Keep it Ventilated

Why should you keep a house well ventilated? Indoor air quality is important. Pollutants can be found in concentrations **2-5 times higher indoors than outdoors**.

Proper ventilation can reduce hazards of:

- Volatile organic compounds
- Moisture
- Environmental tobacco smoke
- Particulate matter
- Allergens
- Mold
- Carbon monoxide
- Formaldehyde

Proper ventilation can also address sources of combustion contaminants

- Oven as heater
- Spillage from furnace, water heater, fireplace
- Ventless heater or fireplace
- Car exhaust from attached garage

Heating

Information from the American Housing Survey provides a context for the type of fuel that people use for heating as well as other purposes. It also describes the heating equipment that many people have as well as the heating problems they encounter.

Type of Heating Fuel

- Water Heater
  - 54.3% have gas, LP/bottled gas
  - 41.3% have electricity
- Clothes Dryer
  - 21.8% have gas, LP/bottled gas
  - 78.1% have electricity

Learning Objective for this Module

- Name five unhealthy conditions associated with poor ventilation.
- List five things (e.g. a room, appliance, mechanical system) in a household that need ventilation.
- Name three things that power airflow in a building.
- List three household contaminants that can be removed by ventilation.
- Describe two ways ventilation reduces air contaminant levels.

Primary Heating Equipment

- 64.1% have warm air furnace
- 11.0% have steam or hot water system
- 11.8% have electric heat pump

But . . .

- 1.1 million homes (1.0%) have room heaters without a flue
- 1.1 million homes (0.9%) rely on wood-burning stoves
- 90,000 homes (0.1%) rely on cooking stoves

. . . For their primary source of heat.

From American Housing Survey – 2011

Heating Problems

- 9.1% were uncomfortably cold for more than 24 hours
  - 12.5% for renters
  - 13.7% for residents below poverty level
- 1.1% were uncomfortably cold for at least 24 hours due to inadequate heating capacity
  - 2.0% for renters
  - 2.2% for residents below poverty level
- 1.1% were uncomfortably cold for at least 24 hours due to inadequate insulation
  - 1.8% for renters
  - 2.0% for residents below poverty level

From American Housing Survey – 2011

Health Effects from Combustion Contaminants

Combustion contaminants is not an uncommon problem. This problem is popping up all over the country, mostly in new homes. Usually families notice a fine layer of soot appears on plastic surfaces, such as TV and computer screens, inside refrigerators and freezers, on walls and ceiling, on carpets, particularly under doors and at baseboards.

Unvented kerosene or gas heaters are also a problem. In the picture to the right, the kerosene heater in this home was used to provide supplemental heat, but the odor of the combustion products was so annoying that the door behind the heater was cracked open while the heater was in use. If the door was not providing ventilation, dangerous gases could build up. Burning fuel without ventilation can produce nitrogen dioxide, carbon monoxide, and nitrogen oxide, as well as particles. Unvented combustion devices should not be used in occupied spaces.

- Carbon Monoxide (CO)
  - Fatigue, headaches, dizziness, confusion
  - The silent Killer
- Nitrogen Dioxide
  - Eye, nose, and throat irritation
  - Shortness of breath

These are the two major pollutants associated with combustion products. At relatively low levels of carbon monoxide, a healthy person may feel fatigued. As levels increase a person may complain of headaches, dizziness, weakness or confusion. It is important to realize that CO is often referred to as the "Silent Killer" because it is colorless and odorless and death can occur without the person being aware that high levels exist. CDC reports that over 15,000 people each year are treated in emergency rooms for non-fire related carbon monoxide exposures. Additionally, an average of 500 people die each year from non-fire related carbon monoxide exposures.

If a flame is yellow, it is not burning hot enough and it will produce more carbon monoxide. However, the hotter the flame, the more nitrogen dioxide is produced.

Carbon Monoxide Limits[1]

The chart below shows exposure limits for people at work for 8 hours a day or for outside air. What about people who are in their home virtually all the time?

Agency	Situation	Maximum CO Level	Duration
Environmental Protection Agency	Outdoor/Ambient Air	9 ppm	8 hours
		35 ppm	1 hour
Consumer Products Safety Commission/Underwriter Laboratories (UL)	Alarms for Immediate Life Threats in Residential Air	70 ppm	1-4 hours
		150 ppm	10-50 min
		400 ppm	4-15 min
Canadian Department of National Health & Welfare	Air in Residences	11 ppm	8 hours
		25 ppm	1 hour
World Health Organization	Indoor Air	32 ppm	Max.

Consumer Product Safety Commission (CPSC) recommendations for CO Alarms:

- Place near sleeping area
- Put on every level of a home to provide extra protection
- Do not install directly above or beside fuel-burning appliances

Carbon Monoxide Alarms

Proper placement of a carbon monoxide alarm is important. If you are installing only one carbon monoxide alarm, the Consumer Product Safety Commission (CPSC) recommends it be located near the sleeping area, where it can wake you if you are asleep. Additional alarms on every level and in every bedroom of a home provide extra protection. Install a battery-operated CO alarm in your home and check or replace the battery when you change the time on your clocks each spring and fall.

Homeowners should remember not to install carbon monoxide alarms directly above or beside fuel-burning appliances, as appliances may emit a small amount of carbon monoxide upon start-up. An alarm should not be placed within fifteen feet of heating or cooking appliances or in or near very humid areas such as bathrooms.

Carbon Monoxide Alarms should not be thought of as a REPLACEMENT for proper use and maintenance of fuel-burning appliances. It is important for you to know that the technology of CO alarms is still developing, that there are several types on the market, and that they are not generally considered to be as reliable as the smoke alarms found in homes today. Some CO alarms have been laboratory-tested, and their performance varied. Some performed well, others failed to alarm even at very high CO levels, and still others alarmed at very low levels that don't pose any immediate health risk. Further, unlike a smoke alarm, where you can easily confirm the cause of the alarm, CO is invisible and odorless, making it harder to tell if an alarm is false or a real emergency.

Installing a CO Alarm

The <u>vertical placement</u> of a CO alarm or monitor does not influence how it functions so it can be placed at any height. Although CO initially "rides up" on hot air, it dissipates fairly quickly and mixes with other indoor air.[1] However, when placed at knee level there is the possibility of tampering or damage by pets, children or vacuum cleaners, so higher placement avoids this problem.

The <u>location</u> of a CO alarm is very important. CO alarms are to be m[1]ounted outside sleeping areas in close vicinity to the sleeping areas. Homes with sleeping areas on multiple levels will need CO alarms on all levels.

Some alarms have a monitor as well that shows the level of CO. Generally, though, people should not waste their time trying to read a monitor, they should be evacuating immediately. Note that the average cost of a basic CO alarm is $25 and the average cost of a CO alarm/monitor with a digital display is $50.

In the photo to the left, a CO alarm is being placed next to a smoke alarm in the hallway outside of a frequently–occupied bedroom. Check or replace the battery

[1] See Hampson NB, Courtney TG, Holm JR, "Should the placement of carbon monoxide (CO) detectors be influenced by CO's weight relative to air?", Journal of Emergency Medicine, 2012 Apr;42(4):478-82. Epub 2011 May 4.

when you change the time on your clocks each spring and fall. A CO alarm should be tested by pressing the TEST button. A common cause of failure is weak or missing batteries, which should be replaced routinely. Most alarms have a 5–year life span.

There are approximately 500 carbon monoxide deaths plus more than 15,000 non-fire-related carbon monoxide healthcare visits per year.

Why Ventilate: Health Effects

Ventilation plays an important role in maintaining health. Poor ventilation can result in higher rates of respiratory irritation and illness . . .

- Common colds
- Influenza
- Pneumonia
- Bronchitis

. . . and increased rates of absence from school or work

A recent study found the following:

- 70% higher respiratory illness in fan-ventilated classrooms compared to window ventilated rooms;
- Nursing homes had much lower (76%) influenza rates in buildings with 100% supplied outside air
- With improved ventilation in housing and buildings, illnesses could decrease in incidence by 18% and costs to the US economy could be decreased by $6-14 billion.

Well Ventilated?

A Very Short History of Ventilation

Ventilation equipment is the visible evidence of a long history of indoor air quality, heat, and moisture problems. Why else would we have invented it?

This is a photo of a woodcut showing a worker pumping air into a mine shaft to provide ventilation for his fellow workers. The woodcut is from De Re Metallica, a text on mining and metallurgy written in 1556 by Georgius Agricola. Agricola describes many of the ailments suffered by miners and the solutions for them, among which is "stagnant air…which… produces a difficulty in breathing; the remedies for this evil are the ventilating machines."

Agricola's chapter on ventilation shows three types of ventilators – scoops to divert wind into the mine, fans resembling radial blowers powered by men, water turbines or wind mills, and bellows powered by men or horses. Indoor air quality problems are not new and the benefit of ventilation has long been understood.

A Well-Ventilated Building?

Is there a difference between a building with plenty of air flow and one that is well ventilated?

A Well-Ventilated Building Provides:

- Local Exhaust Ventilation to remove moisture, odors, and other pollutants at the source
- Whole House Ventilation for supplying fresh air to reduce contaminants by dilution
- Control of airflow through building so airflows can't carry contaminants into and around the house

Ventilation reduces air contaminant levels in two different ways:

- If contaminants are released from a point source, a local exhaust system can be used to collect the contaminants before they spread throughout the building (e.g. chimneys, toilet exhaust, dryers and range hoods).
- Outdoor air with low air contaminant levels can be drawn or blown into the building and mixed with the indoor air through a whole house ventilation system, lowering the concentration by dilution. The contaminant then leaves the building in the exhaust air.

By using ventilation or conditioning air to manage pressure differences, the airflow through a building can be planned to minimize exposures in the most efficient way. Local exhaust ventilation is more efficient than dilution ventilation because it collects the contaminant near the source and intervenes in the transport mechanism. This is why we use local exhaust ventilation for radon removal.

Understanding Ventilation

Key Concepts

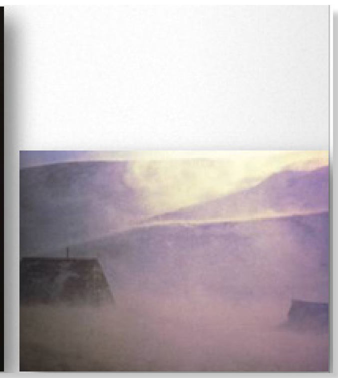
- If any portion of air leaves a house the same amount must enter
- Air like water seeks the path of least resistance
- When heated, air rises
- When cooled, air falls
- Air can be hot, cold, wet, dry, or polluted when it enters or exits a house

What Powers Air Flow?

Air moves through buildings, because a force creates differences in air pressure. The source of the force is most frequently some combination of fans, air temperature differences, and wind. It is easy to understand how fans and wind ventilate and cause air to move through buildings.

Temperature differences

Fans

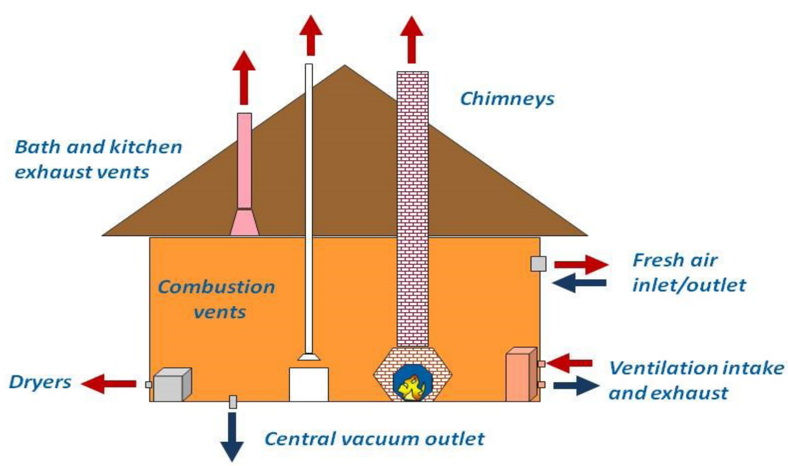


Wind

Air Flow in Homes

- Typical homes do not have a planned supply of fresh air
- We depend on leakage such as windows, doors, and cracks
- his is usually not adequate

Air Flow Needs Designed Holes

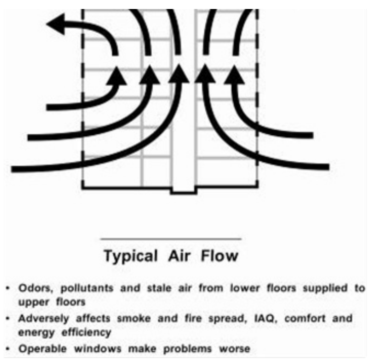


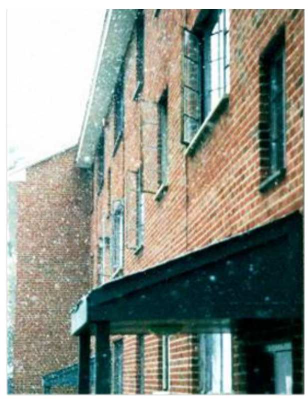
Courtesy of Arnie Katz at Advanced Energy

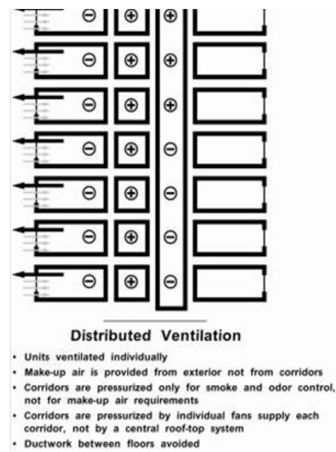
Contaminants in our homes need to have designed pathways to allow the contaminants to exit the building. At the same time we need to bring in ventilation air in a controlled fashion. We don't want the air we breathe to come in through places such as crawl spaces or leak through gaps in moldy walls, for example. Our homes should be air sealed tight and then ventilated right. And the fresh ventilation air needs to come from areas outside that are not near contaminants.

These designed pathways should not be blocked or sealed and the airflow always needs to flow in the direction for which they were designed.

In multifamily buildings with people living so close to each other, planned fresh supply air is very important. In high rise buildings in cold weather, the air from inside the lower apartments can rise and carry contaminants to people in higher apartments. And as the air warms and rises, it creates negative pressure in lower apartments and positive pressure in higher apartments. Now the higher apartments get too warm and the lower ones get colder as cold outside air leaks in. As the lower apartment dwellers turn up the heat to compensate, the higher apartments just get warmer in this vicious cycle. In the middle photo below, you can see an example of this with the upper windows open.







Multifamily Exhaust Only—New Construction

In multifamily high-rise apartments the exhaust ventilation ducts are sometimes commonly connected and may be missing individual dampers. So if the exhaust fans are not running, you can have air from one apartment passing into another, with all the contaminants and odors that may be present. And, as mentioned earlier, the stack effect (warm air rising) just makes this worse. The photo to the right shows rooftop fans providing exhaust ventilation for a six-story multifamily building. Vertical ducts connect the floors. Air may pass from one apartment through the ductwork and into another if the fans are not running, there is a problem with fan flow, the ducts are leaky, or the stack effect overwhelms the system.

Assessing Ventilation: What Are We Looking For?

When assessing a house for ventilation, check to see if the important stationary sources have effective exhaust ventilation and whether there is enough general dilution ventilation.

Local exhausts are easy enough to check—are they there, do they work?

- Bath, dryer, and range exhaust fans?
- Gas stove used as heater?
- Windows work?
- Smoke alarm goes off?
- Unvented gas or kerosene heaters?
- Vented hot water heater?
- Furnaces, boilers, fireplaces vented?
- Rooms without windows?

Because most residential buildings assume that operation of the local exhausts, wind and stack driven air flows, and operable windows provide enough general ventilation, it is more difficult to assess general ventilation. The simplest way to get an idea is to ask the occupant if odors linger, windows fog during cold weather, or the air seems stale?

- Lingering odors?
- Stale air?
- Windows fog?

To go beyond this level requires a fair amount of knowledge and less common test equipment (e.g. blower doors).

Things That Need Exhaust Ventilation

There are two kinds of ventilation needs: ventilation for air quality and ventilation for combustion equipment. Here is a list of rooms and appliances in a home that need exhaust ventilation:

- Bathrooms
- Kitchen ranges
- Clothes dryers
- Boilers, furnaces, hot water heaters
- Fireplaces, wood burning stoves

Bathrooms

Bathrooms are sources of moisture and odors. An exhaust vent should be located in each one. A single fan ducted to the bathrooms is a simple way of doing this. A chemical smoke bottle can quickly answer the question: is it moving air the right way? Chemical smoke allows you to quickly understand how air is moving around a building. It is one of the most powerful tools for solving indoor air quality, condensation and comfort problems. Chemical smoke is a strong irritant and should be used carefully; do not let people in the home keep it.

Placing toilet paper over the fan is another way people sometimes test to see if a fan is working. However, this method only tells you if the fan is actually pulling some air. A large percentage of installed fans don't even pass this test!

Why bother testing exhaust fans? A recent program, in which exhaust fans were tested in over 300 new homes, found that approximately 20% were pulling less than 15 cfm, despite being properly sized (most were 70 cfm fans) and properly ducted. The problem was that the backdraft dampers, either on the unit itself, on the termination, or both, were taped shut to avoid damage while shipping and the installer did not remove the tape.

Damper Work?

Ducted OK?

Local Ventilation: Kitchens

Kitchen ranges and ovens are the source of many contaminants. Since grease tends to collect on kitchen exhaust fans, they need to be cleaned frequently. A buildup of grease can attract cockroaches.

The photo to the right shows a vented range hood. Notice the duct in cabinet. The photo on the left shows a recirculating range hood (not vented) that has no duct in cabinet but has a grille on upper surface of hood—this is not ideal.

Kitchen ventilation should:

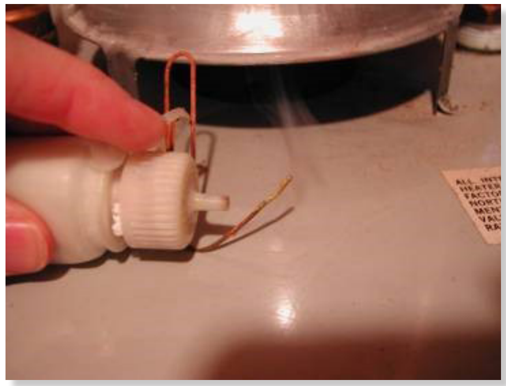
- Remove moisture, odors, grease
- Remove products of combustion (moisture, CO, NO2)I f gas oven or range
- Be vented to the outside
- Be reasonably quiet, otherwise many people will not use it.

Clothes Dryers

Although most people do not think of them in this way, dryers are exhaust vented devices. Dryer exhausts use from 75 to 150 cfm of air to remove heat, lint, the perfumes from fabric softeners, and in the case of gas fired dryers, combustion fumes. The amount of air exhausted by a dryer depends on how heavily it's loaded, the amount of lint on the filter and the resistance of the flex duct used to exhaust the air.

Boilers, Furnaces, Hot Water Heaters

Older boilers, furnaces and water heaters are usually atmospherically vented, which means they rely on the stack effect (warm air rising) to exhaust their combustion gas out of the house. There is no mechanical fan pushing the gas out. So if there is a stronger competing force the combustion gas can sometimes come back into the house. For example, a dryer close to a water heater will exhaust a large amount of air from the area and, in the process, may overwhelm the draft of the water heater gas and suck it back into the room. The photo in the middle on the next page shows someone using a smoke tester on a natural draft water heater to see if the combustion gas is going up the flue as expected. (Please refer to the Building Performance Institute's ANSI standard for protocols.)



Leaks in ductwork can also create pressure difference problems. The leaks in the return side of an air handler can “mine” contaminated air from anywhere the leaks draw air (e.g. crawlspaces, attics, basements). The photo to the right shows an example of a pressure differential. Soot is filtered from the air as it passes beneath the door when it is closed; leaving behind a visible line.

The photo below on the left shows an example of poorly constructed ducts. The photo on the right shows well–sealed ducts.

The photo on the right on the previous page is a good representation of how ducts should be properly sealed: using mastic and mesh. However, this is probably a commercial HVAC system, due to the size of the unit and ducting itself.

The photo on the left on the previous page may cause a fair amount of discussion as many people don't feel this is all that bad, considering that the installation is in an attic. The flexible ducting is well-insulated and it is attached to rigid ducting using zip ties, which is certainly better than having used duct tape. However, this ducting has a number of twists and turns which could reduce airflow to certain registers within the home. In addition, it is corrugated, which again could reduce airflow, because the corrugations disrupt air and do not allow for smooth, laminar flow as would be the case in rigid ducting.

Further, since the unit is in the attic, one can imagine that it would be difficult for the homeowner to routinely check and change filters in the HVAC system. Also, if the condensate line or condensate drip pan becomes clogged, it would almost certainly result in wetting and possible damage to ceiling and wall materials. Lastly, in general attic furnaces are less efficient as they are working against nature by trying to force warm air down into the living space and drawing the cooler return air up. The natural state is that cooler more dense air tends to fall as warmer less dense air rises.

The photo to the right is illustrating how a duct blaster is attached to a residential HVAC system. Once attached, the unit is turned on and pushes air into the ducts at a constant pressure. A manometer (pressure device) can show how much duct leakage is occurring and, if the technician blows chemical smoke into the duct system, leaks can be detected as the smoke leaks through any holes.

Filtration

Filtration serves a number of purposes. It:

- protects coils from clogging with dust.

Further, at high enough efficiencies, it:

- protects coils and ductwork from collecting deposits of fine particles that could support fungal growth if wetted (25% dust spot efficiency);
- begins to collect fine enough particles benefiting the lungs of building occupants (25 % dust spot efficiency).

Poorly sealed filter access panel

MERV – Filter Rating System

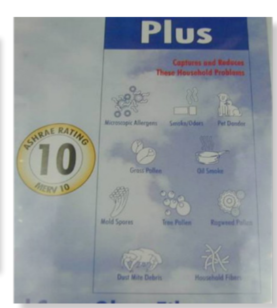
MERV, the Minimum Efficiency Reporting Value, is a way to differentiate between filters that have different levels of filtering particles. It is based on the removal efficiency for particles of different sizes. The MERV) rating of a filter describes the size of the holes in the filter that allow air and particles to pass through. The higher the MERV rating, the smaller the holes in the filter, and smaller the particles that will be captured. Remember the size of the particle plays a role in whether or not it can be taken into the lungs.

MERV Ratings		
MERV	**Particle Size**	**Typical Controlled Contaminant**
1-4	>10.0	*Pollen, sanding dust, textile and carpet fibers*
5-8	3.0-10.0	*Mold, spores, hair-spray, cement dust*
9-12	1.0-3.0	*Legionella, lead dust, welding fumes*
13-16	0.3-1.0	*Bacteria, most tobacco smoke, insecticide dust, copier toner*
17-20	≤ 0.3	*Virus, combustion particles, radon progeny*

MERV is intended to help simplify the filter selection process for users. It is derived by combining the cleaner's average efficiency at removing three particle size fields. If a high MERV filter is used with a fan designed for something lower there may be inadequate airflow which can lead to appliance problems.

MERV 8 vs. MERV 10

MERV 8 filter media should not promote the growth of bacteria, mold, mildew, or fungi in normal operating environments, and are not chemically treated. MERV 10 filters, on the other hand, can capture particles that are smaller, such as legionella and lead dust.



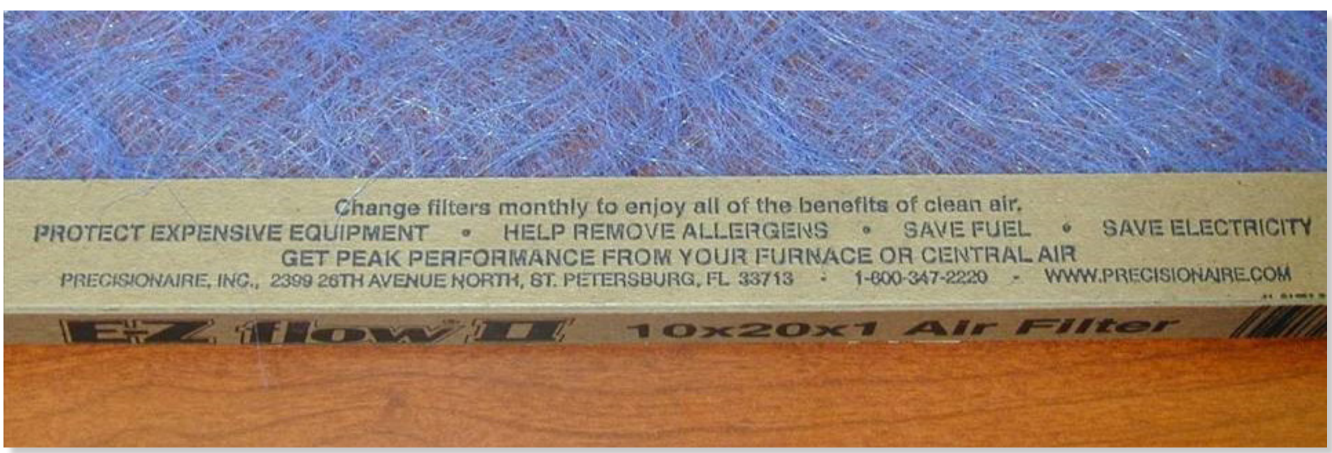
Other Rating Systems

The High Efficiency Particulate Air (HEPA) filter is designed to capture airborne particulates (solids) down to 0.3 microns in size. The HEPA media looks like blotting paper. It is made of very thin glass fibers fashioned into a sheet much the same way as wood fibers are used to make paper. Air passing through the media must continually change direction in order to pass around the thin glass fibers. Large particles cannot make these sharp turns without colliding into, and becoming captured by, the HEPA media.

To qualify as a HEPA filter, the filter must collect 99.97% of a specific particulate that measures 0.30 microns. Please note that "HEPA-type" filters and filters labeled for allergen control have not been certified that they meet the standard.

And……

Look at the claims on the filter below. Are they accurate? This filter is probably only a MERV 4. These are often used in residential air conditioning and heating units and will capture particles such as pollen, dust mites and carpet fibers, but not finer particles such as mold spores.



This filter is probably only a MERV 4.

Code Requirements Related to Ventilation

403.1 Habitable spaces.

- Every habitable space shall have at least one openable window.
- The total openable area of the window in every room shall be equal to at least 45 percent of the minimum glazed area required in Section 402.1.

- **403.2 Bathrooms and toilet rooms.**

- Every bathroom and toilet room shall comply with the ventilation requirements for habitable spaces as required by Section 403.1, except that a window shall not be required in such spaces equipped with a mechanical ventilation system.
- Air exhausted by a mechanical ventilation system from a bathroom or toilet room shall discharge to the outdoors and shall not be recirculated.

302.6 Exhaust vents.

- Pipes, ducts, conductors, fans or blowers shall not discharge gases, steam, vapor, hot air, grease, smoke, odors or other gaseous or particulate wastes directly upon abutting or adjacent public or private property or that of another tenant.

403.4 Process ventilation.

- Where injurious, toxic, irritating or noxious fumes, gases, dusts or mists are generated, a local exhaust ventilation system shall be provided to remove the contaminating agent at the source. Air shall be exhausted to the exterior and not be recirculated to any space.

403.5 Clothes dryer exhaust.

- Clothes dryer exhaust systems shall be independent of all other systems and shall be exhausted in accordance with the manufacturer's instructions.

603.2 Removal of combustion products.

- All fuel-burning equipment and appliances shall be connected to an approved chimney or vent.
  - Exception: Fuel-burning equipment and appliances which are labeled for unvented operation.

607.1 General.

- Duct systems shall be maintained free of obstructions and shall be capable of performing the required function.

505.4 Water heating facilities.

- Water heating facilities shall be properly installed, maintained and capable of providing an adequate amount of water to be drawn at every required sink, lavatory, bathtub, shower and laundry facility at a temperature of not less than 110°F (43°C).
- A gas-burning water heater shall not be located in any bathroom, toilet room, bedroom or other occupied room normally kept closed, unless adequate combustion air is provided.
- An approved combination temperature and pressure-relief valve and relief valve discharge pipe shall be properly installed and maintained on water heaters.

603.5 Combustion air.

- A supply of air for complete combustion of the fuel and for ventilation of the space containing the fuel-burning equipment shall be provided for the fuel-burning equipment.

Key Messages

- Ventilation plays an important role in maintaining health.
- Ventilation is necessary to remove humidity and to dilute or remove contaminants.
- Local exhaust ventilation removes contaminants from a point source, while whole house ventilation uses fresh air to dilute contaminants.

Learning Objectives

- Name five unhealthy conditions associated with poor ventilation.
- List five things (e.g. a room, appliance, mechanical system) in a household that need ventilation.
- Name three things that power airflow in a building.
- List three household contaminants that can be removed by ventilation.
- Describe two ways ventilation reduces air contaminant levels.