TechNote

Whole-House Mechanical Ventilation Code: Safety and Performance Considerations

What is whole-house mechanical ventilation?

Whole-house mechanical ventilation is the intentional exchange of indoor air with fresh outdoor air at a controlled rate using fans. The purpose of whole-house mechanical ventilation is to improve indoor air quality.

Historically, mechanical ventilation was limited to local-exhaust (kitchen and bath exhaust fans) for spot control of moisture and odors. Houses commonly had enough natural ventilation, through leaky building enclosures, that whole-house mechanical ventilation was not necessary. Houses have become significantly tighter during the past 15-20 years as a result of changing codes, energy efficiency programs, and an overall desire to reduce energy use. Above-code programs and more recently the building codes have generally made controlled whole-house mechanical ventilation a requirement.

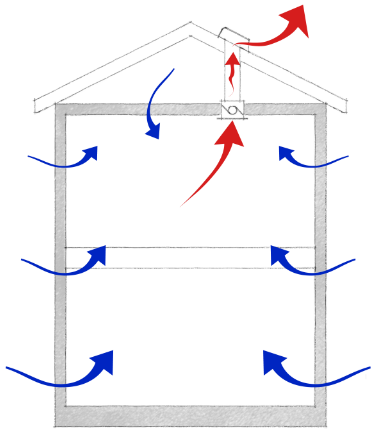
Types of whole-house mechanical ventilation

There are three types of whole-house mechanical ventilation systems: exhaust-only, supply-only, and balanced. Each system uses a combination of fans, ducting, dampers, and controls:

Benefits of whole-house mechanical ventilation

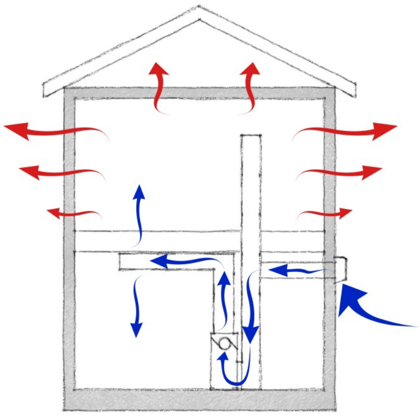
- Provides a consistent supply of outdoor air for improved indoor air quality and occupant comfort
- Improves control over the amount and source of outdoor air
- Dilutes indoor contaminants, such as formaldehyde, cleaning agents, odors, and allergens, which now take longer to dissipate in a tighter house
- Helps control relative humidity and reduce moisture accumulation during the heating or temperate seasons
- Meets new 2012 IRC building code and many energy and green program requirements

Figure 1. Exhaust-only tends to depressurize the building



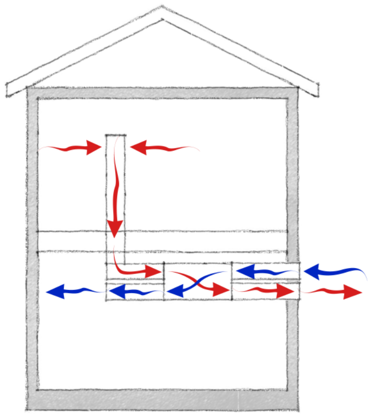
Exhaust-only: A fan, commonly an efficient bath fan, exhausts indoor air. Outdoor makeup air is drawn into the house through leaks in the building enclosure.

Figure 2. Supply-only tends to pressurize the building



Supply-only: A fan draws outdoor air into the house. Indoor air escapes through the building enclosure and exhaust fan ducts. Supply-only could be a dedicated system, or more commonly a central-fan-integrated (CFI) system. With a CFI system, outdoor air is ducted to the return plenum of an HVAC air handler that draws in and distributes the outdoor air.

Figure 3. Balanced limits pressure imbalances



Balanced: A combination of exhaust and supply methods provides approximately equal indoor exhaust and outdoor supply air flows (e.g. an exhaust fan combined with a supply fan or passive inlet vents). A balanced system may include a heat recovery ventilator (HRV) or an energy recovery ventilator (ERV).

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Performance and Cost Considerations

Exhaust-only: tends to depressurize the house

- Contaminants may be drawn into the house from an attic, garage, crawlspace, or wall cavity
- Potential to draw moist outdoor air into the wall cavity that could condense during the cooling season and cause moisture problems, particularly in warm humid climates
- Outdoor air may not be well distributed
- Could cause or contribute to back-drafting of combustion appliances
- Lowest installed cost and low operating cost

A combination of supply-only and exhaust-only components could be a practical and cost effective alternative to an HRV or ERV.

Supply-only: tends to pressurize the house

- Minimizes contaminants entering through the building enclosure
- Potential to drive moist indoor air into the wall cavity that could condense and cause moisture problems during the heating season in colder climates
- Outdoor air is drawn from a single, known location for best air quality
- Must be designed to avoid occupant discomfort due to cold outdoor air
- For a central fan integrated (CFI) system, air is well distributed and can be filtered and conditioned
- Low installed cost, however for a CFI system, the electronically commutated motor may increase the initial cost, and operating cost may be higher

Balanced: limits house pressure imbalances

- An HRV transfers a portion of the heat between the exhaust air and the fresh air; an ERV transfers heat and moisture
- An HRV or ERV may be ducted independently or integrated with the heating and cooling duct system.
- An HRV or ERV provides the benefits, but limits the drawbacks, of supply-only and exhaust-only methods
- Generally, an HRV is recommended for dry, cold climates, and an ERV is recommended for moist, warm climates
- Highest installed cost for HRV or ERV due to equipment and additional ducting. Energy transfer operating cost savings is somewhat offset by fan energy, particularly when integrated with the HVAC system, and additional maintenance.

What air flow rate is required?

ASHRAE Standard 62.2-2010 is a ventilation standard for new and existing homes, and is the basis for the whole-house mechanical ventilation rates in the 2012 IECC and 2012 IRC. Minimum continuous and intermittent rates are prescribed using tables.

The recently released ASHRAE 62.2-2013 prescribes a higher minimum continuous rate that can be modified based on building tightness test results.

Air Flow Performance

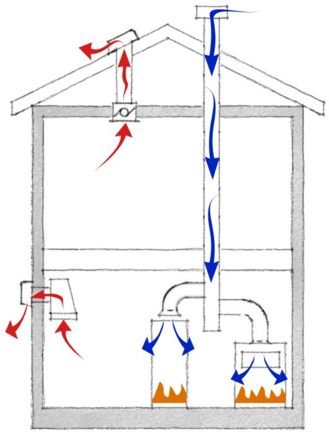
Measured air flows are frequently less than design values due to an overly restrictive duct system. An efficient duct layout will reduce air flow resistance and help ensure expected performance:

- ✓ Locate termination hoods to minimize duct lengths and number of elbows
- ✓ Account for pressure drop of all components including termination hoods
- ✓ Use manufacturer's air flow and static pressure data; prescriptive duct sizing tables may use different static pressures
- ✓ Increase duct diameter if necessary
- ✓ Install in accordance with manufacturer's instructions

Ventilation Controls

Controls prevent under-ventilation and over-ventilation that could lead to excessive energy use (heating, cooling, and fan) or occupant discomfort. A control may be a timer, humidistat, or other duty cycling device that controls ventilation based on time, cumulative hourly run-time of the HVAC system, or severe outdoor conditions.

Figure 4. Back Drafting



Back Drafting

Back-drafting is the dangerous condition when negative house pressure is sufficiently high to draw products of combustion from fuel-burning appliances into the house (instead of being vented out of the appliance through a chimney or vent). Back-drafting can potentially lead to unsafe levels of carbon monoxide – an odorless and colorless poisonous gas which can cause sickness or death. Combustion appliances with potential for back-drafting include furnaces, water heaters, fireplaces, or other equipment that burns natural gas, propane, oil, kerosene, or wood. The factors that affect pressure conditions inside a house include stack effects, wind effects, HVAC, and exhaust fans.

Exhaust fans. Exhaust fans can create a negative pressure inside buildings leading to back-drafting (see Figure 4). A bath exhaust fan used for whole-house mechanical ventilation and operating at the code prescribed continuous rate (e.g., 50-80 CFM) could cause back-drafting, but the operation of a larger capacity exhaust fan (e.g., a 300-1200 CFM kitchen range hood fan or a 150-400 CFM inline multi-inlet bath fan) is more likely to cause back-drafting unless make-up air is provided. Other exhaust appliances (clothes dryer, central vacuum, and conventional bath fans) operating concurrently would further increase the potential for back-drafting.

Testing. Combustion appliances can be tested for potential back-drafting. The BPI Building Analyst Professional Standard (BPI 2012) includes a procedure, summarized below, to perform a depressurization test for each combustion appliance zone (CAZ):

- Measure a baseline pressure
- Measure the largest negative pressure, based on the combined effects of exhaust appliance operation, air handler operation, and door position
- The difference is the worst-case depressurization
- Compare to the back-drafting depressurization limit for the appliance

This procedure is generally performed in conjunction with testing for building tightness, carbon monoxide, and spillage and draft for natural draft and mechanical draft furnaces and water heaters. Based on test results, action items are identified to maintain combustion safety.

2012 International Residential Code (IRC) Requirements

For the first time, the IRC has requirements for whole-house mechanical ventilation. The Chapter 11 Energy Efficiency text in the 2012 IRC is now identical to the residential energy efficiency requirements in the 2012 International Energy Conservation Code (IECC). Additionally, the 2012 IECC directly references the mandatory ventilation requirements in the 2012 IRC for one and two family dwellings or International Mechanical Code (IMC) for multi-family dwellings.

Section R303.4 requires whole-house mechanical ventilation in accordance with M1507.3, where the tested air infiltration rate is less than 5 ACH50 in accordance with N1102.4.1.2.

Section N1102.4.1.2 requires a tested air leakage rate of not exceeding 5 ACH50 in Climate Zones 1-2, or 3 ACH50 in Climate Zones 3-8.

Section N1103.5 mandates mechanical ventilation in accordance with Section M1507 or other approved means, and specifies minimum fan efficacy (see Table 1), including electronically commutated motors where ventilation fans are integral to HVAC equipment.

Section M1507 prescribes minimum continuous and intermittent whole-house mechanical ventilation rates (see Table 2 and Table 3) and equires controls with manual override.

Example: whole-house mechanical ventilation air flow requirement
A 2,400 square foot house with three bedrooms would require, per the tables, 60 CFM continuous air flow, or 120 CFM intermittent air flow at 50% run time.

Table 1. Fan efficacy table from the 2012 IRC

Mechanical Ventilation System Fan Efficacy [Table N1103.5.1]

Fan Location	Air Flow 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

Table 2. Minimum continuous ventilation rates from the 2012 IRC

Continuous Whole-House Mechanical Ventilation System Airflow Rate Requirements [Table M1507.3.3(1)]

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

Table 3. Intermittent ventilation rates from the 2012 IRC

Intermittent Rate Factors [a,b] [Table M1507.3.3(2)]

Run-Time Percentage	25%	33%	50%	66%	75%	100%
Factor [a]	4	3	2	1.5	1.3	1.0

a. For ventilation system run time values between those given, the factors are permitted to be determined by interpolation
b. Extrapolation beyond the table is prohibited

IRC Ventilation References

- Intake and exhaust location restrictions (R303.5)
- Intakes and exhausts require dampers that close when system is off (N1103.5)
- Mechanical exhaust systems must discharge to the outdoors (M1501.1 and M1507.2))
- Intake and exhaust duct details (M1506.2, new for 2012)
- Install ventilation ducts in accordance with ACCA Manual D or equivalent (M1601.1 and M1506.1)
- Outdoor air inlets must be covered using screens (M1602.3)
- Kitchen range hood systems exceeding 400 CFM require makeup air (M1503.4)
- Chapter 17 Combustion Air, for solidfuel burning and oil-fired appliances
- Chapter 24 Fuel Gas, Section G2407, for makeup, combustion, and ventilation air

▶ Existing Homes

Retrofitting an existing house with energy efficiency improvements could significantly reduce the natural air exchange rate with the outdoors, potentially creating a back-drafting hazard. Whole-house mechanical ventilation now may be required to maintain acceptable indoor air quality. Combustion safety testing could be used to identify existing issues before retrofit work begins, and to confirm the safe operation of combustion appliances after work is complete.

Recommendations

The 2012 IRC requires lower building envelope infiltration rates. Existing houses that have undergone an energy efficiency retrofit may be equally tight. Tighter construction has increased the need for effective mechanical ventilation.

Suggestions for best performance of whole-house mechanical ventilation systems:

- ✓ Determine the required minimum continuous air flow rate (Table 2)
- ✓ Select the most appropriate type of system based on desired performance factors (detailed on page 2)
- ✓ Select equipment fan size based on intermittent operation as required (Table 3)
- ✓ Select controls to avoid under-ventilation and over-ventilation
- ✓ Design duct layouts to ensure that tested air flow rates will meet design requirements (using manufacturer instructions and industry standards such as Manual D (ACAA 2009))
- ✓ Inspect bath and kitchen exhaust systems for proper installation – these are the most effective ways to control moisture
- ✓ Test the operation of all mechanical ventilation systems and confirm that controls are operating properly

Combustion safety and exhaust fan operation should be considered together. Generally, the tighter the house, the more likely it is that depressurization could be a problem, even when code approved combustion air requirements are met. A worst-case depressurization test will help to determine if non-direct vent combustion appliances will back-draft.

Suggestions to prevent back-drafting and other combustion safety hazards:

- ✓ Ideally, install direct vent (outdoor air for combustion) equipment
- ✓ If direct vent equipment is not feasible, install induced draft or power vented combustion appliances
- ✓ Exhaust-only whole-house mechanical ventilation may not be appropriate where natural draft and induced draft appliances are installed
- ✓ Confirm that combustion appliances including fireplaces are installed and commissioned in accordance with code and manufacturer instructions
- ✓ Perform worst case depressurization testing, as required, in accordance with industry standards, such as from the Building Performance
- ✓ Institute (BPI 2012), Air Conditioning Contractors of America (ACCA 2011), The Energy Conservatory (TEC 2012), or other approved tests.

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