2015

Montana

Residential Mechanical Ventilation

An Introduction to Energy Efficient and Effective Whole-House Ventilation

This document was compiled by the National Center for Appropriate Technology for the Montana Residential Construction Industry.

Introduction

The 1973 energy crisis caused people to look for ways to reduce the cost of heating and cooling their homes. The building industry responded by developing and installing better windows, more insulation, and high-efficiency furnaces, and by reducing the amount of outdoor air leaking into homes. In the past, most building codes have assumed that "fresh air" would be provided through operable (openable) windows and leaks in the building envelope. Building science has since taught us that we can't rely on natural forces to provide ventilation at all times of the year. In the meantime, we have introduced thousands of chemicals into our houses through building materials, finishes, packaging, furniture, carpets, clothing and other products. This is in addition to the allergens and occupant-generated air borne chemicals.

Air, heat, and water vapor moved easily through the building envelopes of early structures. But those early homes were very uncomfortable and required a lot of energy to heat.

As insulation was increased and building envelopes became tighter, unforeseen consequences appeared. Problems with indoor air quality and moisture in walls and attics became more common.

Natural ventilation using windows and other operable openings can provide adequate ventilation if they are used (which is more likely when the climate is more temperate than in Montana). However, there are many reasons why occupants may choose not to operate the windows, including security, outdoor air quality, dust, or noise. Good ventilation in homes is important because it helps protect both occupant health and the house itself.

People spend about 90% of their time indoors. Indoor air pollution can be a bigger health risk than outdoor pollution, even in crowded cities.

Health

Good ventilation protects home occupants from unpleasant odors, irritating pollutants, and potentially dangerous gases like carbon monoxide and radon. Well-planned ventilation also prevents the growth of mold and mildew, which can cause or aggravate allergic reactions and lung problems such as asthma. As we have built tighter homes with more insulation, the relative humidity in the home has increased and the potential for condensation on cool or cold surfaces has increased as well. The presence of moisture condensation has been a leading cause of mold and mildew in both new and existing construction. Asthma has also increased as interior relative humidity has gotten higher. Therefore, it has become more important to remove the moisture from bathing and cooking right at the source.

Home Durability

Good ventilation protects the home from damage by removing excess moisture laden air from the house. Too much moisture rots window sills and attic eaves, peels paint, and invites insect infestation. Damp insulation in walls and ceilings means lost heat, higher fuel bills, and destructive and harmful mold growth. Carpeting, wallpaper, electronic equipment, and furniture all can be damaged by excess moisture. One example is how condensation occurs on the interior surface of a window based on the temperature of the glass and the relative humidity in the space.

"Build Tight and Ventilate Right"

The mantra of building science experts has become "Build Tight and Ventilate Right." Energy codes now require tight construction. All new houses in Montana must be tested to no more than 4 air changes per hour at 50 pascals pressure. New homes also must comply with the *Air Barrier and Insulation Installation Table* in the Energy Code. Building and testing a tight envelope is fairly straightforward. In fact, if properly ventilated a house building envelope can't be built too tight. Getting ventilation right is by far the more difficult challenge. While building science experts agree that mechanical whole house ventilation is important, those same experts differ on exactly how much ventilation air is required and how to design an effective ventilation system.

Some Useful Terms Explained

Air changes per hour at 50 pascals – The number of times in an hour that the total air volume of a home is exchanged for outside air with the house depressurized by a blower door to 50 pascals with reference to the outside.

Pascals – A measurement of air pressure. One inch of water column is equal to 249 pascals.

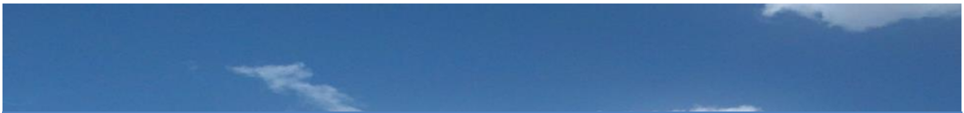
Source: The Energy Conservatory

Cubic foot per minute (cfm) – A measurement of air flow through an opening.

Relative Humidity – The amount of moisture in the air expressed as a percentage compared to the maximum before condensation occurs.

Dew Point – The temperature at which air is saturated with moisture (100% relative humidity) and at which point condensation will occur. Condensation occurs on the outside of a glass of ice water when the temperature at the outside of the glass is at dew point or below.

A well-sealed home is more comfortable and less expensive to heat and ventilate because you can control how much outdoor air comes in and where it goes.



The Question of "Acceptable Indoor Air Quality"

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is the technical body that develops and maintains ventilation standards for the United States. The mechanical ventilation requirements of the energy code are generally based on ASHRAE Standard 62.2 which is the ventilation standard that applies to low-rise residential buildings of three stories or less.

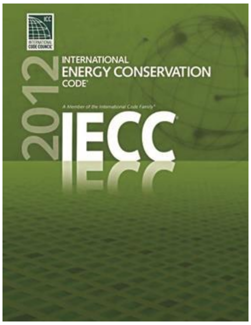
ASHRAE 62.2 assumes the acceptable indoor air occurs when "a substantial majority of occupants express no dissatisfaction with respect to odor and sensory irritation and in which there are not likely to be contaminants at concentrations that are known to pose a health risk." It is in fact a standard that a group of national experts could agree upon that sets a minimum standard for ventilation. It is not necessarily "best practice."

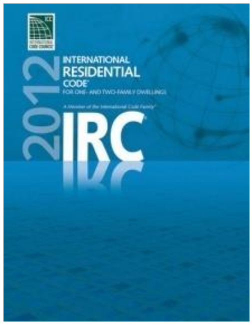
While ASHRAE 62.2 is considered the national ventilation standard there are building science experts that suggest that ASHRAE 62.2, ventilation rates are too low. There are also those that say it is too high. A common sense approach suggested by Joe Lstiburek, of Building Science Corporation, recommends installing systems that provide 1.5 times the required ventilation rate, but setting them to run initially at ½ the rate, letting the occupants adjust it themselves.

Code Requirements for Mechanical Ventilation

A code-compliant whole-house ventilation system may or may not provide effective energy efficient ventilation. But since whole-house mechanical ventilation is mandated by the Montana residential building and energy codes, and is thus the legal minimum, let's start the discussion there.

The 2012 International Residential Code (IRC) requires whole-house mechanical ventilation systems in the Montana climate zone. The IRC (R303.4) requires a whole-house mechanical ventilation system that complies with either Chapter 15 of the IRC or the International Mechanical Code. The requirements of both are similar, but IRC Chapter 15 is much more user-friendly. In this discussion, only Chapter 15 of the IRC will be included.





Every house built in Montana must comply with the energy code.

The Montana state energy code is applicable to all residential buildings constructed in Montana with the exception of garages and storage buildings. The energy code is enforced on residential buildings of less than five units located outside local code enforcement jurisdictions through the "dwelling self-certification program." Montana law requires, as an element of the self-certification program, that the builder provide a signed document to the building owner stating that the house complies with the state energy code.

Whole-House Mechanical Ventilation. Since the fans associated with a whole-house mechanical ventilation system will be operating continuously in most cases, the energy code calls for the use of energy-efficient fans. The following table specifies the efficiency of the fans that provide the required whole-house mechanical ventilation. Efficiency is given in cfm/watt.

TABLE R403.5.1 MECHANICAL VENTILATION SYSTEM FAN EFFICACY			
FAN LOCATION	AIR FLOW RATE MINIMUM (CFM)	MINIMUM EFFICACY (CFM/WATT)	AIR FLOW RATE MAXIMUM (CFM)
Range hoods	Any	2.8 cfm/watt	Any
In-line fan	Any	2.8 cfm/watt	Any
Bathroom, utility room	10	1.4 cfm/watt	< 90
Bathroom, utility room	90	2.8 cfm/watt	Any

An IRC Chapter 15 table, shown below, specifies the minimum required whole-house (also called “primary” or “dilution”) ventilation air flow based on floor area and number of bedrooms. The code assumes that one bedroom will be occupied by two persons and each additional bedroom will be occupied by a single person. The code states that the ventilation may be either exhaust or supply, but a supply-only ventilation system is inappropriate for the Montana climate. The whole-house mechanical ventilation system must be provided with controls that allow manual override.

IRC TABLE M1507.3.3(1)
CONTINUOUS WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM AIRFLOW RATE

DWELLING UNIT FLOOR AREA (square feet)	NUMBER OF BEDROOMS				
	0-1	2-3	4-5	6-7	> 7
	Airflow in CFM				
< 1,500	30	45	60	75	90
1,501 - 3,000	45	60	75	90	105
3,001 - 4,500	60	75	90	105	120
4,501 - 6,000	75	90	105	120	135
6,001 - 7,500	90	105	120	135	150
> 7,500	105	120	135	150	165

DWELLING UNIT FLOOR AREA (square feet)	NUMBER OF BEDROOMS				
	0-1	2-3	4-5	6-7	> 7
	Airflow in CFM				
< 1,500	30	45	60	75	90
1,501 - 3,000	45	60	75	90	105
3,001 - 4,500	60	75	90	105	120

A house of 2,500 ft^2 conditioned floor area with three bedrooms would require 60 cfm of continuous ventilation as shown.

Intermittent Operation. If the home uses intermittent ventilation instead of continuous ventilation, then the capacity of the ventilation system must be greater. For example, if the whole-house mechanical ventilation system will operate only 50% of the time, the capacity of the system must be increased by a factor of 2 as specified by the table shown. If the system operates intermittently then it must have controls that enable operation for not less than 25% of each four-hour period.

TABLE M1507.3.3(2)
Intermittent Whole-House Mechancial Ventilation Rate Factors

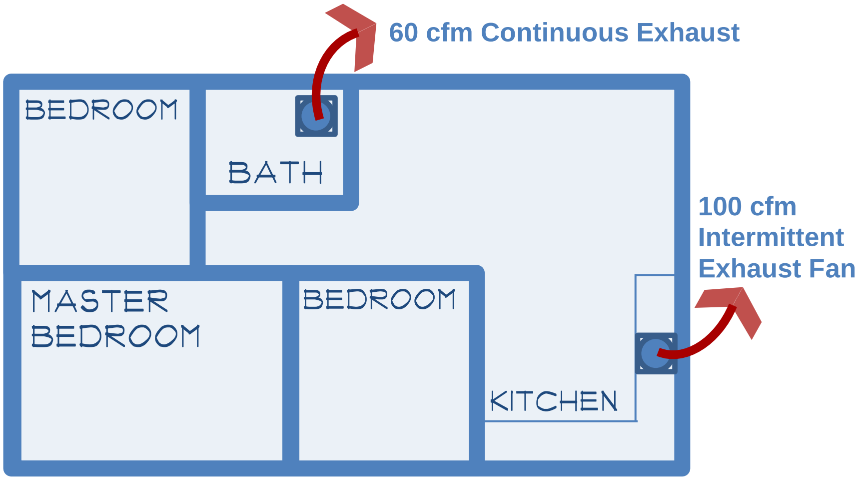
Run-Time Percent in Each 4-Hour Segment	25%	33%	50%	66%	75%	100%
Factor	4	3	2	1.5	1.3	1.0

Local Exhaust. In addition to whole-house ventilation system, the code also requires minimum local (also called "spot" or "point source") exhaust capability in kitchens and bathrooms. Kitchens must have a 100-cfm, intermittent exhaust, or a 25-cfm continuous exhaust. The fans must exhaust to the outside. Recirculation fans do not comply. Bathrooms must have either a 50-cfm intermittent controlled exhaust or a 20-cfm continuous exhaust. If continuous exhaust is used to comply with the local exhaust requirement, it may also be counted toward the whole-house mechanical ventilation.

Table M1507.4
Minimum Required Local Exhaust Rates for One- and Two-Family Dwellings

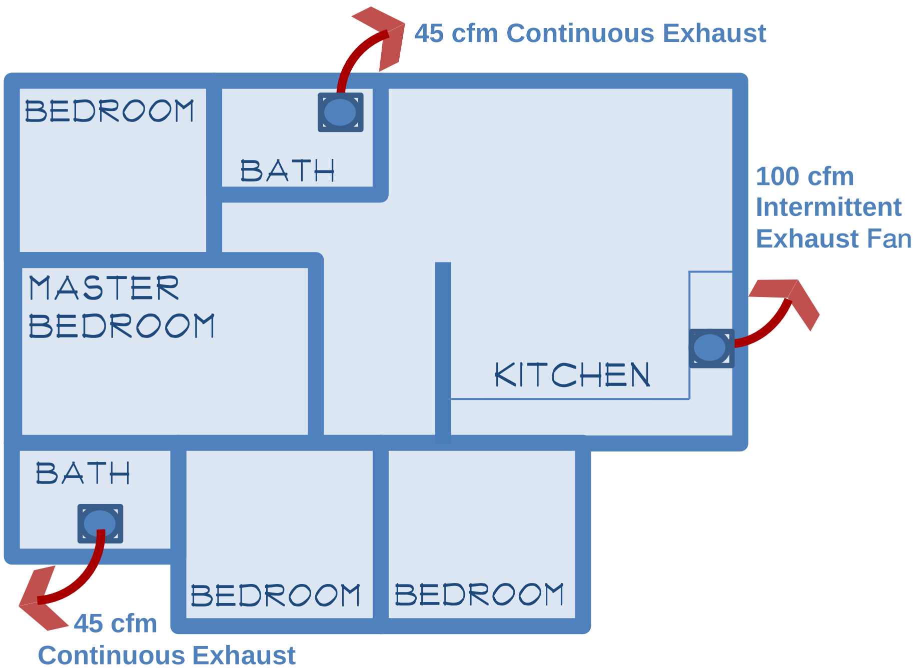
Area to Be Exhausted	Exhaust Rates
Kitchens	100 cfm intermittent or 25 cfm continuous
Bathrooms-Toilet Rooms	Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous

Following are three very simple examples. Example #1 is a 2,000 ft^2 single-story, three-bedroom house. This house requires 60 cfm of continuous ventilation. The house could comply with code with a continuous 60 cfm exhaust in the bathroom and a 100-cfm intermittent exhaust fan in the kitchen.



Mechanical Ventilation Example #1:

3 Bedroom, 2,000 ft^2 House Requires 60 cfm Continuous Ventilation

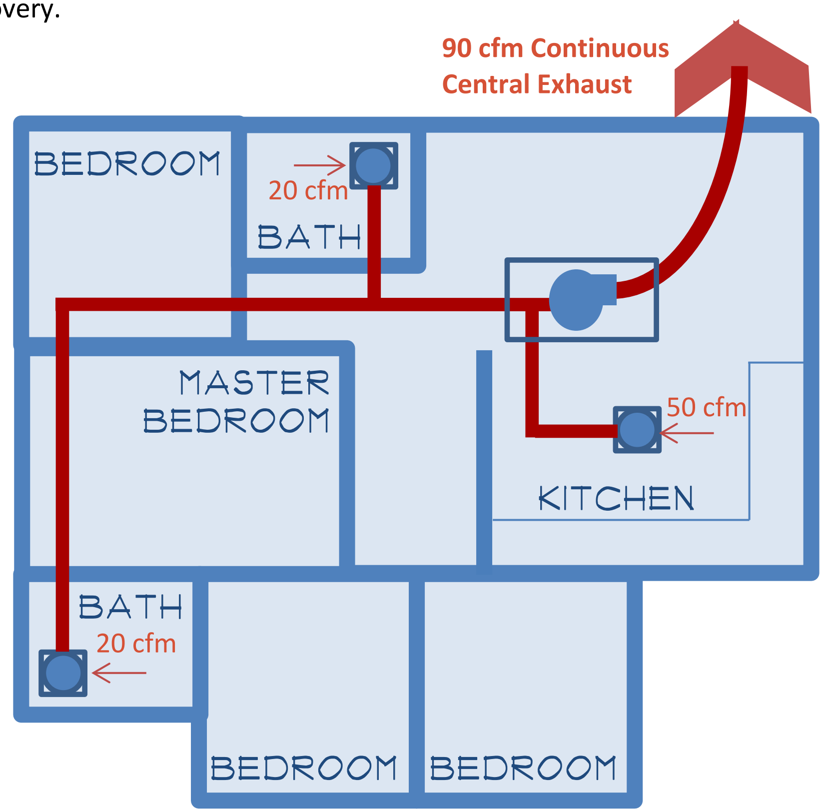


Mechanical Ventilation Example #2:

4 Bedroom, 3,600 ft^2 House Requires 90 cfm Continuous Ventilation

In Example #2 a four-bedroom 3,600 ft^2, one-story home would require 90 cfm of continuous ventilation air-flow according to Chapter 15 of the IRC. One way to accomplish this is to have a continuous 45 cfm exhaust fan in each of the two bathrooms and a 100 cfm manually controlled exhaust fan in the kitchen.

Below in Example #3 another code compliant ventilation solution is shown for the same four-bedroom, 3,600 ft^2, one-story home. A central exhaust system would continuously exhaust 20 cfm from each of the two bathrooms and 50 cfm from the kitchen. This satisfies both the whole-house air flow requirement and the local exhaust requirement. A central exhaust system could feature heat recovery.



Mechanical Ventilation Example #3:

4 Bedroom, 3,600 ft^2 House Requires 90 cfm Continuous Ventilation

Photo Source: EPA 402/F-08/008, "Care for Your Air: A Guide to Indoor Air Quality"

The Importance of Moisture and Pollutant Source Control

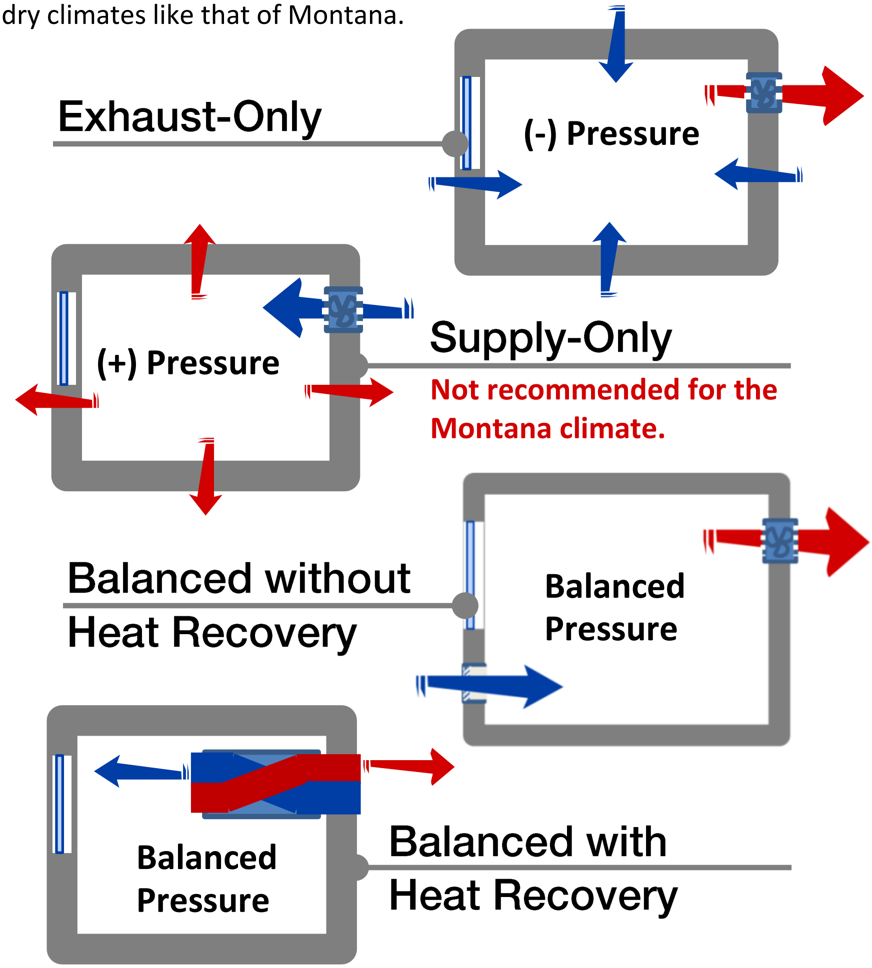
Whole-house ventilation systems introduce outside air to dilute unavoidable pollutants. But the first defense against poor indoor air quality should be eliminating the sources of indoor air pollution and moisture.

The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources release pollutants intermittently such as: smoking; the use of unvented or malfunctioning stoves, furnaces, or space heaters; the use of solvents in cleaning and hobby activities; the use of paint strippers in redecorating activities; and the use of cleaning products and pesticides in housekeeping. Soil gases such as radon and pesticides can also be significant pollution sources.

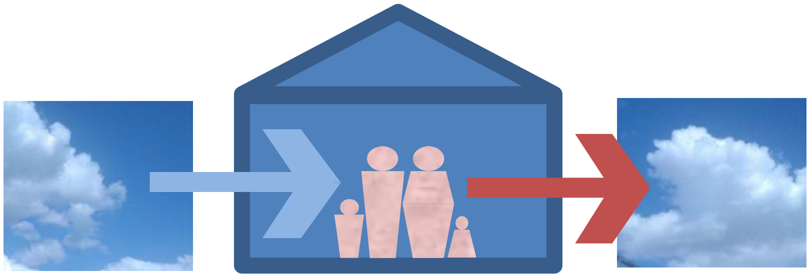
While many pollutant sources can be eliminated by design decisions and lifestyle choices, there will always be sources of moisture. Liquid water and water vapor are not inherently dangerous but, if uncontrolled, excessive moisture can lead to both health problems and deterioration of the building structure. This document about ventilation is too brief to detail all potential indoor air issues, but eliminating or reducing potential indoor air-quality threats should be the starting point in efforts to provide a healthy indoor environment. The minimum ventilation required by the code is not sufficient to address excessive moisture or pollutants.

Mechanical Ventilation System Types

The four basic types of mechanical ventilation are diagramed below. ***Exhaust-only systems*** depressurize the house without providing planned pathways for make-up air. ***Supply-only systems*** pressurize the house without providing planned pathways for exhaust air. The make-up air for both the supply-only and exhaust-only systems is supplied by the various air leaks in the building envelope. Since pressurizing the house will force warm, moist, interior air into the building cavities, supply-only ventilation systems **are not** recommended for cool, dry climates like that of Montana.



Balanced ventilation systems provide planned pathways for make-up air. Balanced systems may or may not include heat recovery.

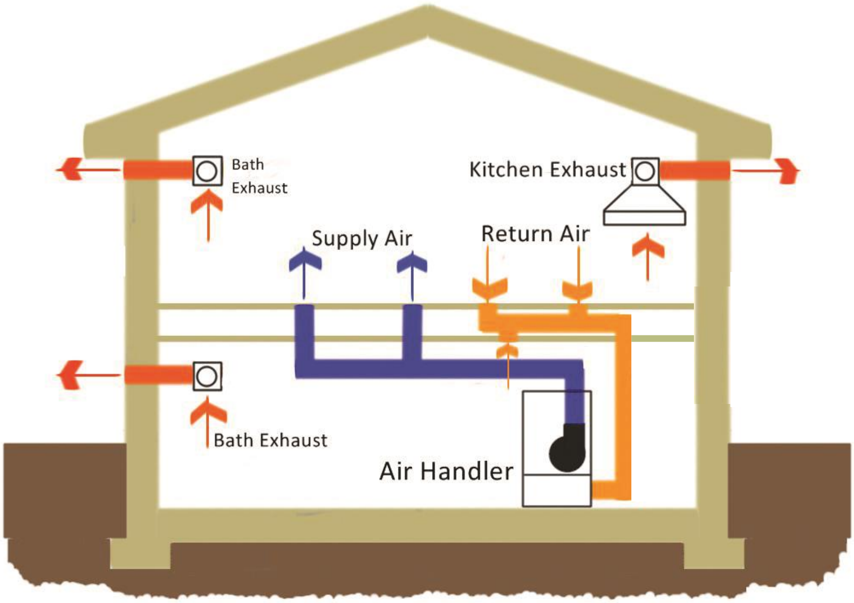


Air in = Air out

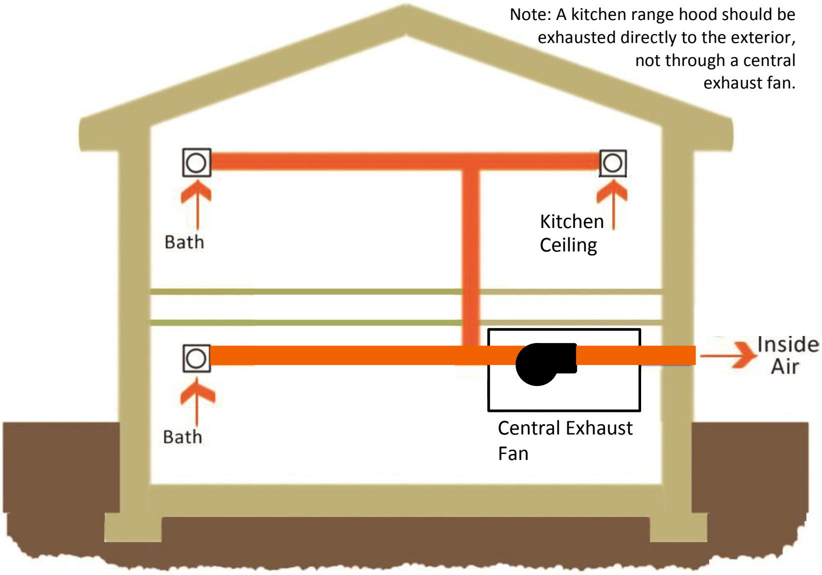
A fundamental building science principle is that if one cfm of air leaves a building, then one cfm must enter the building.

Exhaust-Only Ventilation Systems

A simple exhaust fan, usually located in a bathroom, pulls air out of the house. The fan is operated to provide dilution air for the entire house. The code mandated minimum air flow is based on the number of bedrooms and on run time, which can be either continuous or intermittent. Make-up (replacement) air is drawn into the bathroom from hallways and other rooms in the house which in turn draws outside air through envelope leaks into those spaces. Other intermittently controlled local exhaust fans in bathrooms, kitchen, and laundry room provide local exhaust. Control of the local exhaust fans may be by timer switch or humidistat. Bathroom fans switched with lights turn off too soon to adequately remove moisture buildup from showers of baths. Because replacement air is drawn through uncontrolled leaks, fresh air is not evenly distributed in the home. Uneven distribution of fresh air is more pronounced when bedroom doors are closed. Exhaust-only systems can contribute to depressurization in the combustion appliance zone, which can lead to backdrafting of atmospherically vented appliances. A single central fan can exhaust air from several rooms.



Exhaust-Only Ventilation System

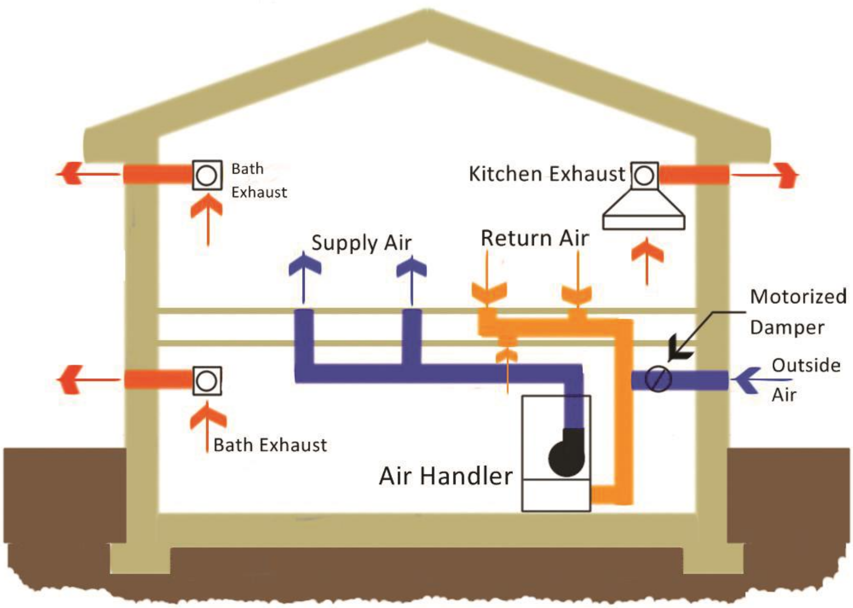


Standalone Central Exhaust Ventilation

Balanced Ventilation Systems

In ***balanced ventilation*** systems, there is a dedicated make-up air pathway designed into the system. Providing this dedicated make-up air pathway has several benefits. It minimizes problems of over-pressurizing and under-pressurizing spaces within the home. A balanced ventilation system is more likely to provide design air quantities. Make-up air is provided through planned pathways, which improves air quality. Balanced systems may also be designed to provide heat recovery with a heat recovery ventilator (HRV). While balanced ventilation has many advantages, it is often more costly to install.

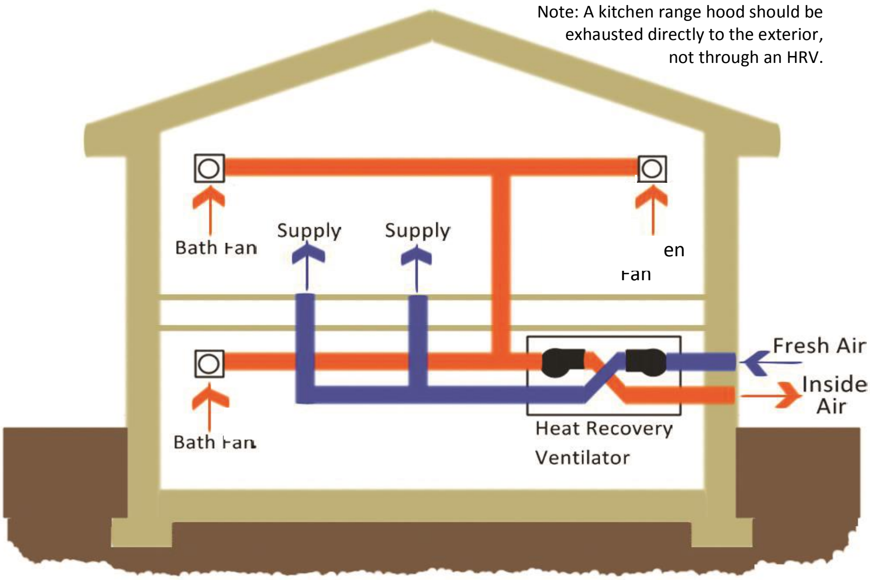
Below is a diagram of a balanced ventilation system without heat recovery. Air is exhausted from fans located in the kitchen and bathrooms. Fresh air is provided through a make-up air duct connected to the return side of the air handler. This make-up air duct is equipped with a motorized damper that is operationally integrated with the air handler and exhaust fans.



Balanced Exhaust Ventilation Integrated with Central Air Handler

The operation of the central air-handler fan pulls air into the return air duct. The motorized damper in the make-up air duct establishes a fixed amount of outside air into the central system and its operation can be integrated with the operation of the primary exhaust fan. This approach allows the central air-handler system to distribute and temper outside air. The outside air duct should be insulated and sloped to the outside to deal with possible condensation. Use of flex duct should be avoided to reduce the chance of reservoirs that can collect condensation. As noted by Joseph Lstiburek in the *Builder's Guide to Cold Climates,* the mixed return air temperature should not be allowed to drop below 50^{o} F in order to control condensation of combustion gases on the heat exchanger surfaces.

The diagram below shows a balanced central exhaust ventilation system with a standalone HRV. An HRV transfers heat from the exhaust air to the intake air. In this system, air is collected from spaces in the home that are most likely to produce moisture or pollutants and is then exhausted at a central point. Fresh air is supplied by the central ventilation system to one or more spaces.



Balanced Ventilation System with Standalone HRV

When an air handler is present, the fresh air supply from the HRV can be connected to the return side of the air handler and the low-speed air handler fan is interconnected with the operation of the HRV. Typically, an HRV will transfer 60% to 90% of the heat in the stale air being exhausted from the home to the fresh air entering the home. While it is possible to integrate an HRV with a central air handler, it is difficult to balance the HRV is this configuration because of the ducting and operating conditions of the central air distribution system.

In many new energy-efficient homes, the balance point temperature is 50° F to 55° F. The balance point temperature is the minimum outdoor temperature at which no space heating is required. When the outdoor temperature is above the balance point temperature, the HRV is not saving energy. In fact, it becomes an air conditioner.

HRVs have the potential to provide energy savings and effective ventilation but only if installed properly and only if the house is not over-ventilated. For small energy-efficient homes HRVs may not be cost effective. If integrated with a central air handler the chances of an HRV providing cost-effective savings is reduced.

Heat Recovery Ventilators

Heat Recovery Ventilators (HRV) are often confused with energy recovery ventilators (ERV). An HRV transfers sensible heat from the exhaust air stream to the make-up air stream. An ERV also transfers moisture between the two streams of air. Therefore both sensible heat and latent heat is transferred by an ERV.

Sensible heat **is the heat absorbed by a gas, liquid, and solid which raises its temperature.**

Latent heat **is the heat absorbed or released by a substance without a change in temperature when it changes state such as when a gas changes to a liquid or a liquid changes to a gas.**

An ERV is typically used in humid climates. HRVs are much more appropriate for Montana's dry climate.

Why is Air Flow Balancing Important?

HRV rated efficiency is given at a specific set of conditions. If air flow is unbalanced, the efficiency is unknown. If exhaust air flow is greater than the in-take air flow then the building pressure will go negative with reference to outside drawing outside air into the house. If the intake air flow is greater than the exhaust airflow then the building pressure will go positive with reference to the outside forcing warm moist air into the building envelope.

HRV Design and Installation Best Practices

- Install HRV in easily accessible location.
- Install HRV inside the conditioned space.
- Standalone installation is preferable to integrating the HRV with a central air handler for distribution.
- Ductwork characteristics: 1) locate inside the conditioned space; 2) minimize length; 3) minimize sharp bends; 4) do not compress; 5) use of flex duct should be avoided to reduce the chance of reservoirs that can collect condensation; 6) seal duct joints with mastic.
- Wall hood characteristics: 1) maintain separation of exhaust and intake hoods; 2) don't use gravity dampers on intakes; 3) place where the homeowner can clean them.
- Commissioning: 1) balance as per manufacturer's recommendation; 2) measure airflow per room; 3) double-check that intakes intake and exhausts exhaust; 4) set controller to meet ASHRAE 62.2; 5) record all readings and post on unit; 6) measure temperatures between incoming and outgoing air and compare with efficiency rating.
- Homeowner Education: 1) leave all manuals, especially ones concerning setting the controller; 2) emphasize filter and screen cleaning; 3) document all testing and commissioning; 4) sell a maintenance contract; 5) emphasize the importance of ventilation.

Beyond Code: Effective, Efficient Ventilation

As noted previously complying with code requirements for whole-house mechanical ventilation will not necessarily result in effective and energy-efficient ventilation. Following are some design and operation considerations that improve the effectiveness and energy efficiency of the ventilation system.

Ventilation Effectiveness Factors

- **A whole mechanical ventilation system must be used to be effective.** Factors that discourage use and cause occupants to disable the systems include noise, blowing cool air on occupants, complex controls, lack of understanding of system operation by occupants, controls not being labeled.
- **Simplify and label controls.** Although not mandated by the code, the mechanical ventilation system manual control should be clearly and permanently labeled, especially the required override switch.
- **Exhaust air from source locations.** Air should be exhausted from the rooms where most pollutants, odors, and moisture are generated such as bathrooms, laundry rooms, and kitchen.
- **Supply Air to Occupied Rooms.** Supply and returns to each bedroom will assure that each is well ventilated, even when doors are closed.
- **Distribute fresh air directly to occupied rooms.** Good distribution means fresh air is supplied to the rooms where occupants spend most of their time such as living room and bedrooms.
- **Exhaust kitchen range hoods to exterior.** Kitchen range hoods should exhaust outside to remove moisture, odors, and pollutants. Recirculation hoods allow grease vapors and odors to remain in the house and should be avoided.
- **Install quiet fans.** Fan noise can be a major factor in whether occupants use the ventilation system provided. If fans are rated over one sone, there is a good chance the system will be deactivated by the occupants.

Exhaust fans are rated for noise. A sone is a measure of loudness. The higher the sone rating the louder the sound. Exhaust fans with a sone rating of one or less will be quiet and much less likely to be disabled by the occupant.

- **Beware of backdrafting.** Backdrafting is the spillage of combustion gases, including carbon monoxide, from a combustion appliance such as fireplace, woodstove, atmospherically vented gas furnace, or atmospherically vented gas water heater. Installing sealed combustion, power vented, direct vented, and induced draft appliances will assure backdrafting is not a problem. Of course, these types of combustion appliances are usually more expensive. Gas ovens and gas stovetops are other sources of combustion gases and should only be used with an exhaust hood directly vented to the exterior. Unvented gas fireplaces or gas heaters should never be installed.

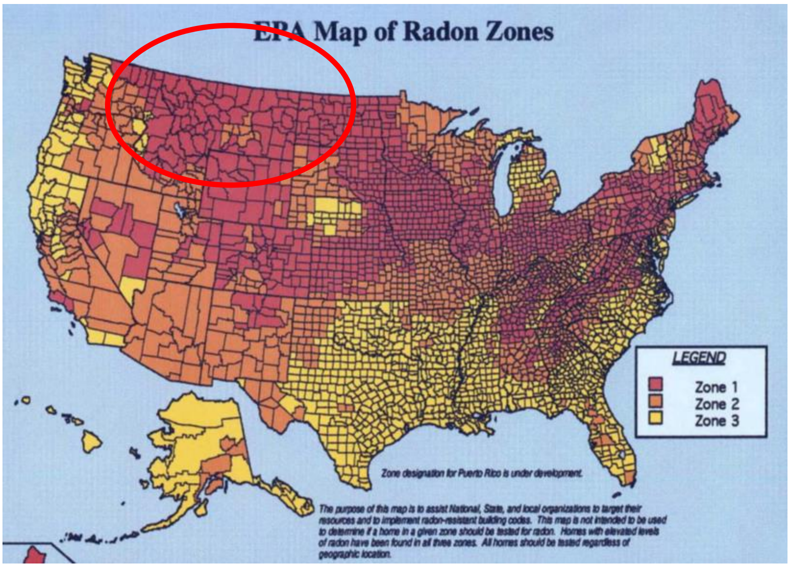
A combustion appliance zone worst-case depressurization test is used to determine if backdrafting is a possibility from atmospherically vented combustion appliances such as furnaces and water heaters. Several appliances and design factors can contribute to negative pressure in a house. Some those factors are listed below:

- Exhaust Fans
- Clothes Dryers
- Leaks in Return Air Ducts
- Fireplace
- Wind
- Stack Effect
- Inadequate Return Air Volume from Bedrooms
- Atmospherically Vented Combustion Appliances
- Central Vacuum Systems
- Leaks in Supply Ducts Outside the Air Barrier

By performing a worst case depressurization test in the combustion zone, a trained professional can determine if backdrafting will occur. The negative pressure that can cause backdrafting depends on the appliance type. For the first time, the IECC in the 2015 edition includes an optional worst case depressurization test procedure as an appendix.

This will allow jurisdictions to include such a test in house compliance if they choose.

- **Testing Exhaust and Supply Flow.** Flow hoods and other testing equipment are available to test the air flow at ventilation devices. The test is usually quick and easy. Actual fan flow depends not only on the fan capacity but also on the length and character of the duct. If the duct to the exterior is long, compressed, or has sharp bends then then flow will be significantly reduced.
- **Beware of Radon.** Radon enters a home through cracks in concrete, joints in construction below grade, and through poorly sealed crawl space construction. You can't test for radon before construction. That is why the U.S. EPA recommends that all homes built in Zone 1, which includes most of Montana, have radon mitigation systems installed at time of construction.



Ventilation Energy Efficiency Factors

Don't over-ventilate. Provide controls that allow ventilation to be adjusted by occupants to reflect the number of occupants and lifestyle. This may require the assistance of an HVAC professional.

- **Use energy-efficient motors.** The code now establishes minimum efficiency values for whole-house ventilation fans. If the ventilation system is integrated with a central air handler, then the air handler should be equipped with an electrically commutated motor (ECM).
- **Operate the exhaust system only when people are present.** If the house is unoccupied for some period of time, the whole-house ventilation system should be activated prior to occupancy to purge stale air.
- **Avoid integrating ventilation system with air handler.** Using the air handler fan to distribute ventilation air has an energy penalty. Air handler fans typically consume considerably more energy than do exhaust or HRV fans. If a central air handler is incorporated into the ventilation strategy its low speed ECM fan will need to operate when the house is being ventilated. Extra care must be taken with air handler integrated ventilation system controls, mixed air temperature at the heat exchanger, and condensation within the make-up air duct. While central air handler integrated ventilation systems provide good distribution, they also result in greater energy consumption by fans.
- **Outside air intake location must be carefully selected.** For balanced systems the location of the outside air intake must be chosen to avoid drawing poor quality air into the house and returning exhausted air to the interior.

Residential Ventilation Effectiveness In the Pacific Northwest

A recent study in the Pacific Northwest provides some insights into how current ventilation systems are performing. In 2014, the Washington State University Extension Energy Program completed a study funded by the Northwest Energy Efficiency Alliance (NEEA). The study took an in-depth look at ventilation effectiveness in houses with low air leakage (<3 ACH50). A total of 29 houses were included in the study. The system types studied were exhaust-only, exhaust with inlet vents, standalone HRV systems, balanced exhaust integrated with a central air handler, and HRV systems integrated with an air handler.

Key findings:

- Interior door closings significantly reduce fresh air distribution for all ventilation system types, unless fresh air is supplied directly to that room with designed return pathways.
- The state of Washington requires "trickle" or "passive" vents in the bedrooms when an exhaust-only ventilation system is installed. Trickle vents did not result in improved ventilation effectiveness compared to exhaust-only systems without vents.
- Properly designed, installed, and operated HRV systems were more effective than exhaust-only systems. However, many HRV systems were not very effective. Overall, HRV systems were only 5% better than exhaust-only systems at providing effective ventilation.
- Ventilation systems often didn't work properly and were disabled by the occupants. Complex ventilation system controls contributed significantly to systems not being operated as designed.
- The greatest ventilation fan energy consumption occurred when the ventilation system was integrated with the central air handler. This study did not attempt to estimate the space conditioning energy savings associated with HRVs or ERVs.
- Occupant perception of indoor air quality did not correlate well with actual ventilation rates. In other words, many occupants are not good judges of indoor air quality.

References:

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Reviewing Agencies:

Montana Department of Labor and Industry
Montana Department of Environmental Quality

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