roof ventilation (sometimes bad, some-

Indoor air pollutants

Air pollution usually makes us think smokestacks and exhaust pipes, but indoor air is usually dirtier than outdoor air. Listed at right are some of the common pollution sources arguing for good whole-house ventilation.



AN **EXHAUST-ONLY SYSTEM** REMOVES THE BAD AIR



The simplest way to make sure contaminants don't build up in a house is to suck them out with one or more continuously running exhaust fans. This approach is the least expensive, is the least invasive, and has the advantage of working in houses without existing ductwork. For whole-house ventilation, existing kitchen and bath fans must be left running, a noisy prospect unless you've got super-quiet models. A better solution is to use a multiport fan (drawing p. 68) in the attic that exhausts many rooms simultaneously.

PASSIVE INTAKE

In this exhaust-only system, makeup air comes in through open doors and windows, or through leaks if you've got a leaky house. If you've got a tight house, passive vents serve the same purpose. The Thermastor vent pictured here comes from www.efi.org and costs about $35. Similar vents are available from www.aldesamerican.com and www.panasonic.com.

Pull cord opens and closes vent.

times good). We're not talking about that stuff. Here, we're talking about mechanical ventilation, using fans to blow out old air (exhaust), suck in new air (supply), or both (balanced ventilation).

Leaky houses are not the answer

On average, the air in older homes is replaced once every hour (1 ACH, or air change per hour) because older homes have a built-in ventilating method that's simple and reliable: leaks (or infiltration). The average house in the United States has about 3 sq. ft. of holes in it, but infiltration is a pretty bad way to ventilate because it wastes a tremendous amount of energy. You could plaster that 3 ft. of holes with $20 bills, and the work would pay for itself in less than a season.

Since the oil shock of the 1970s, houses are tighter and better insulated. Even conventionally framed new houses can be 5 times tighter than the general stock. Many builders and designers are tempted to take the Goldilocks approach and to look for that level of leakage that is just right, neither too little nor too much. Unfortunately, there is no hole for all seasons. The best a leaky house can do is waste energy much of the year and be underventilated the rest of the year.

Won't open windows provide the ventilation we need? In principle, yes, but in practice, no. People are pretty bad at sensing exactly how much, how often, and for how long to open the window to provide

Building materials
Volatile organic compounds (VOCs) may or may not be considered toxic, but they are the largest class of chemicals found in indoor air. The most common VOC is formaldehyde from glues used in engineered-wood products, such as particleboard. Synthetic carpet and oil-based paint are other sources of indoor VOCs.

Biological
Pets, dust mites, mold, and other nano-critters are not contaminants by themselves, but the particles they shed can cause various kinds of allergic reactions and/or asthma. Mites and mold require specific moisture and temperature conditions to grow and usually can be controlled by controlling the humidity. Bioeffluents from pets can be difficult to control.

Smoke
Smoke from candles, tobacco, and frying fish contains particles (soot and ash), VOCs, and other gaseous contaminants in addition to semi-VOCs, many of which can cause health problems.

Drawings: Don Mannes. Photo: Daniel S. Morrison.

optimal ventilation. Furthermore, noise, dirt, drafts, and creeps in raincoats dissuade people from opening their windows.

Indoor air usually is dirtier than outdoor air

Because indoor air starts as outdoor air, then grows more polluted from contaminants in a house (see "Indoor air pollutants," pp. 64-65), indoor air needs to be cleaned. Flushing a house with fresh air removes much of the indoor pollution.

The most obvious way to control some contaminants is to isolate them. Paint thinner and other poisons can be stored in a garden shed. Another way to control contaminants is to eliminate them from the construction process: Use low-VOC paint, low-emitting carpet, and solid wood, rather than particleboard, in furniture and cabinetry. A third way to control the pollution level in a house is to exhaust spaces where contaminants are produced, such as kitchens, laundries, utility/storage rooms, and bathrooms. But even after you've isolated, eliminated, and exhausted, there are still pollutant sources that are most practically diluted with controlled whole-house ventilation.

> **Pressurized/depressurized**
>
> When the inside of a house has a higher pressure than the outside, the house is pressurized (think of a balloon). This happens when air is blown into a tight house. The effect is to push interior air into openings in the walls and ceiling. When the inside of a house has a lower pressure than the outside, it is depressurized. This happens when a lot of air is exhausted from a tight house (such as with a large range hood) without any makeup air. The effect is to suck air through openings in the walls or ceiling, chimneys being the biggest and most obvious, potentially causing backdrafting.

Good ventilation: Different paths to the same place

When ventilation removes contaminants, it's your friend, but in doing so, it's usually bringing in outdoor air that must be heated, cooled, or dehumidified, which costs money. Just because it costs you money, though, doesn't mean ventilation is your foe. The energy savings of a tight house more than offset the operating cost of a small fan, not to mention the costs of asthma and allergy medication. The trick is to design a ventilation system that provides acceptable indoor air as efficiently as possible. The system's design will depend on where you live, but the ASHRAE ventilation standard can guide you through alternatives. Every ventilation system likely will be a little different. In general, though, there are three approaches to whole-house ventilation—exhaust, supply, and balanced systems—each a little more involved and more expensive than the last.

> **Backdrafting**
>
> When air flows opposite the direction of its intended path, often through a flue or chimney. This can happen if the house is depressurized. In backdrafting, contaminants are pulled into the house instead of being expelled, which can cause sickness or death.

Exhaust ventilation clears pollutants at their source

The simplest system, exhaust only, provides mechanical ventilation with a continuously operating exhaust fan (drawing p. 65). This fan can be as simple as upgrading your bath fan or as complex as installing a multiroom exhaust fan. The exhausted air is replaced by air infiltrating through leaks (in humid climates, this can cause moisture problems). But rather than doing so at the whim of the weather, it is being done at a steady level with the fan. With the quiet, energy-efficient fans available today, this option is cheap and easy. Because its makeup-air requirements are small, a low-volume exhaust fan won't depressurize your house enough to cause backdrafting. This system also has the advantage that it can be used in homes without ductwork.

A downside is that this system blows out heated (or cooled) air and, therefore, wastes energy. Another downside is that you don't know where the ventilation air you're sucking in is coming from (or where it has been). We'd rather not have air from a garage or other polluted space inadvertently being brought into the house. Passive-intake vents are a simple way to offset this problem (photo p. 65).

Supply ventilation dilutes pollutants throughout the house

A supply system has the advantage of allowing you to select where the air comes from and how it is distributed throughout your home. For example, fresh air can come from a duct run connected to the return plenum of an HVAC

Three design choices for hot, humid climates

In a hot, humid climate, sucking fresh air into your house can be a problem. You inadvertently can introduce 8 gallons of water a day from the ventilation air. When combined with internally generated moisture sources, this is way too much. There are three design options to consider or combine.

1. TOLERATE

You can accept periods of high-moisture levels if you use moisture-tolerant materials. Hard, cleanable surfaces are better choices than fuzzy ones. Use hardwood floors instead of carpet, or tile, plaster, or brick rather than paper-faced drywall.

2. DESICCATE

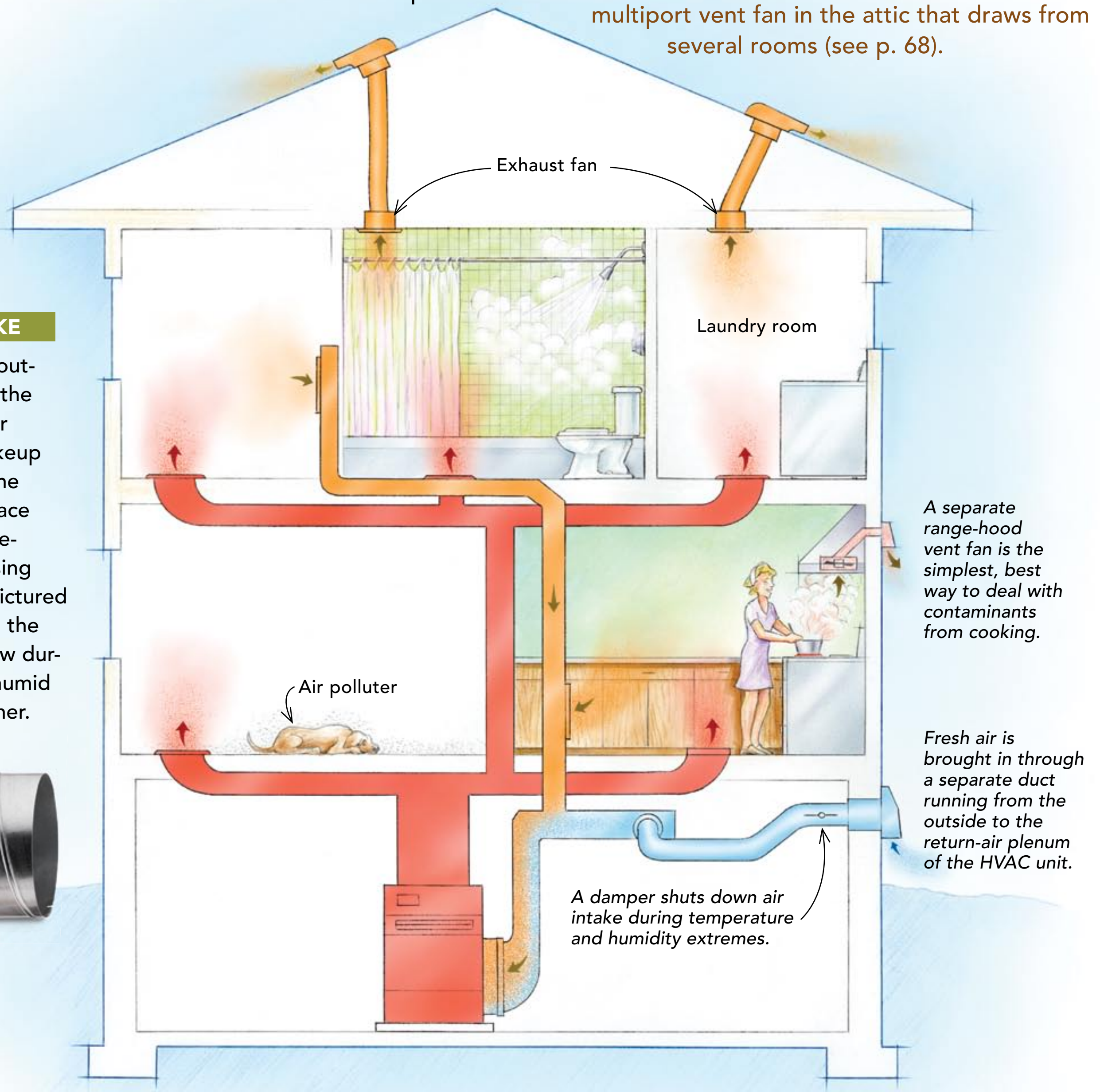
Get the extra moisture out of the air by condensing it and draining it. Air conditioners can remove moisture, but they usually are sized and designed for controlling temperature. In some climates, they won't dehumidify enough under normal use. A better option is a standalone dehumidifier or enhanced dehumidification gear.

3. PROCRASTINATE

Some humid climates have dry seasons. It may be possible to use reservoir-type buffer materials that store moisture during hot, humid periods, then release it during dry ones. Examples of such materials are brick interior walls, cellulose insulation, and solid-wood exposed beams.

A SUPPLY SYSTEM REMOVES BAD AIR AND BRINGS IN FRESH

Houses with a forced-air heating system or with central air conditioning have a built-in air-distribution network. A supply system uses it to distribute fresh outside air through the existing ductwork. But you still need exhaust fans in the wet rooms. The best approach is a quiet, continuously running multiport vent fan in the attic that draws from several rooms (see p. 68).



ACTIVE INTAKE

With a duct from outside the house to the furnace's return-air plenum, fresh makeup air is drawn into the house by the furnace fan. A temperature- and humidity-sensing damper system (pictured below) installed in the duct curtails airflow during very hot and humid or very cold weather.

system (drawing above). This way, outdoor air is pulled in to the house through the air handler whenever it operates.

Such an air intake must have controls (such as a timer or cycler) to turn on the air handler to make sure there is enough ventilation air. This system also should have a damper to prevent overventilating when the heating or cooling system is operating most of the time (very hot or very cold weather). Without these controls, this supply system is just a hole in the return duct, which is worse than a leaky house.

Supply systems must temper ventilated air to moderate temperatures in all but the mildest climates. The system above does this, when there is no heating or cooling call, by running the air handler and mixing unconditioned outside air with large volumes of conditioned indoor air. While this process tempers the outside air, it uses a lot of electricity because the air-handler fan is overkill for the amount of ventilation air being sucked in.

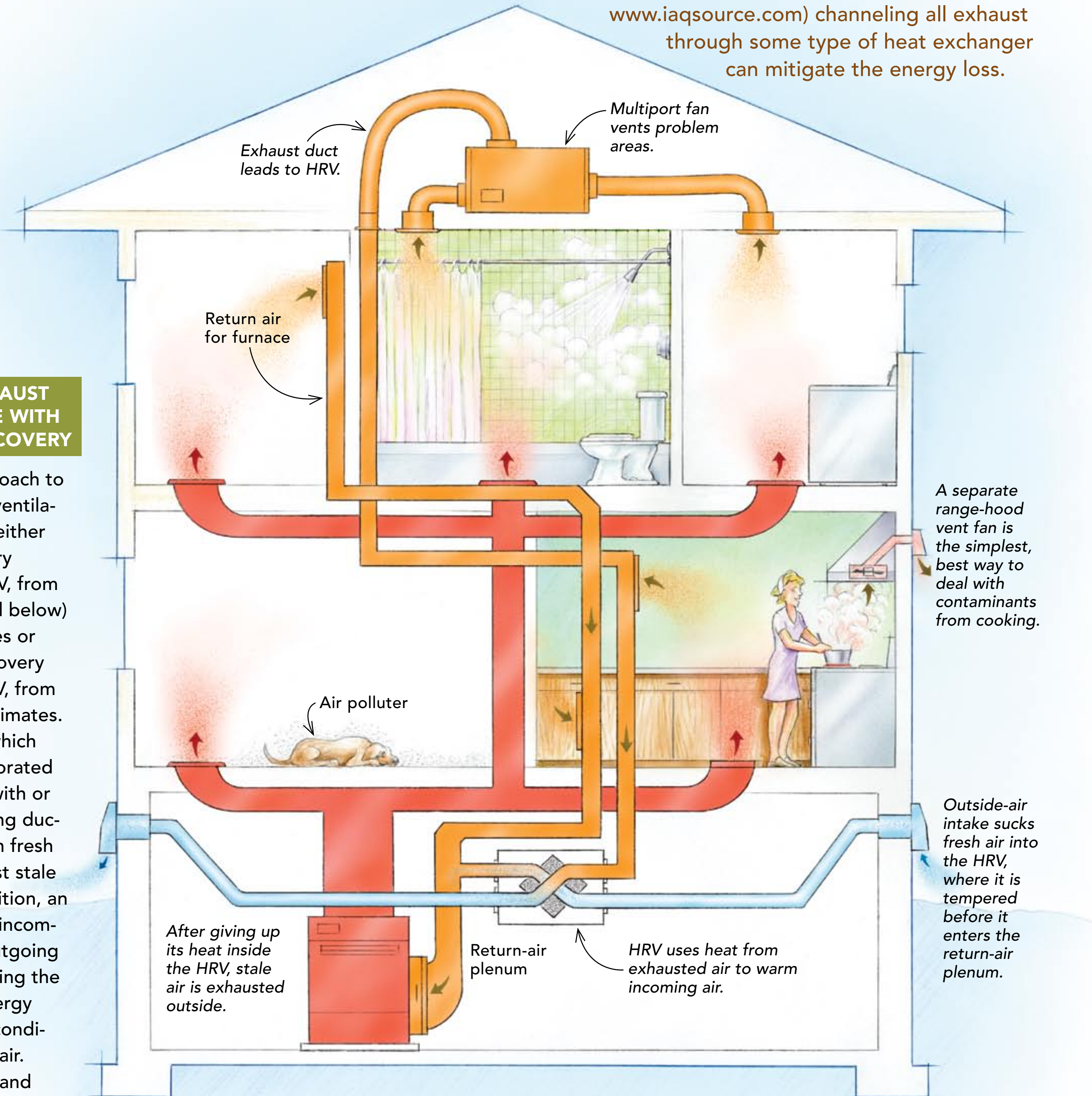
Balanced ventilation brings in the good air, banishes the bad, and conserves energy

The best way to temper incoming air while reducing HVAC energy consumption is to use a heat-recovery ventilator (HRV) or an energy-recovery ventilator (ERV) (drawing p. 68). These systems are balanced approaches that use the temperature and humidity of an exhaust-air stream (which otherwise would have been wasted) to temper the air of a supply stream, thereby reducing the HVAC energy cost. HRVs heat or cool incoming fresh air and can recapture up to 80% of the energy that would be lost without them. ERVs are better suited for

Photo: Courtesy of Aprilaire (www.aprilaire.com)

A **BALANCED SYSTEM** REMOVES BAD AIR, BRINGS IN FRESH, AND CAN SAVE HEAT (OR COLD)

The problem with exhausting stale air from your house is that you've likely paid good money to heat or cool that air, and venting it directly outside is like throwing away money. A balanced system with a multiport vent fan (from $185 at www.sheltersupply.com or www.iaqsource.com) channeling all exhaust through some type of heat exchanger can mitigate the energy loss.



ACTIVE EXHAUST AND INTAKE WITH ENERGY RECOVERY

The best approach to whole-house ventilation employs either a heat-recovery ventilator (HRV, from $700; pictured below) in cold climates or an energy-recovery ventilator (ERV, from $800) in hot climates. These units, which can be incorporated into a house with or without existing ductwork, bring in fresh air and exhaust stale air. But in addition, an HRV tempers incoming air with outgoing air, thus lowering the amount of energy necessary to condition the fresh air. An ERV looks and functions similarly, but it dehumidifies and cools hot, humid air, which reduces the load on the air conditioner.

Photo: Courtesy of Fantech (www.fantech.net)

America's first residential ventilation standard

Until recently, not much had changed since 1631 when King Charles passed the first ventilation code (you had to have operable windows that were taller than they were wide). Because today's houses aren't leaky enough to provide fresh air, the American Society of Heating, Refrigeration and Air Conditioning Engineers wrote a ventilation standard. ASHRAE 62.2 is a minimum standard applicable to both new and existing homes (including small multifamily ones). Keep in mind that 62.2 is a standard, not a code. Think of it as a recommendation that may lead to a new code requirement.

hot, humid climates because they dry incoming air, thus reducing the work that the air conditioner has to do.

You still need to clean up

Ventilation is good at diluting gaseous compounds and small particles because small particles act like gases. They mix quickly in the air and follow air currents when air is expelled. But large particles such as pollen, pet dander, and dust mites must be cleaned up or vacuumed rather than exhausted or diluted because they're too heavy to mix with air. Other large particles, semi-VOCs, are solids or liquids at room temperature. While they're not gaseous, as with VOCs, they are volatile enough to emit lots of gaseous vapor. This is important because if you filter out SVOC particulates, you haven't really done anything until you clean the filter; the SVOCs keep emitting gaseous vapor from the filter. If you don't replace filters on your HVAC system regularly, the system itself becomes a contamination source.

The three ventilation systems discussed here are by no means comprehensive; they can be combined in various recipes to meet particular conditions. In addition to climate and house tightness, cost can be a big consideration, but it shouldn't be the major one. Be sure to consider long-term durability and maintenance requirements. Systems with heat recovery (HRV/ERV) require a lot more maintenance than those without. Systems with multiple filters or requiring seasonal adjustment can be confusing.

Tempered air

Outdoor air that is mixed with indoor air so that it is at a temperature that is not objectionable (but not necessarily comfortable). For example, a dedicated outdoor-air system may temper 1 part of the incoming outdoor air with 3 parts interior air in the supply plenum before supplying it to occupied zones.

Tight houses are good, and they should breathe

Excessively leaky houses are one way for a house to breathe, but not the best. While there's a lot of ongoing research and a robust scholarly debate on the best way to achieve acceptable indoor-air quality, building scientists all agree that houses need to breathe.

As houses become higher and higher performance, they need to breathe in a steady, reasonably controllable way. We cannot afford to let them breathe at the whim of the weather or with windows only. We also sometimes need to be able to have them hold their breath when conditions outside are exceptionally bad. Only with designed ventilation systems can we make sure that indoor-air quality and energy efficiency advance hand in hand. □

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The major requirements of 62.2 are:

• Whole-house mechanical ventilation

Exhaust, supply, or balanced ventilation. For a typical house, 50 cubic feet per minute (cfm) will do.

• Mechanical exhaust in kitchens and bathrooms

In addition to the whole-house ventilation requirement above:

- **Kitchen:** a user-operable vented range hood of at least 100 cfm; or a fan giving 5 kitchen air changes per hour of continuous or intermittent exhaust.
- **Bathroom:** a user-operable fan of at least 50 cfm; or a continuously operating 20-cfm exhaust fan.

• Fans must meet performance levels

A third-party rating is required for airflow under reasonable operating conditions. The sound rating is 1 sone for continuously operable fans and 3 sones for intermittently used kitchen and bath fans in item 2.

• Combustion appliances must follow building codes

For some circumstances, vented combustion appliances are prohibited from being indoors. Because 62.2 is not about combustion safety, it addresses the few cases where combustion and ventilation equipment can interact.

• Garage duct systems must be airtight

Air handlers or return ducts in an attached garage must be tested for tightness. While tight ducts save energy, 62.2 sets only minimum requirements to protect indoor-air quality.

• Particle filtration upstream of air handlers

Dirty ducts and coils can become a pollution source, so 62.2 requires pleated furnace filters (MERV 6 or better). To clean the air inside the house, more aggressive filtration would be needed.