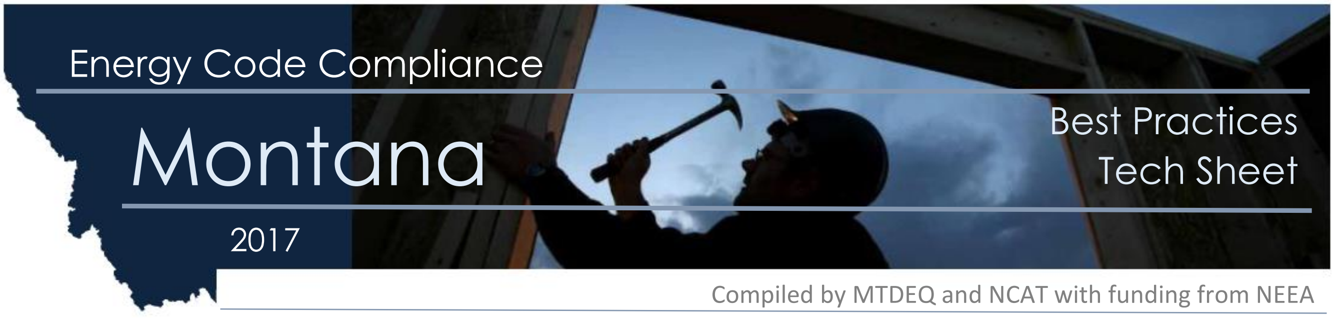

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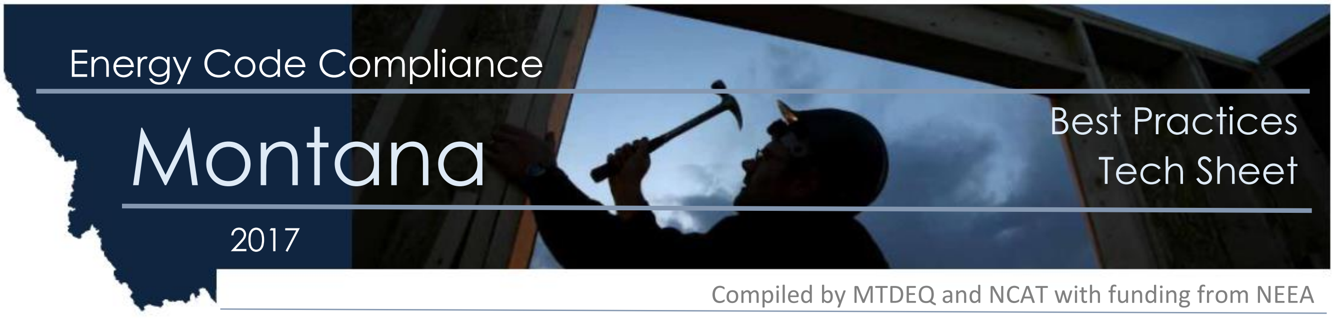
Energy Code Best Practices Guide Introduction

On November 7, 2014, Montana adopted the 2012 International Energy Efficiency Code (IECC) with a number of amendments. The previous state energy code was based on the 2009 IECC. These articles were produced to assist builders and designers in complying with Montana's new energy code and to assist in the construction of homes that are more energy-efficient, healthier for the occupants, and more durable. This document is a complement to the Montana Residential Buildings Energy Code Summary, published by the Montana Department of Environmental Quality. The following set of articles address key residential energy code compliance issues.

2017 Energy Code Best Practices Tech Sheets



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Residential Energy Code Compliance Approaches

Compliance Approaches

New residential buildings must comply with both the “mandatory” provisions of the energy code and the thermal envelope provisions. There are three alternative prescriptive approaches and a performance approach. The most commonly used but least flexible prescriptive alternative is the ***Insulation/Fenestration Table*** alternative, which is based on a table of R-values and U-factors. The ***U-factor Alternative*** is based on a table of U-factors which must consider the entire component assembly, both the insulation and other assembly elements. The ***Trade-off Alternative*** is also based on the table of U-factors but allows tradeoffs between the different building envelope components. For example windows that do not meet the U-factor value can be acceptable if additional roof or wall insulation is installed. Use of the REScheck^{TM} software makes the trade-off alternative relatively simple. The trade-off alternative is the most flexible of the prescriptive alternatives but not as flexible as the performance approach. The performance approach is the most flexible of all options but is also the most complex in that it requires detailed inputs of all building energy systems and the analysis must be performed with an approved building performance simulation software such as REM/Rate^{TM}, REM/Design^{TM}, or Energy Guage^{TM}.

Residential Energy Code Compliance Approaches

Mandatory Provisions

+

Envelope Provisions

Prescriptive Approaches

- Insulation/Fenestration Table
- U-Factor Alternative
- Trade-off Alternative (REScheck)

Performance Approach

The insulation and fenestration table alternative lists the minimum R-value or maximum U-factor requirements for each building component such as windows, walls, and roofs. This approach is quick and easy to use, but many users find it somewhat restrictive because the requirements typically are based on worst-case assumptions, and all requirements must be met exactly as specified.

Table R402.1.1 in the 2012 IECC contains a table that directly specifies the energy characteristic required for the windows, skylights, walls, ceiling, floor, slab, and crawlspace. Montana amended the wood frame wall (R-21 or R-13 + R10 continuous) requirements. The table below shows the required characteristics including the amended value. The R-values in the table refer only to the insulation and not to other components of the wall assembly. Log, concrete block, and insulated concrete form walls must comply with the “mass” wall requirements.

R-Value Prescriptive Requirements		Table R402.1.1
Component	**Insulation, Window, Door, and Skylight Requirements**	**Remarks**
Windows & Doors	**U-0.32**	
Skylights	**U-0.55**	
Ceiling	**R-49**	R-38 complies if uncompressed insulation extends over top of exterior wall top plate
Wood Frame Wall	**R-21 or R-13+5**	First value is cavity insulation, second value (if present) is continuous sheathing
Mass Wall	**R-15/R-20**	Second value applies when more than half of R-value is on interior of mass wall
Floor	**R-30**	Insulation that fills cavity (R-19 minimum) also complies
Basment Wall	**R-15/R-19**	First value is continuous, second value is cavity
Slab	**R-10, 4'**	Insulation must extend downward continuously from top of slab for 4 feet vertically or horizontally
Crawlspace Wall	**R-15/R-19**	First value is continous inside or outside, second value is cavity insulation on inside

U-Factor Alternative

When using the U-factor table, the characteristics of the entire assembly are considered. For example, in a wall, the insulating characteristics of the air films, sheathing, and interior finish are included in the calculation. The area weighted U-factors of the wall and framing members and headers must be included in the calculation. Each envelope component (windows, skylights, walls, ceiling, floor, slab, and crawlspace) must each comply with the characteristic specified in Table R402.1.3.

U-Factor Table R402.1.3	
Component	Insulation, Window, Door, and Skylight Requirements
Windows & Doors	U-0.32
Skylights	U-0.55
Ceiling	0.026
Wood Frame Wall	0.054
Mass Wall	0.06; 0.57 if >50% insul. on interior
Floor	0.033
Basment Wall	0.05
Crawlspace Wall	0.055

Trade-off Alternative Alternative

The third prescriptive compliance approach to envelope compliance is called the Trade-off or Total UA Alternative. This approach is typically less restrictive than prescriptive approaches because components that exceed the requirements can compensate for those that do not meet the code.

The trade-off approach allows you to trade better energy efficiency in one building component for decreased energy efficiency in another component. This method allows tradeoffs between the various envelope components. For example, the walls of a particular building may not meet the R-value table minimum requirement, but if the windows are better than code, the envelope as a whole may comply. In this method, each area of the envelope with a different thermal characteristic is multiplied by its associated area in square feet. The sum of all UA products (U-factor x area) for the proposed building is compared to a building based on the code maximum U-factors. If the UA total of the proposed building is less than the UA of the code-based building, then the building complies. REScheck™ software uses the Trade-off Alternative to demonstrate compliance. REScheck™ software may be obtained at no cost from www.energycodes.gov/rescheck.

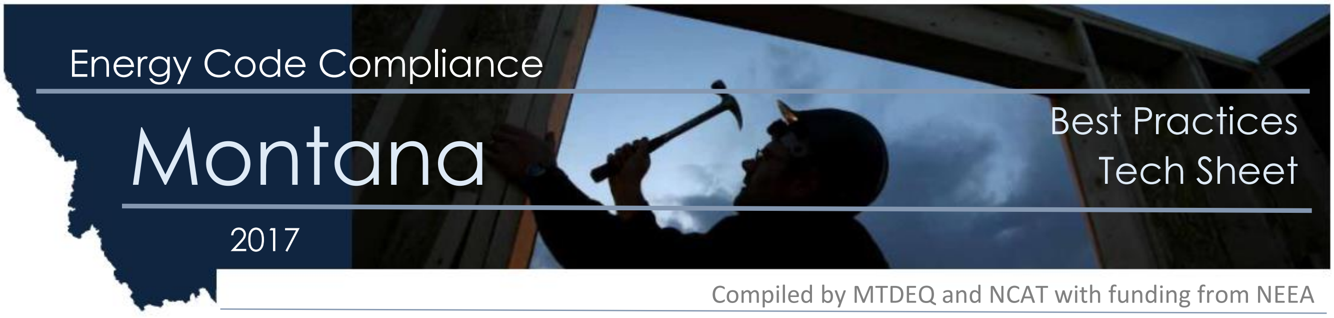
Performance Compliance Alternative

The performance path is seldom used despite offering the greatest flexibility in demonstrating energy code thermal envelope compliance. This alternative uses sophisticated energy-performance software, such as REMDesign™, REM/Design™, or Energy Gauge™, to determine if the proposed design has an annual energy cost less than or equal to a reference design. The reference design is often termed a geometric twin. The energy code mandatory provisions remain applicable when the performance compliance approach is used. Some of the building energy characteristics that can be considered using the performance alternative that are not considered by the prescriptive compliance approaches include:

- **Exterior Shading**
- **Solar Heat Gain**
- **Innovative Framing Techniques**
- **Cool Roofing Systems**
- **Thermal Mass**
- **Solar Energy Systems**
- **Low Infiltration**
- **Insulation Identification**

Summary

The alternative compliance approaches can yield different results. Performance approaches require more building details be used in the analysis. Prescriptive approaches tend to be conservative and use worst-case default assumptions in order for the prescriptive packages to apply to all buildings. The prescriptive approaches do not account for several features that affect energy use, which are included in the performance approach. The trade-off alternative is a compromise that is more flexible than using the insulation and fenestration table but not as complicated as the performance approach.



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Topic: Unvented Attics & Cathedral Ceilings

While the vast majority of roof designs are vented, a growing number of homes are being constructed with unvented attics or unvented cathedral ceilings. The building codes have included requirements for ventilating attics for some time. The primary purpose for the ventilation requirements are to remove moisture that can accumulate in the attic and potentially result in condensation. The primary source of water vapor that enters an attic is from air leaks in the ceiling. Proper attic ventilation also reduces the chance of ice damming at the eaves.

The International Residential Code allows the construction of unvented attics and cathedral ceilings but includes specific design requirements. Unvented attics are constructed with insulation installed above or below the roof sheathing. The insulation must be in direct contact with the sheathing. One major benefit of an unvented attic is that mechanical equipment and ducts are within the thermal envelope which eliminates heat losses to the outside.

Code Citation: 2012 IRC, R806.5 Unvented Attic and Unvented Enclosed Rafter Assemblies

Unvented attic and unvented enclosed rafter assemblies are permitted if all of the following conditions are met.

1. The unvented attic space is completely contained within the building thermal envelope.
2. No interior Class I vapor retarders are installed on the ceiling side of the unvented attic assembly or enclosed rafter assembly.
3. Where wood shingles or shakes are used, a minimum ¼ inch vented air space separates the shingles or shakes and the roofing underlayment above the structural sheathing
4. Any air-impermeable insulation shall be a Class II vapor retarder, or shall have a Class III vapor retarder coating or covering in direct contact with the underside of the insulation.
5. Either Items 5.1, 5.2 or 5.3 shall be met, depending on the air permeability of the insulation directly under the structural roof sheathing.

5.1 Air-impermeable insulation only. Insulation shall be applied in direct contact with the underside of the structural roof sheathing.

5.2 Air-permeable insulation only. In addition to the air-permeable insulation installed directly below the structural sheathing, rigid board or sheet insulation shall be installed directly above the structural roof sheathing as specified in Table 806.5 for condensation control.

5.3 Air-impermeable and air-permeable insulation. The air-impermeable insulation shall be applied in direct contact with the underside of the structural roof sheathing as specified in Table 806.5 for condensation control. The air-permeable insulation shall be installed directly under the air-impermeable insulation.

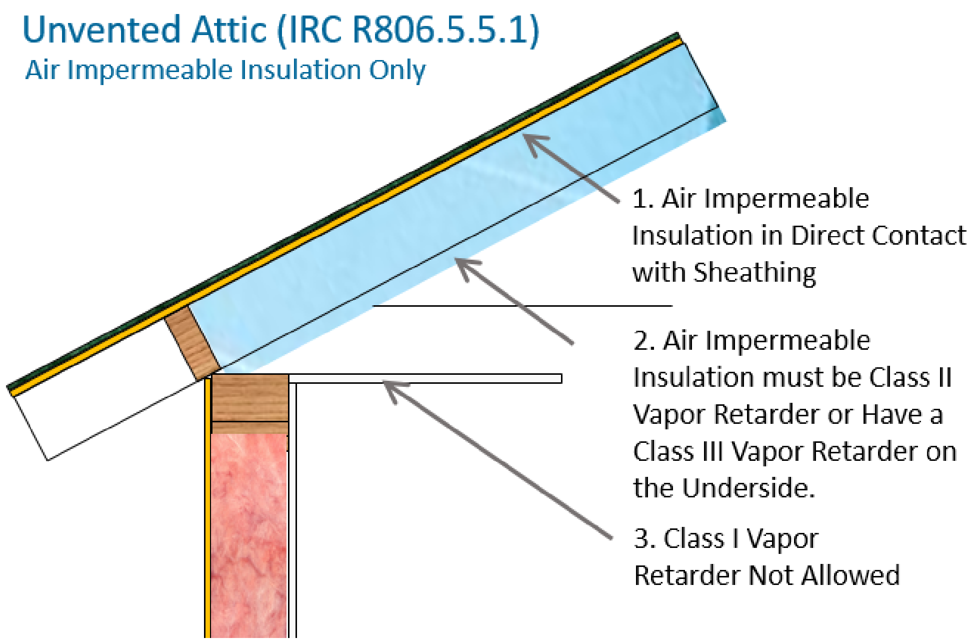
5.4 Where performed insulation board is used as the air-impermeable insulation layer, it shall be sealed at the perimeter of each individual sheet interior surface to form a continuous layer.

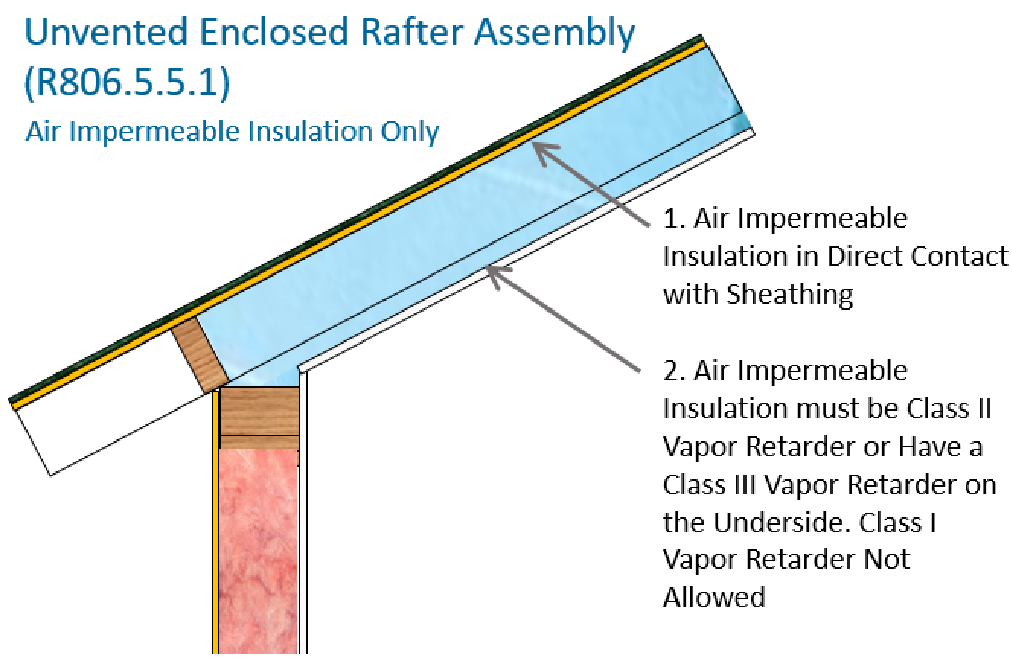
Table 806.5 Insulation for Condensation Control

Climate Zone 6 – Minimum Rigid Board On Air-impermeable Insulation ***R-25*** Required

Air-Impermeable Insulation Only (IRC R806.5.5.1) – Attic and Enclosed Rafter Assembly

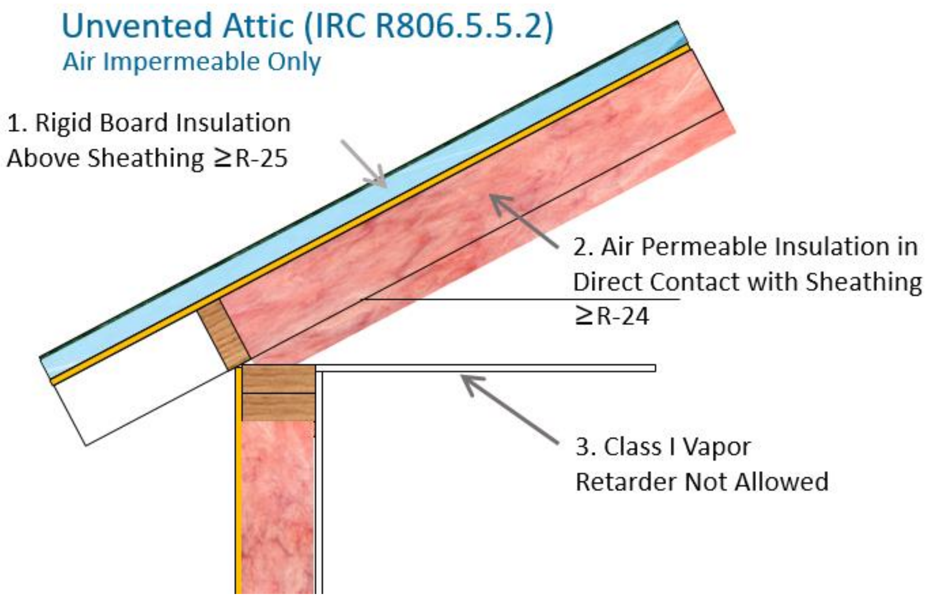
Air-impermeable insulation is typically high density foam. Installation of a Class I vapor Retarder on the ceiling side (attic floor) is prohibited. A Class I Vapor Retarder would prevent the assembly from drying to the inside. A Class 2 or 3 vapor retarder will allow the assembly to dry to the inside while minimizing the movement of water vapor into the assembly.





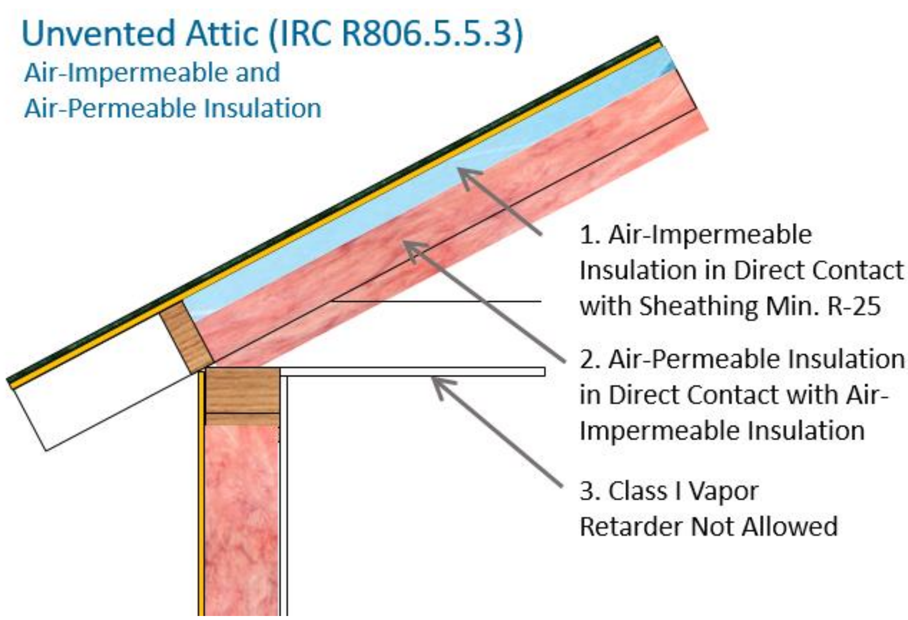
Air-Permeable Insulation Only (IRC R806.5.5.2) – Attic

While the IRC refers to this assembly as *Air-Permeable Insulation Only*, it also involves installation of rigid board insulation above the roof sheathing. Air-permeable insulation is typically fiberglass, cellulose, or low density foam. The addition of the rigid board insulation (≥R-25) above the roof sheathing will keep the temperature at the underside of roof sheathing warm to minimize the possibility of condensation.



Air-Impermeable and Air-Permeable Insulation (IRC R806.5.5.3) – Attic

Air-permeable insulation is typically fiberglass, cellulose, or low density foam. Air-impermeable insulation is typically high density foam. The addition of the air-impermeable (rigid board) insulation (≥R-25) below the roof sheathing will keep the temperature at underside of the air-impermeable insulation warm to reduce the possibility of condensation. Installation of a Class I vapor Retarder on the ceiling side (attic floor) is prohibited.



Plan Review

1. Verify that the total insulation R-value proposed for the roof assembly meets or exceeds the energy code, refer to Table R402.1.1 in the IECC.

2. Verify that the insulation is specified to be installed in direct contact with the roof sheathing.

3. Verify that there is no Class I vapor retarder to be installed on the warm side of the insulation, including at the attic floor.

4. Where air-impermeable insulation is to be installed underneath the roof sheathing, verify that the air-impermeable insulation is to be a Class II vapor retarder or will have a Class III vapor retarder on the underside.

5. Where air-permeable and air-impermeable insulation will be installed, verify that at least R-25 of rigid board insulation is specified to be placed on top of the roof deck.

6. Verify that a ¼-inch air gap is called out for wood-shingle roof systems.

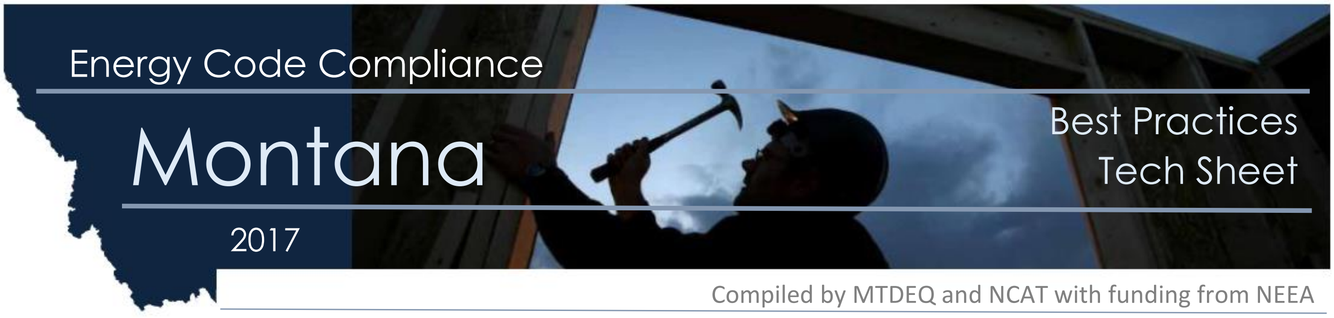
Field Inspection

1. *Insulation beneath Sheathing*. Verify that roof insulation installed under the roof sheathing is well supported and in substantial contact with the sheathing. For air-impermeable insulation, verify that the installed insulation is the correct thickness to meet the R-value requirement called out on the plans.

2. *Insulation above Sheathing*. Verify that the correct R-value of insulation is installed on top of the roof sheathing, if required by code.

3. *Vapor Retarder*. Very that a vapor retarder is installed under the air permeable insulation where air-impermeable insulation is used.

4. *Insulation Type.* Verify that the type of insulation installed is the same as approved during plan review. It is particularly important to determine if foam insulation is air-permeable (low-density foam) or air-impermeable (high-density foam).



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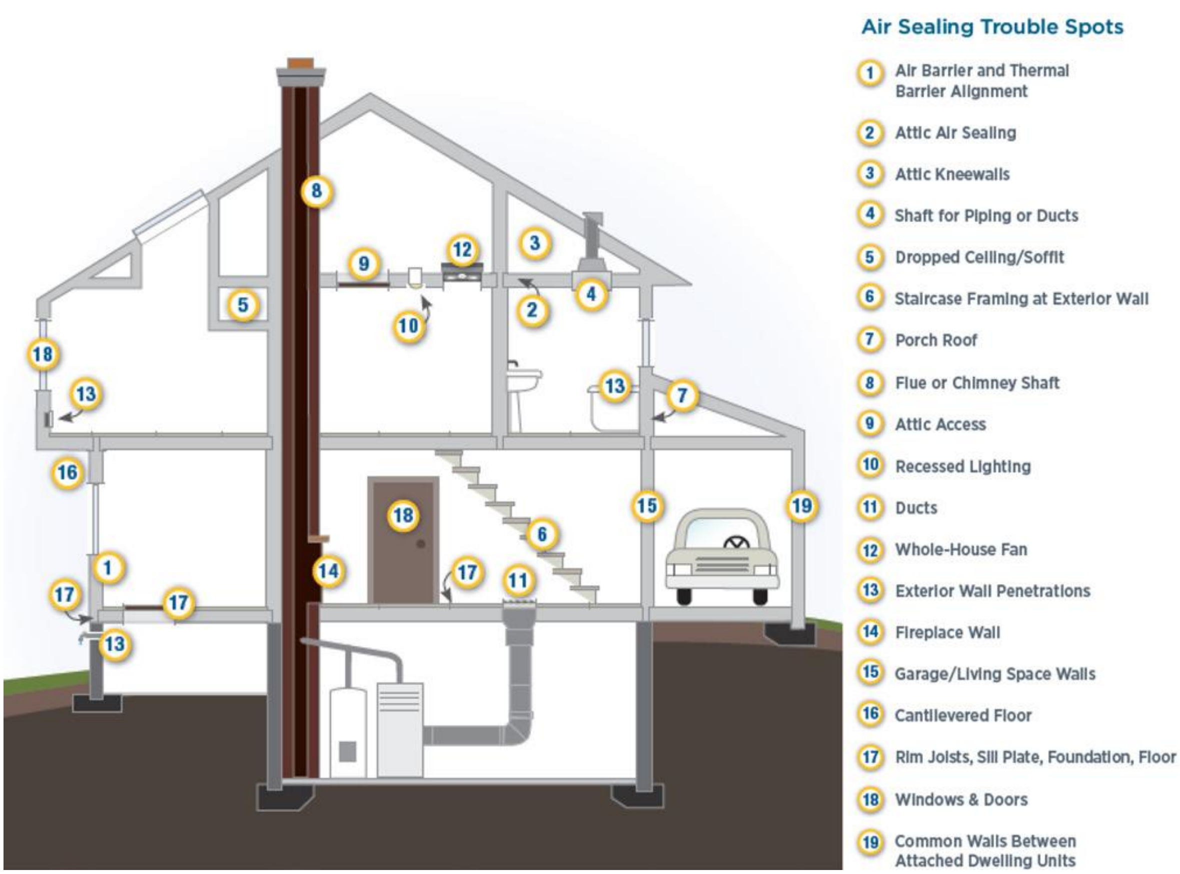
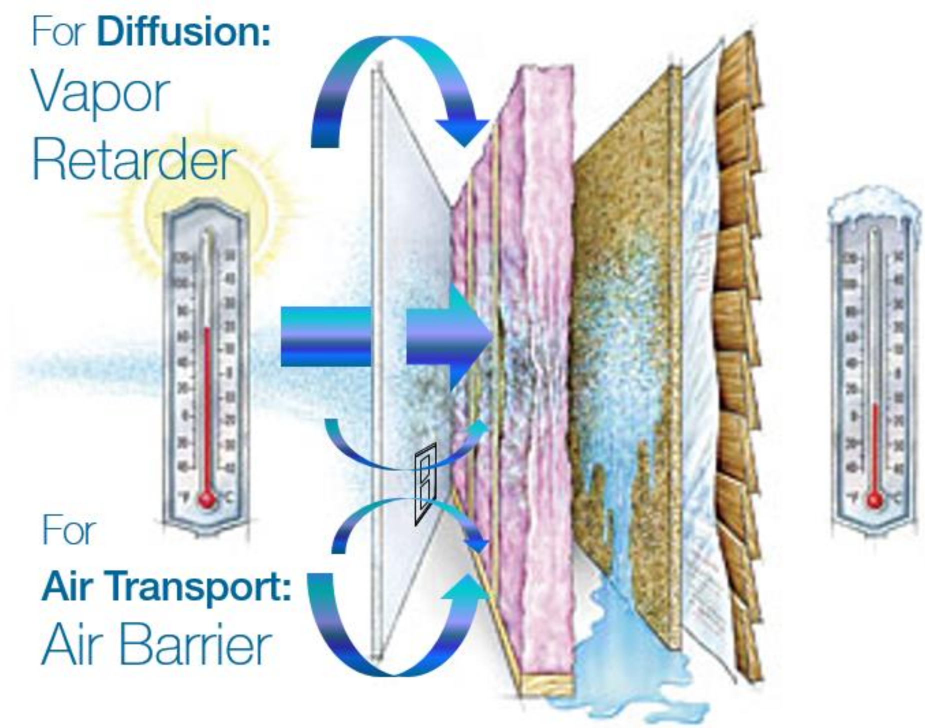
Air Barrier and Building Tightness

Air-leakage control is an important but commonly misunderstood component of the energy-efficient house. Tightening the structure with caulking and sealants has several positive impacts. A tight house will have lower heating bills due to less heat loss and fewer drafts to decrease comfort. A tight house reduces the chance of mold and rot because moisture is less likely to enter and become trapped in building cavities. Tight homes have better-performing ventilation systems and potentially require smaller heating and cooling equipment capacities. Air leakage is sometimes called *infiltration*, which is the unintentional or accidental introduction of outside air into a building. Whenever there is infiltration, there is corresponding exfiltration elsewhere in the building. In the winter, this can result in warm, moist indoor air moving into cold envelope cavities where condensation can occur, resulting in mold or rot. Infiltration is caused by wind, stack effect, and mechanical equipment, such as fans, in the building. The figure below identifies likely points of air infiltration or exfiltration.



Air Barriers

The energy code requires that a "continuous air barrier shall be installed in the building envelope." A Montana amendment to the definition of an air barrier further requires that the air barrier be installed on the warm side of the wall, ceiling, or floor assembly. An air barrier is a material or assembly of materials that reduces air flow through or into the building envelope. While the energy code addresses the installation of air barriers, the International Residential Code (IRC) addresses vapor retarders. A primary purpose of both the air barrier and vapor retarder is to minimize water vapor movement into the building cavities where damage may result. The purpose of a vapor retarder is to minimize the movement of water vapor into building cavities by diffusion through solid materials such as gypsum board. The purpose of an air barrier is to minimize the movement of water vapor into building cavities by air transport. Air transport is many times more significant in the movement of water vapor. Therefore, the air barrier is critical.



A variety of materials make good air barriers. Some of the most common are drywall, plywood, polyethylene sheeting, oriented strand board (OSB) sheathing, and rigid foam insulation. Although air cannot leak through these materials, air can travel through openings and seams. The joints in the air barrier must be sealed with tape, gaskets, foam, or caulk as approved by the manufacturer.

The energy code requires compliance with the air barrier checklist (a so-called *visual inspection*) shown on the following page. The energy code also requires that air barrier effectiveness be tested with a blower door test. Passing a blower door test should help confirm that the air sealing requirements have been met. The energy code requires that the house must pass the test with a result of 4 air changes per hour at 50 Pascal pressure (ACH 50) or less. The blower door test result must be provided to the building code official, who may require that the test be performed by an independent third party. A future newsletter will address building tightness testing in more detail.

It is recommended that builders and designers develop an air-sealing plan. Begin by setting a tightness goal, reviewing the building plans, and identifying potential areas of air leakage. The plan should include the types of materials that will be used to create the air barrier. The code does not identify specific air barrier products but does require that the materials allow for expansion and contraction while also following the manufacturer's instructions.

To achieve the energy code air tightness requirements, a pre-construction meeting with trades that share responsibility such as the building contractor, framing contractors, insulation contractors, and the person who will conduct the tightness testing. It is also important to perform quality-control inspections, including a blower door test early in the building process. A preliminary blower door test can be performed once windows, doors, and ceiling are installed. The primary purpose of this early test is to identify the location of air leakage sites. A thermal infrared camera can help locate air leaks.

Along with a blower door test, the energy code also requires that a visual inspection(s) be conducted for air barriers and insulation installation. The inspection checklist is shown on the following page.

Mold at the Rim Joist. To the right are two examples of mold behind rim or band joist in a basement and in a crawl space insulated with only fiberglass batts. Water vapor in a house air can travel through the fiberglass batt and, in cold weather, condense on the rim/band joist to cause mold. The purpose of the air barrier and vapor retarder are to prevent this serious problem.

Mold in Walls. Both photos show mold behind unsealed electrical boxes. The energy code Air Barrier and Insulation Installation Table details code-required air barrier practices that would have prevented this problem from occurring. Because localized air leakage problems can occur, both the Air Barrier and Insulation Installation Table and building tightness testing is required by the energy code.

House Address		City
	Air Barrier and Insulation Installation	
☑ ☒ N/A	**Component**	**Criteria**
☐ ☐ ☐	**Air barrier and thermal barrier**	A continuous air barrier installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier sealed. Air-permeable insulation not be used as a sealing material.
☐ ☐ ☐	**Ceiling/attic**	The air barrier in any dropped ceiling/soffit aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop-down stair, or knee wall doors to unconditioned attic spaces sealed.
☐ ☐ ☐	**Walls**	Corners and headers insulated and the junction of the foundation and sill plate sealed. The junction of the top plate and top of exterior walls sealed. Exterior thermal envelope insulation for framed walls installed in substantial contact and continuous alignment with the air barrier. Knee walls sealed.
☐ ☐ ☐	**Windows, skylights, and doors**	The space between window/door jambs and framing and skylights and framing sealed.
☐ ☐ ☐	**Rim joists**	Rim joists insulated and include the air barrier.
☐ ☐ ☐	**Floors (above-garage and cantilevered floors)**	Insulation installed to maintain permanent contact with underside of subfloor decking.
☐ ☐ ☐	**Crawl space walls**	Where provided in lieu of floor insulation, insulation permanently attached to the crawlspace walls. Exposed earth in unvented crawl spaces covered with a Class I vapor retarder with overlapping joints taped.
☐ ☐ ☐	**Shafts, penetrations**	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space sealed.
☐ ☐ ☐	**Narrow cavities**	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
☐ ☐ ☐	**Garage separation**	Air sealing shall be provided between the garage and conditioned spaces.
☐ ☐ ☐	**Recessed lighting**	Recessed light fixtures installed in the building thermal envelope shall be air-tight, IC-rated, and sealed to the drywall.
☐ ☐ ☐	**Plumbing and wiring**	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
☐ ☐ ☐	**Shower/tub on exterior wall**	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
☐ ☐ ☐	**Electrical/phone box on exterior walls**	The air barrier installed behind electrical or communication boxes or air sealed boxes installed.
☐ ☐ ☐	**HVAC register boots**	HVAC register boots that penetrate building thermal envelope sealed to the subfloor or drywall.
☐ ☐ ☐	**Fireplace**	An air barrier installed on fireplace walls. Fireplaces have gasketed doors.

Q & A - Air Barriers

Q. What materials make good air barriers?

A. Most air barriers are an assembly or system of several materials. Sheet polyethylene and gypsum board are the most common elements of most air barriers. A gypsum board-based air-barrier system requires no polyethylene. Polyethylene is classified as a Class I vapor retarder and will prevent a wall from drying. A wide variety of materials can make up an air-barrier system, including wood, poured concrete, glass, some rigid foam insulations, some spray foams, plywood, and peel-and-stick rubber membrane. Although air can't leak through these materials, it can leak at penetrations, edges, and seams. When these materials are used to form an air barrier, additional materials such as tape, gaskets, or caulk are required to complete a code-compliant air barrier. To make a good air barrier, a material not only must stop air flow, but it also must be durable.

Q. If house wrap has been installed under the house siding, is that a code-compliant air barrier?

A. No. The primary purpose of house wraps is to provide a water-resistant barrier to protect against moisture that penetrates the siding or cladding. In other words, house wraps protect the wall sheathing from wind-driven rain that gets past the siding. The Montana energy code requires that an air barrier be installed on the warm side of the wall, not under the siding on the wall's exterior. There are certainly benefits from installing a house wrap, but a house wrap does not meet code requirements for an air barrier.

Q. If a house has sheet polyethylene installed under the drywall, is the polyethylene an air barrier?

A. That depends. The sheet polyethylene would have to be sealed at all edges, seams, and penetrations to fulfill the code requirements for a continuous air barrier. To act as an effective air barrier, however, polyethylene needs to be installed with careful attention to a long list of details, including the use of non-hardening sealant at all seams and the use of airtight electrical boxes.

Q. Where are the most common air barrier defects located?

A. Most air leaks occur at the joints between different materials: for example, where floors meet walls and where walls meet ceilings. Although gaps around windows and doors occasionally contribute to air leakage, the most significant air leaks are usually in hidden areas. Here's a list of some of areas that are often poorly sealed, and therefore responsible for significant air leakage:

- Basement rim joist areas
- Cracks between finish flooring and baseboards
- Utility chases that hide pipes or ducts
- Plumbing vent pipe penetrations
- Kitchen soffits above wall cabinets
- Fireplace surrounds
- Recessed can light penetrations
- Cracks between ceiling-mounted duct boots and ceiling drywall
- Poorly weather-stripped attic access hatches
- Cracks between partition top plates and drywall

Q. What's the best way to identify air leaks in the air barrier?

A. Tracking down air leaks can be a challenge, especially for builders not familiar with tight building practices. The best way to test the integrity of a home's air barrier is to perform a blower door test. While the blower door fan is exhausting air from the house, an infrared camera, infrared thermometer, or smoke stick is used to find air leaks. It surprises many builder that significant air leakage paths can occur through interior partitions located far from exterior walls.

Plan Review Pointers - Air Barriers

1. Verify that submitted construction documents identify location (warm side of wall) and details of continuous air barrier installation, including specification of how joints in materials will be sealed. The code required air barrier installation details are included in Table R402.4.1.1 *Air Barrier and Insulation Installation*.
2. Verify that the construction documents specify a tested envelope tightness of 4 ACH50 or tighter.

Field Inspection Pointers - Air Barriers

1. Verify installation of continuous air barrier in accordance with Table R402.4.1.1 *Air Barrier and Insulation Installation*.
2. Verify that all joints and penetrations in the air barrier are sealed.
3. Verify that all air barrier materials are installed per manufacturer's instructions.
4. Verify that the building envelope has been tested by an approved entity to a tightness of 4 ACH50 or tighter.

Vapor Retarders

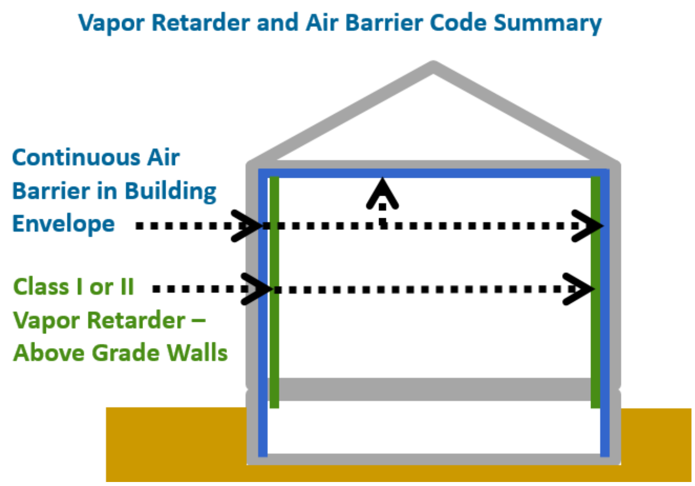
As noted earlier, both vapor retarders and air barriers are intended to reduce the penetration of water vapor into the walls. Vapor retarders are materials used to slow or reduce the movement of water vapor through a material or building assembly by diffusion. The IRC R702.7 requires that a Class I or II vapor retarder be installed in our climate on the interior side of exterior walls. Exceptions for the vapor retarder requirement include a basement wall or any portion of wall below grade and walls not affected by freezing moisture. The vapor retarder class is based on the manufacturer's certified testing or a tested assembly. The following are some materials that meet the class specified:

• Class 1: ≤ 0.1 perm. Examples are sheet polyethylene and aluminum foil.
• Class II: > 0.1 perm but ≤ 1.0 perm. Examples are Kraft-faced fiberglass batts and low-perm paint.
• Class III: > 1.0 perm but ≤ 10 perm. Examples are latex or enamel paint.

Class III vapor retarders are allowed with vented cladding (i.e., vinyl siding) over fiberboard or gypsum wall sheathing. A Class III vapor retarder is also allowed on a 2X6 stud wall that is constructed with at least R-11.25 continuous exterior insulation sheathing.

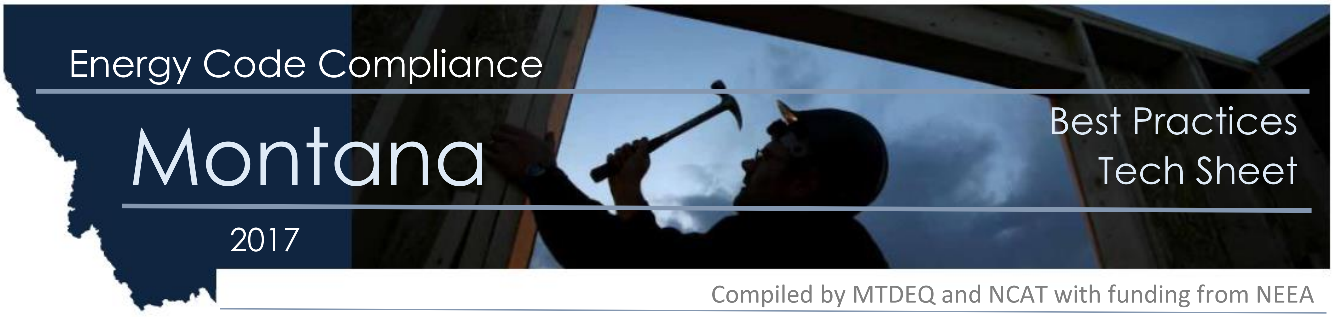
IRC Section R806.5 includes provisions addressing vapor retarders in unvented attic assemblies. In general, it requires that assemblies with air impermeable insulation shall not have a Class 1 vapor retarder and shall have a Class II or Class III vapor retarder in direct contact with the underside of the insulation.

Vapor Retarders and Insulated Basements Below-grade basement walls differ from above-grade walls in that they are vulnerable to ground moisture wicking into the wall or basement floor. Because of this, it is important to maintain the drying potential of the wall, since one never knows if the long-term moisture drive will be from the outside or the inside.



Air sealing and the resulting tighter house can lead to air-quality concerns due to lack of fresh air flow entering the house. Contaminants from household chemicals and elevated moisture levels can build up, creating health concerns. Tighter buildings also increase the risk of backdrafting of unsealed combustion appliances, such as conventional gas furnaces, water heaters, fireplaces, and wood stoves. Montana code requires a minimum level of ventilation, depending on the house size and number of bedrooms. Options range from an upgraded bath fan to heat-recovery ventilation systems. Mechanical ventilation will be discussed in more detail in a future newsletter.

For questions, suggestions, or to be removed from the newsletter distribution list email daleh@ncat.org.



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- Class II: > 0.1 perm but ≤ 1.0 perm. Examples are Kraft-faced fiberglass batts and low-perm paint.
- Class III: > 1.0 perm but ≤ 10 perm. Examples are latex or enamel paint.

Class III vapor retarders are allowed with vented cladding (i.e., vinyl siding) over fiberboard or gypsum wall sheathing. A Class III vapor retarder is also allowed on a 2X6 stud wall that is constructed with at least R-11.25 continuous exterior insulation sheathing.

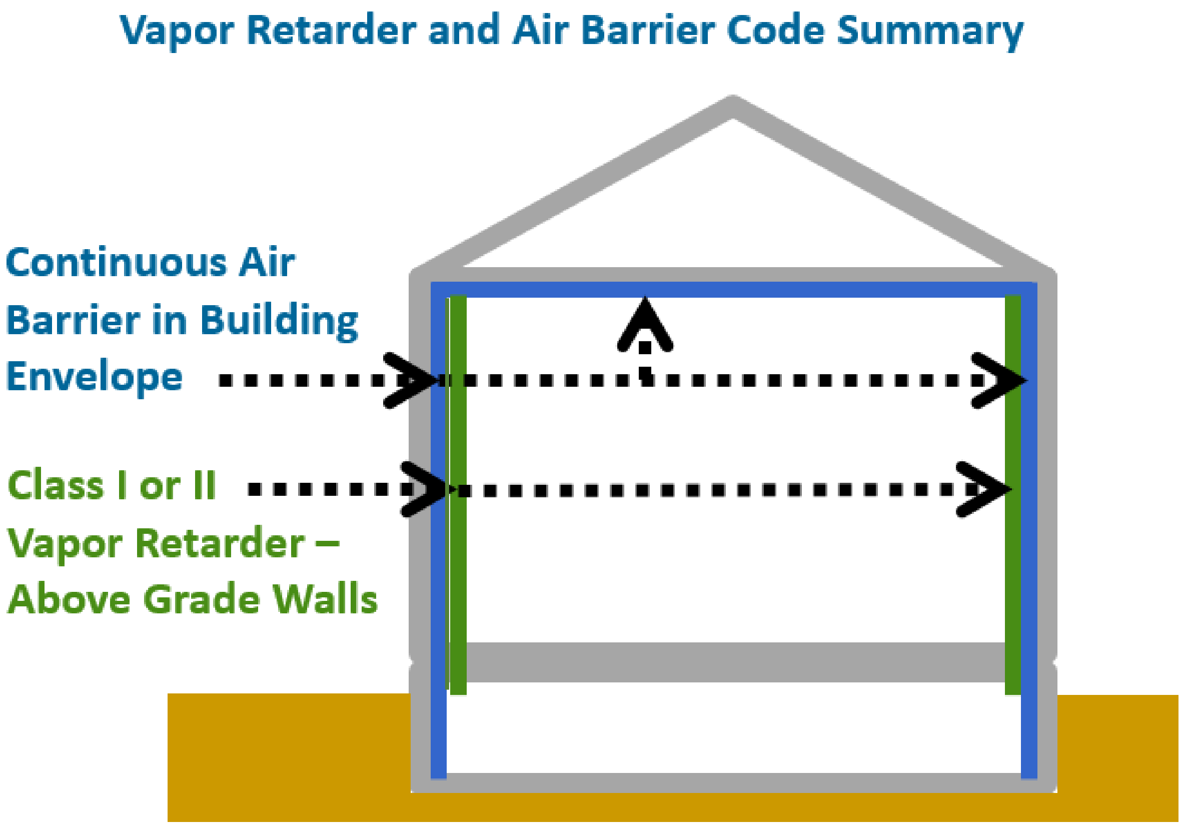
IRC Section R806.5 includes provisions addressing vapor retarders in unvented attic assemblies. In general, it requires that assemblies with air impermeable insulation shall not have a Class 1 vapor retarder and shall have a Class II or Class III vapor retarder in direct contact with the underside of the insulation.

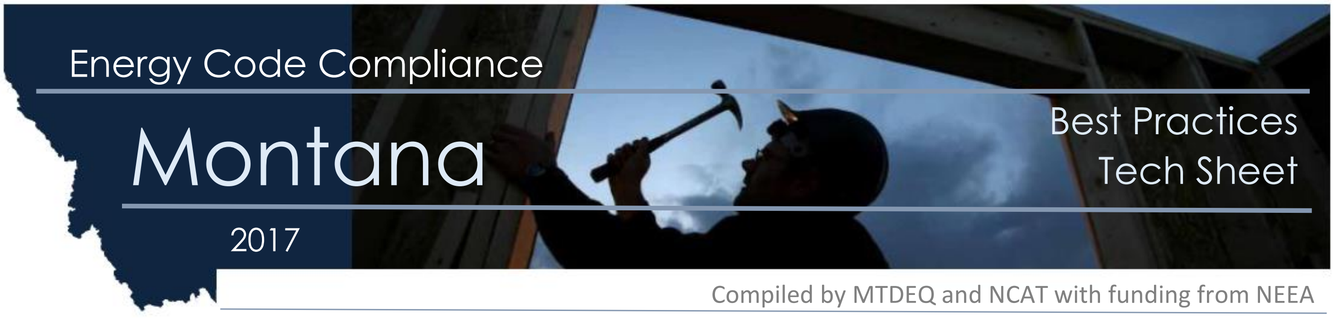
Vapor Retarders and Insulated Basements Below-grade basement walls differ from above-grade walls in that they are vulnerable to ground moisture wicking into the wall from the ground. Because of this, it is important to maintain the drying potential of the wall, since one never knows if the long-term moisture drive will be from the outside or the inside.

The Importance of Mechanical Ventilation

Air sealing and the resulting tighter house can lead to air-quality concerns due to lack of fresh air flow entering the house. Contaminants from household chemicals and elevated moisture levels can build up, creating health concerns. Tighter buildings also increase the risk of backdrafting of unsealed combustion appliances, such as conventional gas furnaces, water heaters, fireplaces, and wood stoves. Montana code requires a minimum level of mechanical ventilation, depending on the house size and number of bedrooms. Options range from an upgraded bath fan to heat-recovery ventilation systems.

The code provisions related to vapor retarders are found in the IRC. The code provisions related to the air barrier are found in the energy code. Below is a diagram that summarizes the basic requirements.





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House Tightness Testing

Why is a Tight Building Envelope Important?

With greater use of blower doors, testing building tightness has become commonplace. Since November 2015, blower door testing has been mandatory for all new residential construction, both within and outside local code enforcement jurisdictions. Current building science is based on the adage “Build it tight, ventilate it right.” It has been demonstrated that natural ventilation provides too much outside air sometimes and too little outside air at other times. To provide the right amount of outside air it is important to limit unintentional or accidental envelope air leakage and to provide adequate outside air with mechanical ventilation. A tight house will have lower heating bills due to less heat loss and fewer drafts to decrease comfort. A tight house reduces the chance of mold and rot because moisture is less likely to enter and become trapped in building cavities. Tight homes have better-performing ventilation systems and potentially require smaller heating and cooling equipment capacities.

Blower Door Test

Code Citation: 2012 IECC, R402.4.1.2 Testing
The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding 4 air changes per hour.

House tightness is measured by a ***blower door test***. In a blower door test, an exterior door is fitted with a nylon skirt with an opening for a large fan. For new construction, it is most common to perform a depressurization blower door test. The blower door exhausts air from the house until the home has a negative pressure of 50 Pa with reference to the outside. The amount of air that flows out of a house is equal to the amount of air that leaks into the house through the envelope and exterior ducts. A digital manometer is used to measure the pressure difference and the air flow out of the fan.

Pressurization blower door tests are performed most often in existing homes when there is a possibility that asbestos or other unwanted dust or particles may be present in the building cavities. A pressurization blower door test usually takes longer to perform since the exhaust backdraft dampers must be sealed before testing occurs.

The blower door fan includes the fan housing and several rings to adjust the size of the fan opening. The nylon skirt is held in the doorway by a metal frame. The motor speed controller allows the technician to control the speed of the fan. The knob on the fan controller is turned until the manometer displays the pressure in the house as 50 Pa with reference to outside. The air flow at this pressure is equal to envelope leakage.

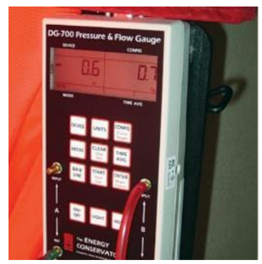
The blower door test procedure includes closing all exterior doors and windows and disabling all combustion appliances and exhaust fans. The air- flow measurement at 50 Pa is then used to calculate the air change rate for the house. While the blower door testing process is not complex, it takes care to properly set up the house and configure the digital manometer.

Blower Door Math

To calculate air changes per hour at 50 Pascals

$$\text{ACH50} = \frac{\text{CFM50} \times 60}{\text{House Volume}}$$

House volume is cubic feet enclosed by the thermal envelope including exterior walls.



Air Changes per Hour at 50 Pascals (ACH50) – The number of times in an hour that the total air volume of a home is exchanged for outside air with the house depressurized or pressurized 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.

Blower Door Test Procedures

1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed. Beyond the intended weatherstripping or other infiltration control measures;

The energy code states that the blower door testing shall be performed at *any time after creation of all penetrations of the building thermal envelope*. The code goes on to identify several conditions that must be met during testing.

Remarks: Special care must be taken when dealing with wood fireplaces. If there is ash in the fireplace when the house is depressurized to 50 Pascals, that ash could be sucked into the house if there are any leaks in the required gasketed doors. All ash or dust should be removed from the fireplace prior to depressurizing the house.

2. Dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures;

Remarks: Dampers obviously must be installed in order to be closed. Other than the operation of the backdraft dampers, these envelope penetrations should not be sealed. These requirements assume that the blower door test will depressurize the house. The code does not designate whether the house is to be depressurized or pressurized for the required blower door test. Since this provision would not

3. Interior doors, if installed at the time of the test, shall be open;

yield an accurate result for a pressurized blower door test it can be reasonably assumed that a depressurized test is intended.

All interior doors should be open so that the entire house volume will be at the same pressure.

The use of the term *doors* in this provision can be confusing. The intent is that the dampers and

4. Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed;

exterior openings shall be sealed if an exhaust fan or a heat recovery ventilator will be operating

5. Heating and cooling systems, if installed at the time of the test, shall be turned off;

continuously. The fan should be deactivated for the test.

Shutting down the heating and cooling systems will help create equalize pressure throughout the house. More importantly, if a combustion appliance such as a gas furnace or gas water heater is allowed to fire while the house is depressurized to 50 Pascals, the flames could be sucked out of the appliance starting the house on fire.

The house tightness test is intended to include any air leaks associated with the duct system regardless

6. Supply and return registers, if installed at the time of the test, shall be fully open.

of the location of the ducts. By leaving the supply and return registers unsealed, the entire duct system will be at the same pressure as the rest of the house.

Note: The current energy code has limited information about how to conduct and report a blower door test. Subsequent editions of the IECC list three different standards that may be used when conducting a blower door test. The most user friendly of the standards is RESNET/ICC 380.

Blower Door Test Results Reporting

Code Citation: 2012 IECC, R402.4.1.2 Testing
A written report of the results of the test shall be signed by the party conducting the test and provided to the code official.

The exact nature of the blower door test report is not specified in the energy code and is therefore decided by the local code official. Good practice is to require relevant test information along with the final test result in the report submitted to the building department as a confirmation of the procedure employed by the tester. Below is an example of such a report. If you would like an electronic copy of this report form, email NCAT at daleh@ncat.org and request the standard blower door test report form.

Montana Blower Door Test Results – Standard Form

Test: Date____________________ Time_________________

Tester Information

Name (Printed)____ Phone___________________________

Company ____

Tester Email ____

Tester Signature ____

Manometer: Manufacturer & Model____________ Serial #__________ Date Last Calibrated_________

Fan: Manufacturer & Model_________________ Serial #____________ Visible Damage ____Yes ___ No

House Information

House Address____City______________________

Builder Name ____Phone_____________________

Builder Email ____

House Floor Area (Include all conditioned floor areas measured to the outside of exterior walls; do not included unvented crawlspace areas)

Above Grade Conditioned Floor Area _______________________ (Ft^2)

Basement Conditioned Floor Area _______________________ (Ft^2)

Total Conditioned Floor Area _______________________ (Ft^2)

House Volume (Include all conditioned house volume including basements and unvented crawlspaces; includes volumes created by cathedral ceilings; includes floor framing volume between conditioned spaces as well as exterior walls)

Above Grade Conditioned Volume_______________________ (Ft^3)

Basement Conditioned Volume _______________________ (Ft^3)

Crawlspace Conditioned Volume _______________________ (Ft^3)

Test Record

Fan Location ____ Flow Ring Installed ____________

Measured Air Flow at 50 Pascals (CFM50) ____

Air Changes at 50 Pascals [**ACH50 = (CFM50 x 60)/Volume]**: $\boxed{\qquad\qquad\qquad \textbf{ACH50}}$

Code Required Procedures

The energy code states that the blower door testing shall be performed at *any time after creation of all penetrations of the building thermal envelope*. The code goes on to identify several conditions that must be met during testing.

☐ Exterior windows and doors, fireplace and stove doors closed, but not sealed.

☐ Dampers including exhaust, intake, makeup air, backdraft and flue dampers closed, but not sealed.

☐ Interior doors, if installed at the time of the test, shall be open.

☐ Exterior doors (dampers) for continuous ventilation systems and heat recovery ventilators shall be closed and sealed.

☐ Heating and cooling systems, if installed at the time of the test, shall be turned off.

☐ Supply and return registers, if installed at the time of the test, shall be fully open.

Who May Conduct a Blower Door Test?

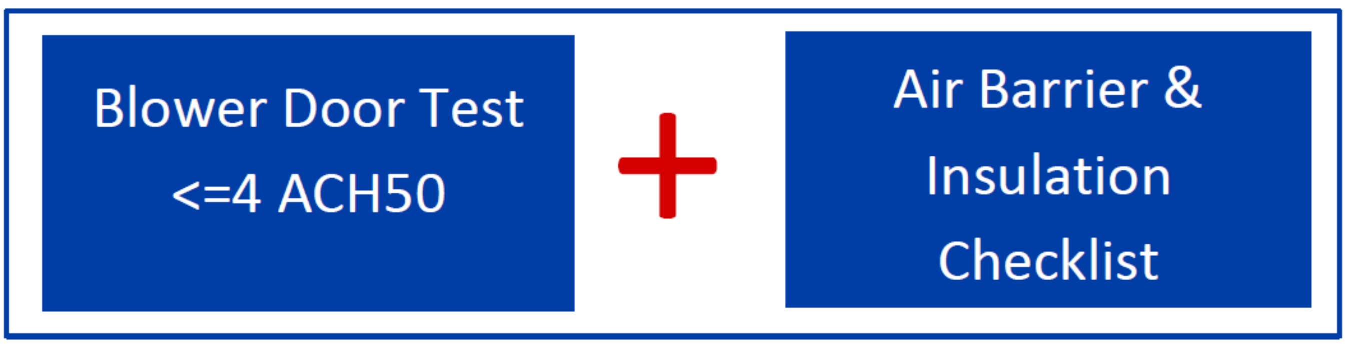
Code Citation: 2012 IECC, R402.4.1.2 Testing
Where required by the code official, testing shall be conducted by an approved party.

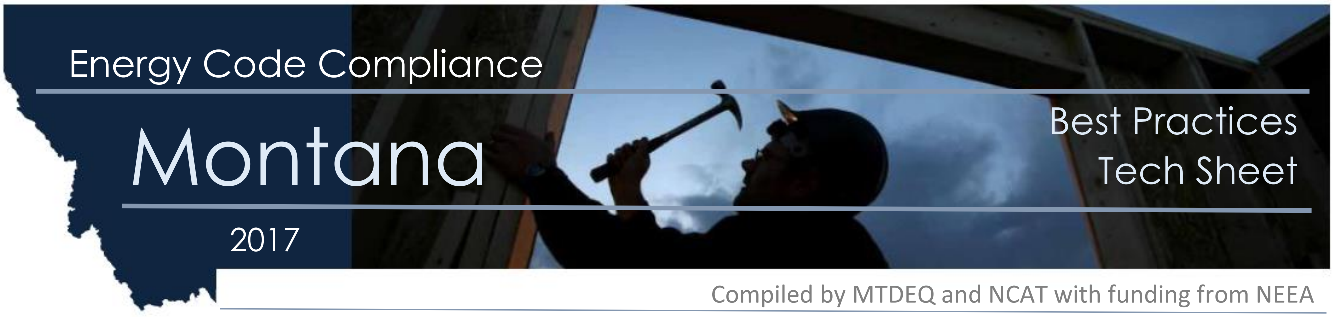
This provision in the IECC was amended by Montana. The original IECC language read "Where required by the code official, testing shall be conducted by an approved *third* party." The Montana amendment removed the word "third" because the homebuilders argued that builders should be able to test their own houses.

Air Barrier and Insulation Installation Table

Code Citation: 2012 IECC, R402.4.1 Building Thermal Envelope
The building thermal envelope shall comply with Sections R402.4.1.1 (installation per *Air Barrier and Insulation Installation Table*) and R402.4.1.2 (blower door test).

In the 2009 IECC, a home was required to either be tested for envelope tightness (maximum leakage being four air changes at 50 Pascals) or to comply with the Air Barrier and Insulation Installation Table 402.4.1.1. This table is often referred to as the v*isual checklist*. In the current code, a home must pass a blower door test **as well as** comply with the visual checklist.





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Multi-family Building Tightness Testing

Performing a ***blower door test*** to determine building envelope tightness is fairly straightforward for a single family home. Multi-family buildings present a challenge since a typical blower door test will measure leakage to the adjacent spaces as well as leakage to the outside. From an energy perspective, it is leakage to the outside that is of concern. As discussed below, there are methods to eliminate leakage to adjacent spaces but they are more time consuming and require additional test equipment.

The basic blower door setup procedures are the same for a multi-family building as for a single family house with the exceptions noted below. An important concept to keep in mind is that if the pressure is the same on both sides of a wall, ceiling, or floor, then there will be no air movement through that assembly even if gaps and openings exist. For that reason pressurizing a space adjacent to the unit being tested to the same pressure with reference to the outside will eliminate air leakage through those assemblies from the test results.

Multifamily Building Tightness Testing

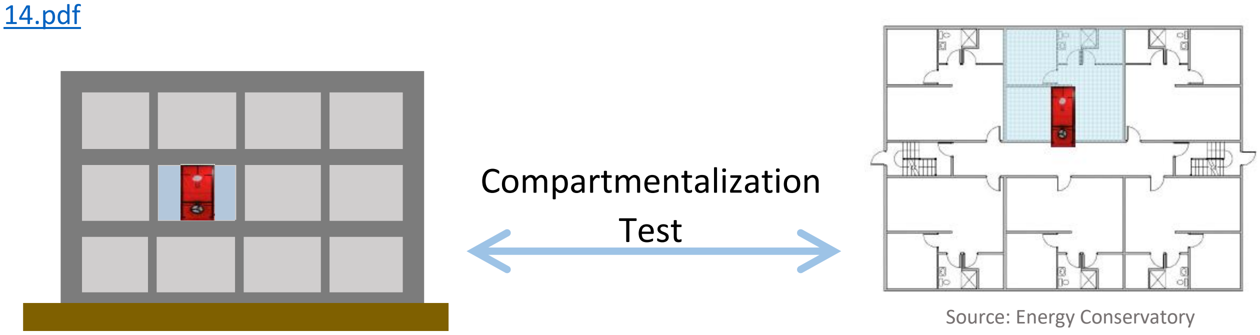
The basic blower door test on a single family home measures only the leakage through the exterior envelope, which is all leakage to the outside. This leakage includes leakage through ducts located outside the thermal envelope. In multifamily buildings a simple one fan blower door test on a single unit will measure leakage to the outside and leakage to the adjacent spaces.

There are several methods used to measure air leakage from multifamily buildings. The *compartmentalization* test is similar to a single-family home test. A single blower door is used to test one unit and the result will include air leakage to adjacent spaces. This is the simplest and most commonly used method. However if the construction of interior walls, ceiling, and floor are not relatively tight the leakage could exceed the code maximum.

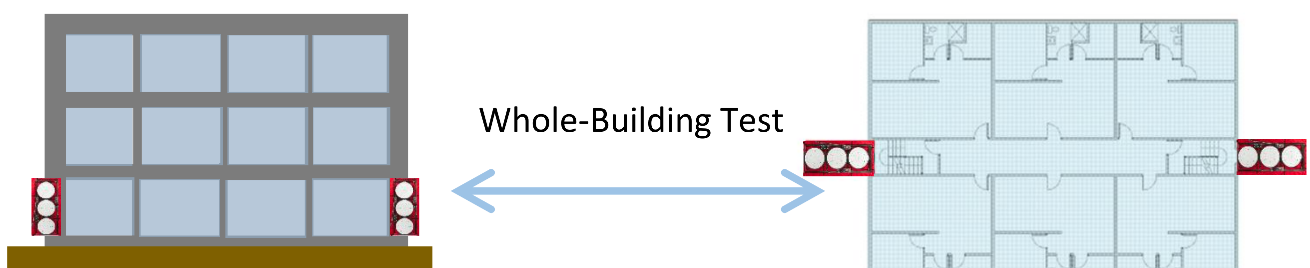
Another option is the *whole-building* test. This test measures only leakage to the outside but usually requires multiple blower door fans and multiple operators. On very large buildings this can be prohibitive. Because all spaces in the building are under the same pressure, inter-unit leakage is negated. Factors such as building height, design, stage of construction, and especially weather on the testing day can make a whole-building test a challenge.

Another method is a *guarded* blower door test, which also requires multiple blower doors and experienced technicians to perform the operation. It also aims to measure exterior envelope leakage by manipulating inter-compartment pressures with multiple fans. It's called a guarded test because it uses secondary "guard" blower doors placed in the spaces adjacent to the target unit. These are maintained at the same test pressure as the target unit with reference to outside, which neutralizes any inter-unit leakage. The result is that only exterior leakage is recorded from the target unit. By moving the doors around a building like a tic-tac-toe board, the exterior leakage of all the spaces can be isolated and recorded.

Refer to RESNET Guidelines for Multifamily Ratings for more information.
http://www.resnet.us/professional/standards/Adopted_RESNET_Guidlines_for_Multifamily_Ratings_8-29-14.pdf



Source: Energy Conservatory



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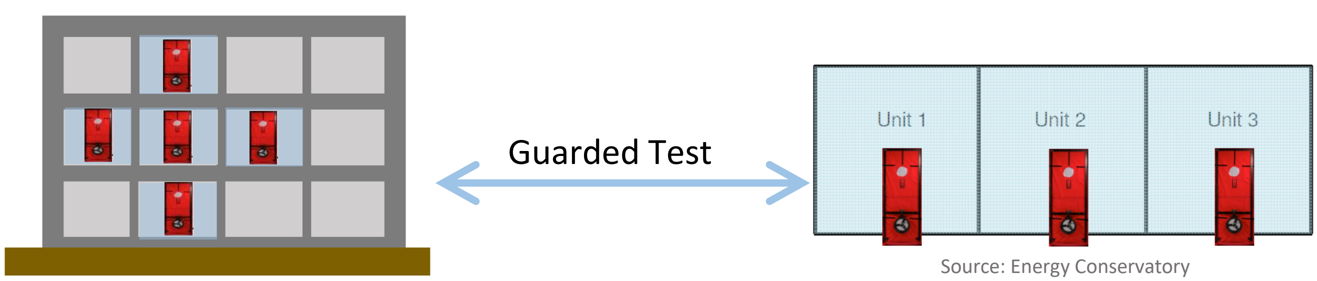

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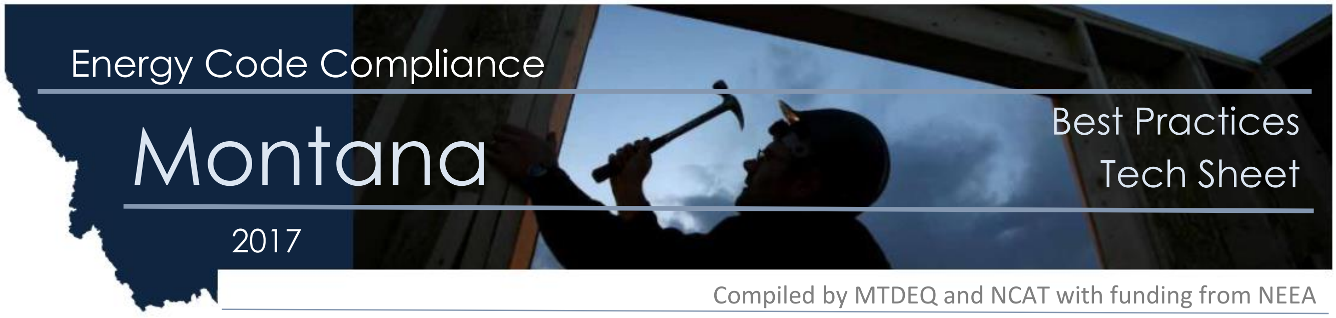
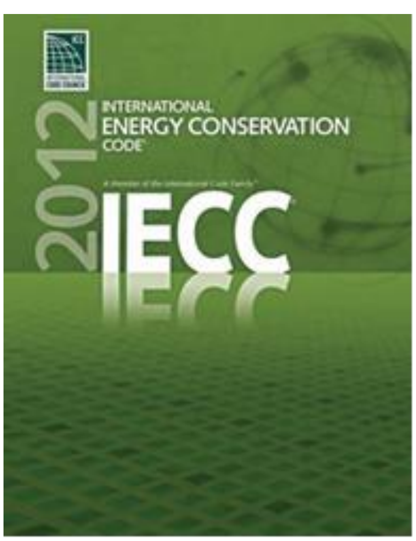


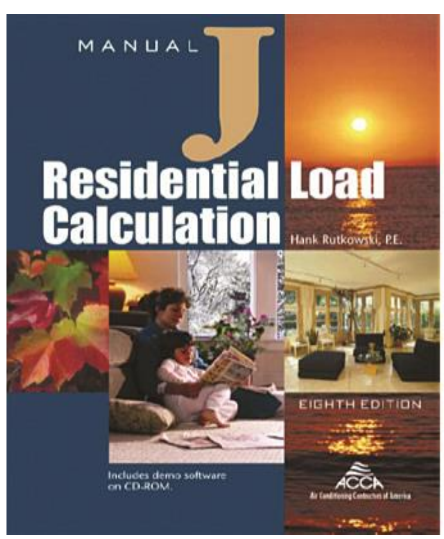
Residential Heating and Cooling Calculations

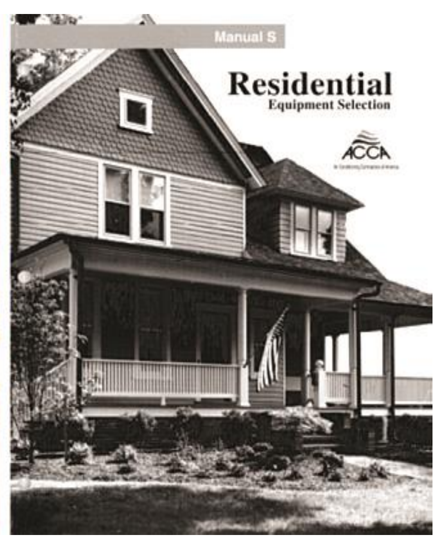
Code Citation: Energy Code R403.6 Equipment Sizing (Mandatory). Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies.

Space heating and cooling systems in residential new construction are commonly oversized which increases installation costs, wastes energy, and reduces comfort. In homes with space cooling oversizing also reduces moisture control. Properly sized equipment will last longer, provide greater comfort, reduce noise, and save homeowners money. Yet builders and code officials are often uncertain as to how to evaluate such calculations to make sure they meet the intent of the code and the sizing methodology approved in the Air Conditioning Contractors of America (ACCA) Manual J (or equivalent).

The first step in performing a load calculation is to calculate the net surface area and orientation of all walls, ceilings, floors, and glass that are exposed to unconditioned spaces. The second step is to inspect and identify the type of building materials used in the construction of the home, including style of windows, skylights, doors, roofing, flooring, and siding. This information is used to obtain the equivalent R-values, U-factors, and solar heat gain coefficients (SHGC) needed in the final load calculation. The final step is to combine the surface areas and building material information to calculate the sensible, latent, and heating loads for all opaque elements. The opaque element loads are then combined with the duct, infiltration, ventilation, piping, and internal loads (from occupants and appliances) to determine the total load.







The simplest method is a “block load” assessment (also known as “whole house”), which only looks at the opaque elements and glass exposed to the elements. A more complex method is the “Room-by-Room” assessment that breaks down the load for each room. Room-by-Room calculations are more accurate and also allow the practitioner to determine the space conditioning air flow requirements for each room.

The most widely accepted method to perform whole-house or room-by-room calculations is to follow ACCA Manual J. Since performing an ACCA Manual J by hand is very tedious, the preferred approach is to use ACCA approved software.

The 2012 IECC requires sizing calculations be performed on every home according to ACCA Manual J or other approved heating and cooling load calculations. It is important to follow all instructions in Manual J, use precise area measurements, and specific data. Manual J specifies that the target value heating indoor design temperature be 70°F, and the target value cooling design temperature be 75°F.

Montana Outdoor Design Temperatures

Table IA in Section 18 of ACCA Manual J requires that the outdoor winter and summer design temperatures be based on the 99 percent value for winter, and 1 percent value for summer. Excessively oversized equipment causes short-cycling, and creates unnecessary stress on the equipment. Also, larger systems require larger duct sizes, increasing the installation cost. When designing a residential heating and cooling system, it is important to use the correct indoor climate data (outdoor design conditions) for the locality in which the building receiving the new system is located. This data is used when calculating the building component heating load and component cooling load, which in turn are used to determine the required air flow (cubic feet per minute or CFM) for each room, design the appropriate duct work, and select the optimal equipment for the application.

Location	Elevation	Latitude	Winter	Summer					
	Feet	Degrees North	Heating 99% Dry Bulb	Cooling 1% Dry Bulb	Coincident Wet Bulb	Design Grains 55% RH	Design Grains 50% RH	Design Grains 45% RH	Daily Range (DR)
Billings	3567	45	-7	90	62	-31	-24	-18	H
Bozeman	4475	45	-12	87	60	-36	-29	-23	H
Butte	5553	46	-14	84	56	-51	-44	-38	H
Cut Bank	3838	48	-16	84	59	-36	-29	-23	H
Glasgow	2760	48	-17	90	63	-28	-21	-15	H
Glendive	2456	47	-13	92	64	-26	-19	-13	H
Great Falls	3652	47	-13	88	60	-38	-31	-25	H
Great Falls, Malmstrom AFB	3525	47	-11	89	61	-11	-4	2	H
Havre	3200	48	-19	90	62	-33	-26	-20	H
Helena	3828	46	-10	87	59	-41	-34	-28	H
Kalispell	6780	48	-3	86	61	-29	-22	-16	H
Lewistown	4122	47	-12	86	60	-27	-27	-21	H
Livingston	4654	45	-14	87	60	-36	-29	-23	H
Miles City	2634	46	-13	93	65	-23	-16	-10	H
Missoula	3190	46	-1	88	61	-33	-26	-20	H

Plan Review Pointers

1. Verify that the correct outdoor design temperatures are used for the heating and cooling load calculations, and that they are consistent with values in Table 1A of ACCA Manual J.

2. Verify that the correct indoor design temperatures are used based on ACCA Manual J.

3. Verify that the building geometry and glass area match what is shown on the plans and compliance documentation. Glazing orientation is important to verify for cooling load calculations but has no effect on heat loss calculations.

4. Verify that the levels of efficiency shown in the load calculations are consistent with the energy code compliance documentation. Insulation R-values, glazing U-factor, and SHGC are important to confirm.

5. Verify that the make, model number, and equipment size as specified on the plans agree with the sizing calculations.

Field Inspection Pointers

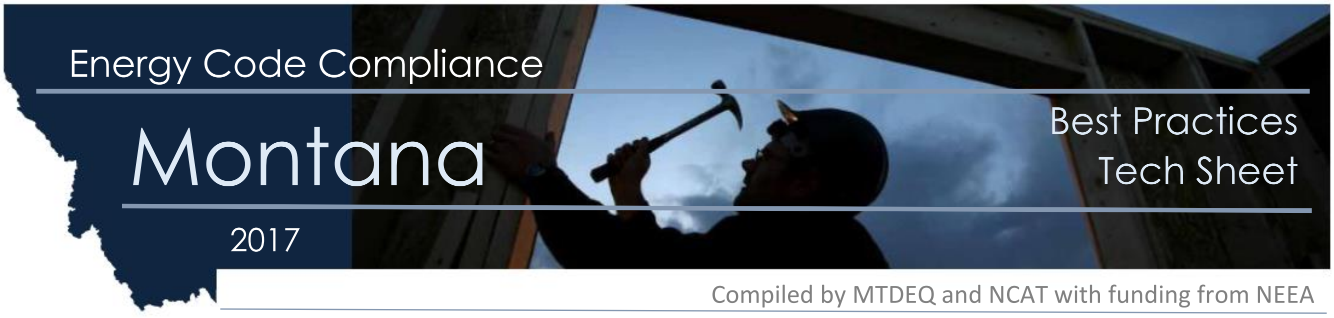
1. Verify the make and model numbers for the heating and cooling systems installed for the building, and compare those to the building plans and specifications.

2. Verify that the system has the same output capacity, and the same level of efficiency as specified in the plans and specifications.

3. Verify that the efficiency levels of insulation and windows (U-factors and SHGC) meet or exceed the levels that are called out on the permit submittal plans and specifications. Levels that are too low can cause the system to be undersized. If cooling is installed, verify that the glazing area and orientation is installed per the approved building plans.

5. Verify that the energy features of the house are installed per the manufacturer's instructions.

6. Verify that the refrigerant charge level was tested by the installer.



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Duct Sealing and Tightness Testing

Tightly sealed ducts can reduce utility bills. Tight ducts improve indoor air quality because leaky ducts in attics, unfinished basements, crawl spaces, and garages can allow dirt, dust, moisture, pollen, pests, and fumes to enter the home. When ducts are leaky, the heating and cooling system has to work harder to condition the home. Duct sealing, along with proper insulation, allows the installation of a smaller, less costly heating and cooling system. Leaky ducts located outside the building thermal envelope are more important, from an energy point-of-view, than leaky ducts located within the conditioned space. However leaky interior ducts can cause indirect air leakage to the outside and impact occupant comfort. When ducts are properly sealed, they deliver conditioned air more effectively to all rooms—helping to ensure a more constant temperature and improved comfort throughout the home.

Montana Energy Code Amendments

Code Citation: 2012 IECC, R403.2.2 [Duct] Sealing (Mandatory)
Ducts, air handlers, and filter boxes shall be sealed. Joints and seams shall comply with either the International Mechanical Code or International Residential Code as applicable.

Duct tightness testing shall be verified by either of the following:

1. **Postconstruction test: Leakage to the outside of a condition[ed] space or total leakage shall be less than or equal to four cfm per 100 square feet of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. [25 Pa] across the entire system, including the manufacturer's air handler enclosure. All register boots shall be taped or otherwise sealed during the test. *[Shown as amended.]***
2. **Paragraph #2 in the 2012 IECC regarding rough-in testing was deleted.**

Exception: The duct tightness testing is not required for ducts and air handlers located entirely within the building thermal envelope.

There are two significant Montana amendments regarding duct tightness testing.

1. The 2012 IECC allowed only one type of duct tightness test, the total duct leakage test. The Montana amendment allows either a total duct leakage test or a leakage to the outside test. While each of these tests measures a significantly different duct leakage characteristic the maximum allowed leakage for both tests is the same, four cfm per 100 square feet of conditioned floor area.

2. The 2012 IECC allowed testing at rough-in, before construction was complete. The Montana amendment deleted that provision. Therefore construction must be complete before duct tightness testing is performed.

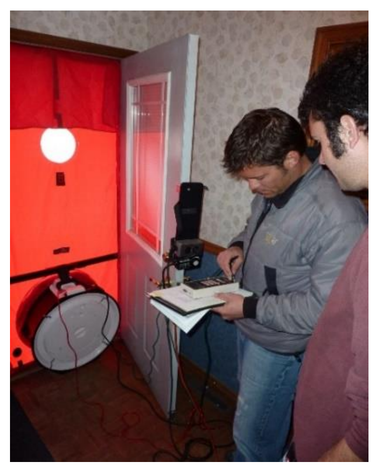
The loophole. By establishing the same allowable leakage rate for both the total duct leakage test and the leakage to the outside test the Montana amendment created a loophole. In the 2009 IECC, when both types of tests were allowed by the code, the allowable leakage for the leakage to the outside test was only 2/3 of that allowed for the total duct leakage test. By using a leakage to the outside test this loophole allows leakier ducts than would be allowed by a total duct leakage test.

Is Partial Duct System Testing an Acceptable Practice?

Should a builder be allowed to test only that portion of the duct system that is located outside the building thermal envelope? The energy code language does not address this issue directly. However, there are two reasons why this approach should not be deemed acceptable. The first reason is the use of the phrase "across the entire system" by the code when addressing duct testing requirements. The second reason has to do with the physics of the test procedure. Testing only isolated sections of ducts outside the building thermal envelope will not capture indirect leakage to the outside. For example, a leaky supply duct in a floor joist cavity could pressurize that cavity resulting in air leakage to the outside through a poorly sealed rim joist. While the code language is somewhat ambiguous, partial duct testing is clearly not a good practice and should be discouraged.

Who may conduct duct tightness testing?

The code provides no guidance regarding who may conduct duct tightness testing. Therefore it the code official determines who may conduct duct tightness testing.

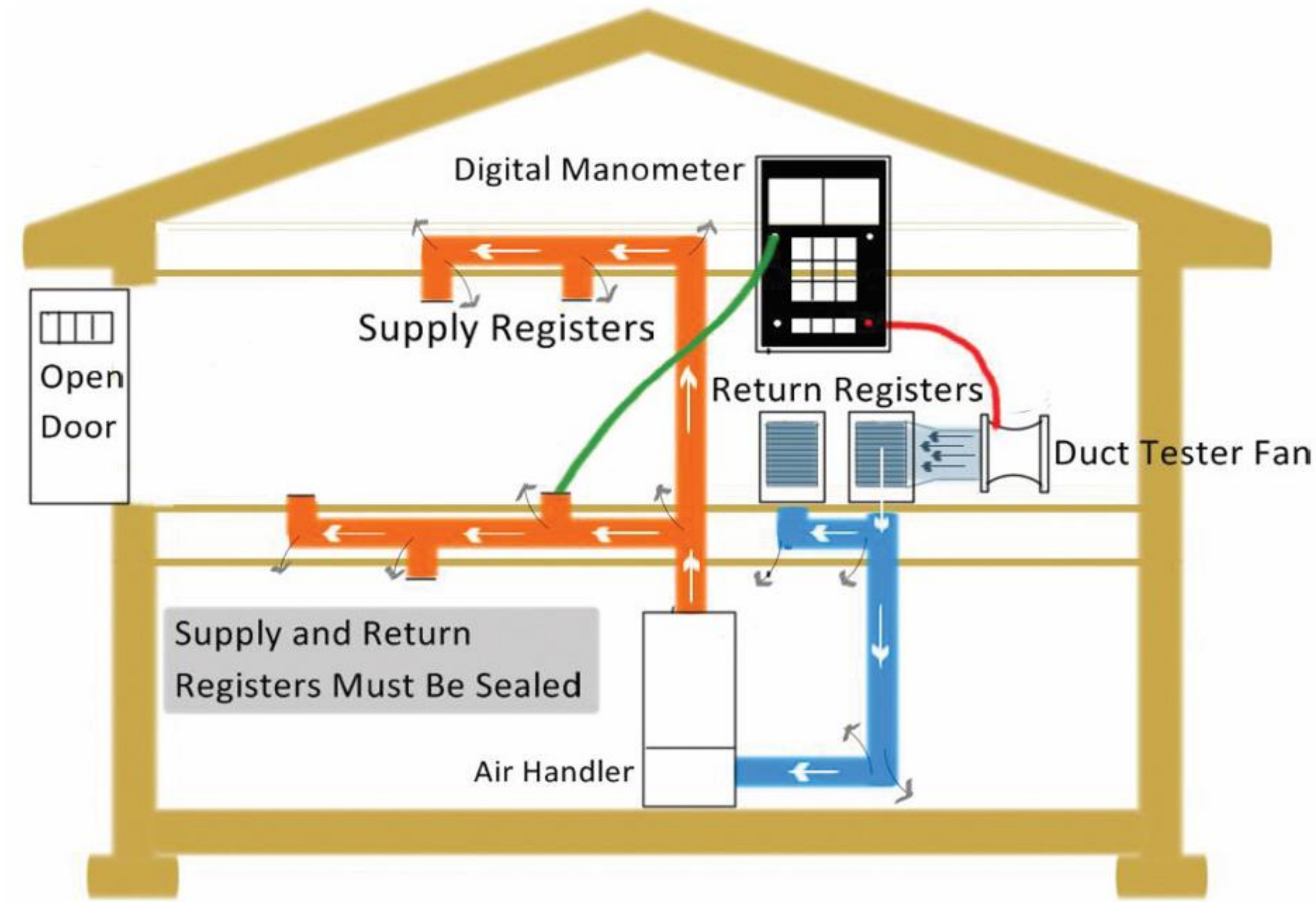


A duct tightness test involves the use of a duct tightness fan (shown above at the left), a digital manometer (center), and in the case of a duct leakage to the outside test, a blower door fan (right).

Duct Tightness Test Procedures

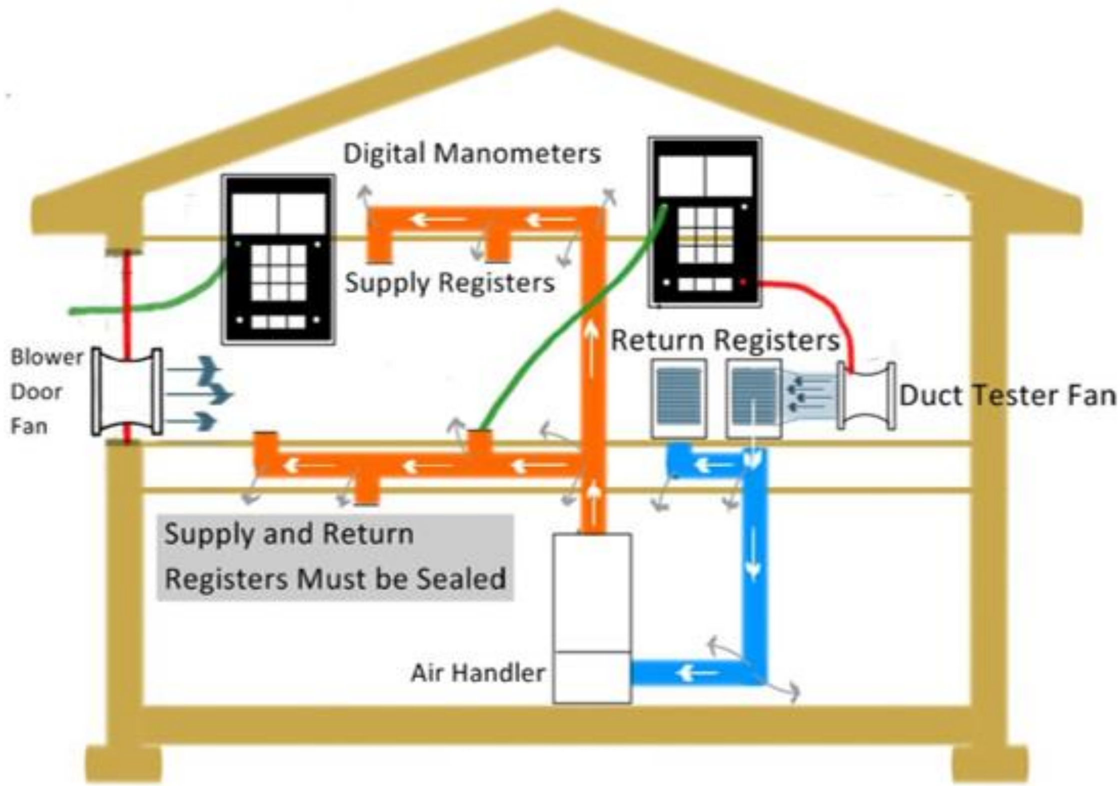
A duct tightness test involves using a fan to force air into the duct system and measuring how much air leaks out through cracks and holes (the supply and return registers are taped closed for the test). ***A duct pressure test is not required if the air handler and all ducts are located inside the building thermal envelope.***

Two types of duct tightness testing are allowed by the Montana energy code. The ***total duct leakage*** test measures the duct leakage from the entire duct system regardless of whether it is located inside or outside the conditioned space. To conduct a total duct leakage test, all supply and return registers are sealed. The duct tightness tester fan is attached at the air handler cabinet or the return register nearest the air handler. The air flow required to bring the duct system to 25 Pascals pressure with reference to the house is equal to the air leaking out of the duct system at that pressure. The total duct leakage test is simpler and takes less time to perform than the duct leakage to the outside test.



Total Duct Leakage Test

The ***duct leakage to the outside*** test is more complex because the blower door fan must also be used to pressurize the house to 25 Pa with reference to outside. The duct tester fan is then used to bring the pressure in the duct system to zero with reference to the house. Since air requires an opening and a pressure difference to flow, the duct leakage to the outside test eliminates air leakage within the house from the test results (since duct pressure is the same pressure as the house). Therefore, the only leakage measured with the duct tester fan will be outside of the conditioned space.



Section R403.2.2 of the IECC, as noted previously, requires that ducts, air handlers, and filter boxes be sealed. That section goes on to say that joints and seams shall comply with either the International Mechanical Code (IMC) or International Residential Code (IRC) as applicable. Because Montana did not adopt Chapter 16 of the IRC which addresses duct sealing, the relevant reference is the IMC. Section 603.9 of the IMC requires that ducts be sealed and specifies acceptable sealant systems. Duct sealing materials must be listed and labeled in accordance with UL 181A.

Duct Sealing

Code Citation: 2012 International Mechanical Code (IMC), 603.9 Joints, Seams, and Connections

All joints, longitudinal and transverse seams and connections in ductwork shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems, liquid sealants or tapes.

Duct Tightness Test Reporting

The 2012 IECC does not specifically require a duct tightness testing report. However Section R401.3 requires that the results of the test be included on the permanent certificate posted on the electrical distribution panel. The local code official determines if a report must be submitted and the character of that submission. Good practice is to require relevant test information along with the final test results in the report submitted to the building department as a confirmation of the procedure employed by the tester. An example of such a report is included below. If you would like an electronic copy of this report form, email NCAT at daleh@ncat.org and request the standard duct test report form.

Montana Energy Code Duct Leakage Test Record Form

Test: Date__________________ **Time** ______________

Tester Name (Printed)__________________________________ Phone_________________________

Company ____

Tester Email ____

Tester Signature ____

_______________ Ft² House Conditioned Floor Area (CFA)

_______________ CFM25 Maximum Allowable Duct Leakage [CFA / 100 x 4 cfm]

Fan: Model_____ Serial #______________ Manometer: Model____ Serial #_______________

Toe-kick Supply Registers

Are unducted toe-kick supply registers present? **Y N**

If present, were supply registers below cabinets sealed for test? **Y N**

Unvented Crawlspace Supply Registers

Are supply registers present in unvented crawlspace? **Y N**

If present, were supply registers in crawlspace sealed for test? **Y N**

Total Duct Leakage Test

_________________Attachment Location of duct blaster fan (Return Grill or Air Handler Cabt.)

____Duct Pressure Measurement Location

_________________Rings Installed for Test (Configuration)

_________________Pa Duct Pressure Reading WRT House

_________________CFM25 Duct Test Fan Flow Reading (Total Leakage)

Duct Leakage to Outside Test

_________________Attachment Location of duct tester fan (Return Grill or Air Handler Cabt.)

____Duct Pressure Measurement Location

__________________Pa Building Pressure WRT outside

__________________Duct Testing Fan Ring Configuration

__________________Pa Duct Pressure Reading WRT House

__________________CFM25 Duct Test Fan Flow Reading (Duct Leakage to Outside)

Template Sticker for Notification of Ductwork Testing

2012 IECC section 403.2.2 requires testing of all ductwork located outside conditioned spaces such as in attics and unheated garages. The label shown to the right was designed by the Bozeman Building Department and is a convenient way to notify building inspectors that ductwork testing is required. Testing is not required if all ductwork and air handlers are moved into conditioned spaces.

Testing for tightness is required if ductwork is located outside of a conditioned boundary, such as in an attic or garage.

Section 403.2.2 IECC 2012

This label is available from the Montana Department of Environmental Quality. A digital template is available that can be printed on 2 inch by 4 inch label sheets.

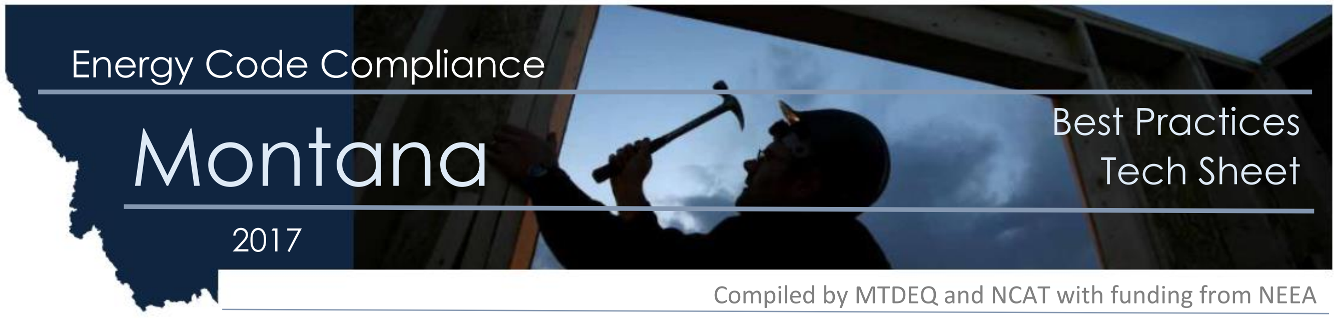
Keeping Ducts Inside – A Best Practice

The code allows ducts to be located outside the building thermal envelope. But keeping ducts inside eliminates the need for duct tightness testing and reduces energy use. Duct leakage in unconditioned spaces can be a cause of builder callbacks for comfort issues, moisture problems, and high energy bills. Indoor air quality can also be compromised since any air leaks will pull unconditioned replacement air into the living space from the attic, crawlspace, or basement. Even when ducts are tightly sealed, conduction losses can increase heating and cooling energy usage. The benefits from locating all of the ducts inside the building thermal envelope include:

- Reduced installation costs from short, straight, and un-insulated ducts with no tightness testing.
- Reduced equipment costs from smaller capacity equipment needed to meet reduced loads.
- Reduced duct system costs from smaller equipment with lower air volume.
- Reduced operating cost from reduced loads met by lower capacity equipment.

Besides, as any home inspector knows, attic ducts are often crushed, ripped, or completely disconnected. Since homeowners rarely visit all the nooks and crannies of their attics, these problems can remain uncorrected for years.

Duct tightness testing will identify significant duct problems such as disconnected duct joints. This is one reason why duct tightness testing is good practice even when all of the ducts are located within the building thermal envelope.



Residential Mechanical Ventilation

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. 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.

Why is Mechanical Ventilation Important?

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.

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.

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

Common Terms

Air changes per hour at 50 Pascals (ACH50): The number of times in an hour that the total air volume of a home is exchanged for outside air with the house depressurized or pressurized by a blower door to 50 pascals with reference to the outside.

cfm: A measurement of air flow, cubic feet per minute, a standard measurement of fan airflow.

Efficacy: Useful work divided by power For ventilation fans the efficacy is measured in cfm per watt (cfm/W).

HVAC: Heating, ventilating, and air conditioning.

Mechanical ventilation: The active process of supplying air to or removing air from an indoor space by using powered equipment.

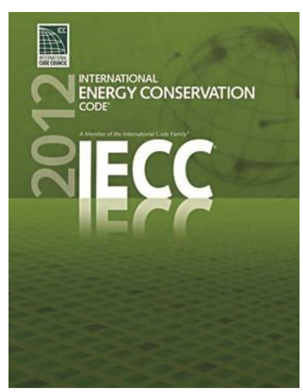
Pascals: A measurement of air pressure. One inch of water column is equal to 249 Pascals of pressure.

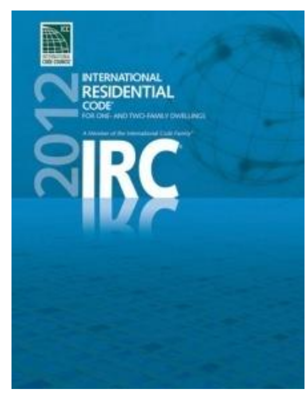
Watts: Electrical power input to a fan or other equipment.

Whole-house mechanical ventilation system: The fans, controls, dampers and ducts included in the system that supplies and exhausts or relieves ventilation air for the residence. An important distinction is that a "whole-house fan" intended to flush air out of a house on summer nights is not typically part of the whole-house mechanical ventilation system; the airflow of a whole-house fan is much higher than that for continuous ventilation. A small whole-house fan may be used to provide the needed ventilation.

Code Citation: IRC 2012, Section M1507.3 Whole-House Mechanical Ventilation System
Whole-house mechanical ventilation systems shall be designed in accordance with sections M1507.3.1 through M1507.3.3.

Both the 2012 International Energy Conservation Code (IECC) and the 2012 International Residential Code (IRC) require 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 addressed.





Code Citation: IECC 2012, Section R403.5.1 Whole-House Mechanical Ventilation System Fan Efficacy
Mechanical ventilation system fans shall meet the efficacy requirements of Table R403.5.1.

As a result of the new ventilation requirements, fans designated for whole-house ventilation will have many more operating hours than bathroom or kitchen exhaust fans that are temporarily operated to remove local humidity and odors. Homes and dwelling units under the new ventilation requirements will expend significantly more energy on fan use; consequently, improved fan efficiency for those fans is cost effective. The energy code calls for the use of energy-efficient fans used to provide the whole-house mechanical ventilation. The adjacent table specifies the efficiency of the fans that provide the required whole-house mechanical ventilation.

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

Code Requirements: Whole-House Ventilation

IRC Table M1507.3.3 (1) shown to the right, specifies the minimum required whole-house 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 REQUIREMENTS					
	NUMBER OF BEDROOMS				
DWELLING UNIT FLOOR AREA (square feet)	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

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

	NUMBER OF BEDROOMS				
DWELLING UNIT FLOOR AREA (square feet)	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

Intermittent Operation. If the home uses intermittent ventilation instead of continuous ventilation, then the capacity of the ventilation system must be greater. Refer to IRC Table M1507.3.3 (2) shown on the next page. 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 below. 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

Code Requirements: Local Exhaust

Code Citation: IRC 2012, Section M1507.4 Local Exhaust Rates

Local exhaust shall be designed to have the capacity to exhaust the minimum air flow rate determined in accordance with Table M1507.4.

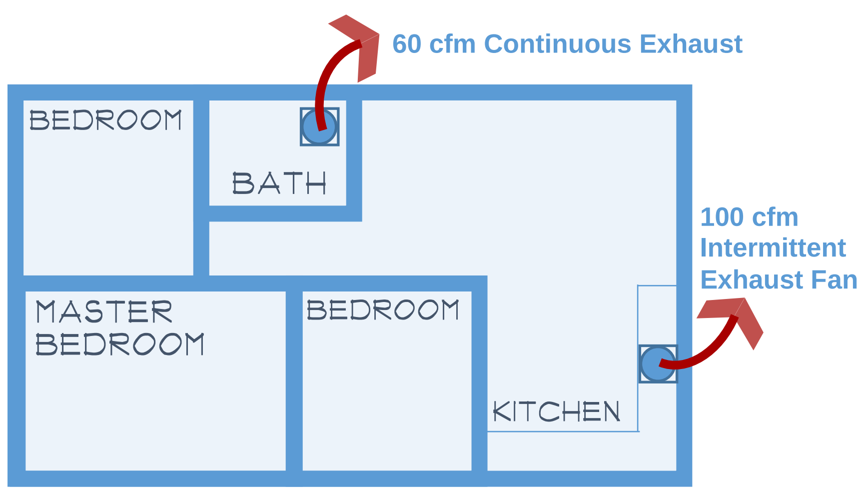
Local Exhaust. In addition to a whole-house ventilation system, the code also requires minimum local (also called "spot" or "point source") exhaust capability in kitchens and bathrooms. Kitchens must have a 100-cfm, intermittent exhaust, or a 25-cfm continuous exhaust. The fans must exhaust to the outside. 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

Code Requirements: Examples

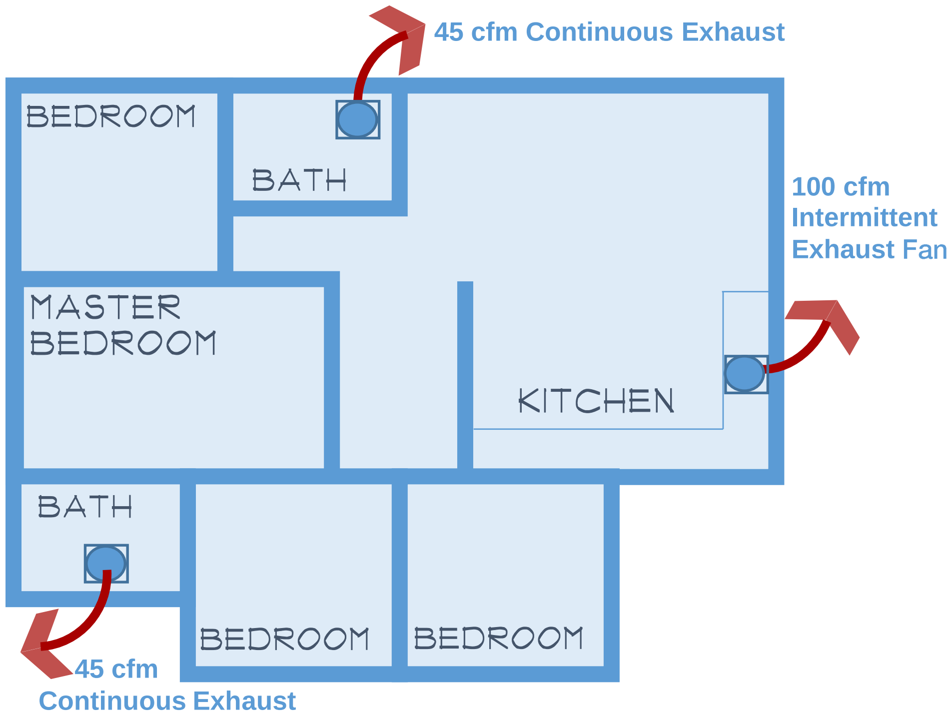
Example #1: 2,000 ft² House, 3 bedroom, 1 Bath



Example #1 is a 2,000 ft² 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.

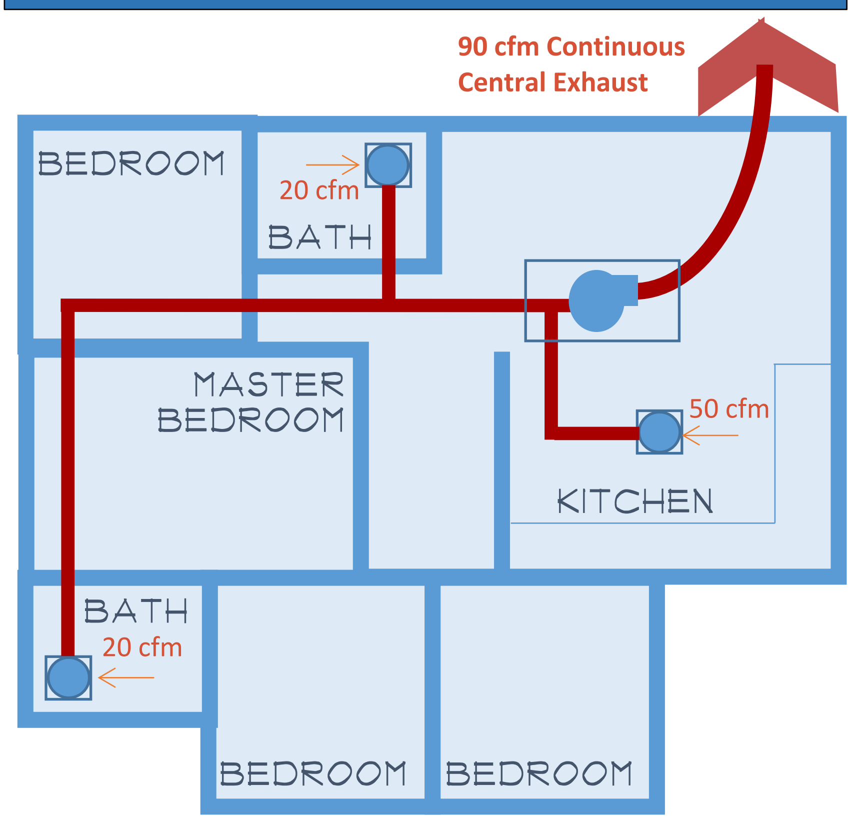
Example #2: 3,600 ft², 4 bedroom, 2 bath

In Example #2 a four-bedroom 3,600 ft², 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.



Example #3: 3,600 ft², 4 bedroom, 2 bath

In Example #3 another code compliant ventilation solution is shown for the same four-bedroom, 3,600 ft², 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.



Plan Review Pointers

1. Identify that the fans that are part of the whole house mechanical ventilation system provide the required airflow rate (cfm). (Note: Supply only exhaust-only whole-house exhaust systems are not recommended for Montana's climate.)

2. Review specification information on the proposed fans and verify efficacy for each fan in terms of cfm/W.

3. Verify that all fans included in the whole-house mechanical ventilation system meet the efficacy requirements, and if integral with a central air handler, the air handler fan is powered by an electronically commutated motor.

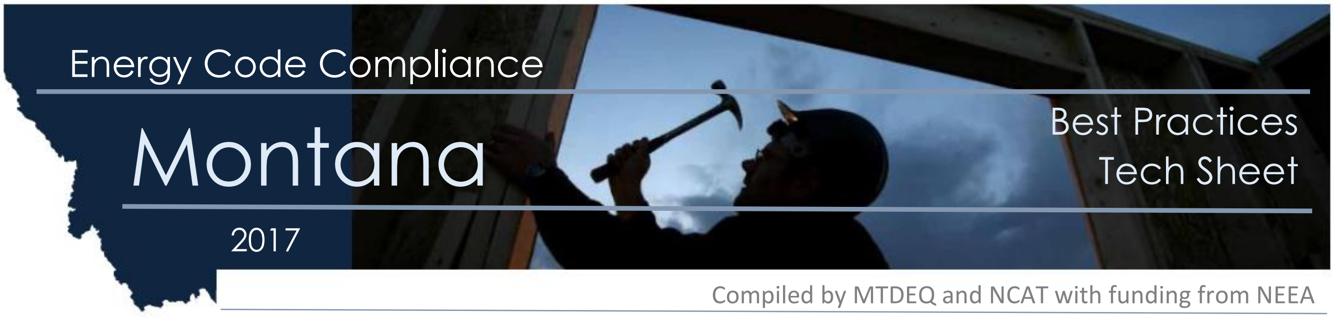
4. Check that required local exhaust fans in kitchens and bathrooms, either continuous or intermittent, have been identified and sized per the code.

Field Inspection Pointers

1. Verify that all fans included in the whole-house mechanical ventilation system match the efficacy of specified units or the submittals provided and assessed during plan review. Verify that all exhaust is to the outside. Recirculation fans do not comply.

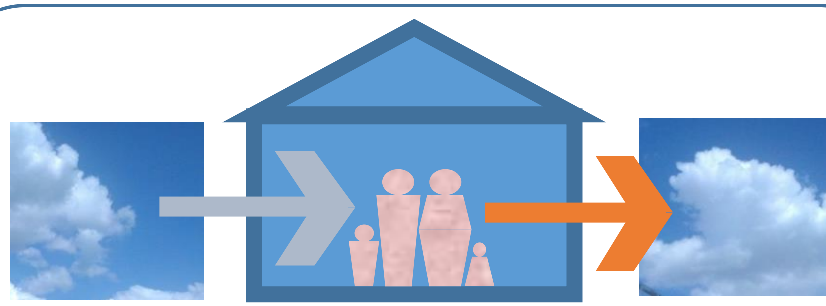
2. Verify that an occupant override has been installed as required for the whole-house mechanical ventilation system.

3. Verify that all local exhaust fans match the efficacy of specified units or the submittals provided and assessed during plan review. Verify that all exhaust s to the outside. Recirculation fans do not comply.



Residential Mechanical Ventilation Types

Before describing four basic types of mechanical ventilation let's review an important building science principle related to ventilation. As shown in the adjacent diagram, the volume of air that is exhausted from a building is equal to the volume of air that enters the building. This basic principle of physics rings true for all types of ventilation systems.



Air in = Air out

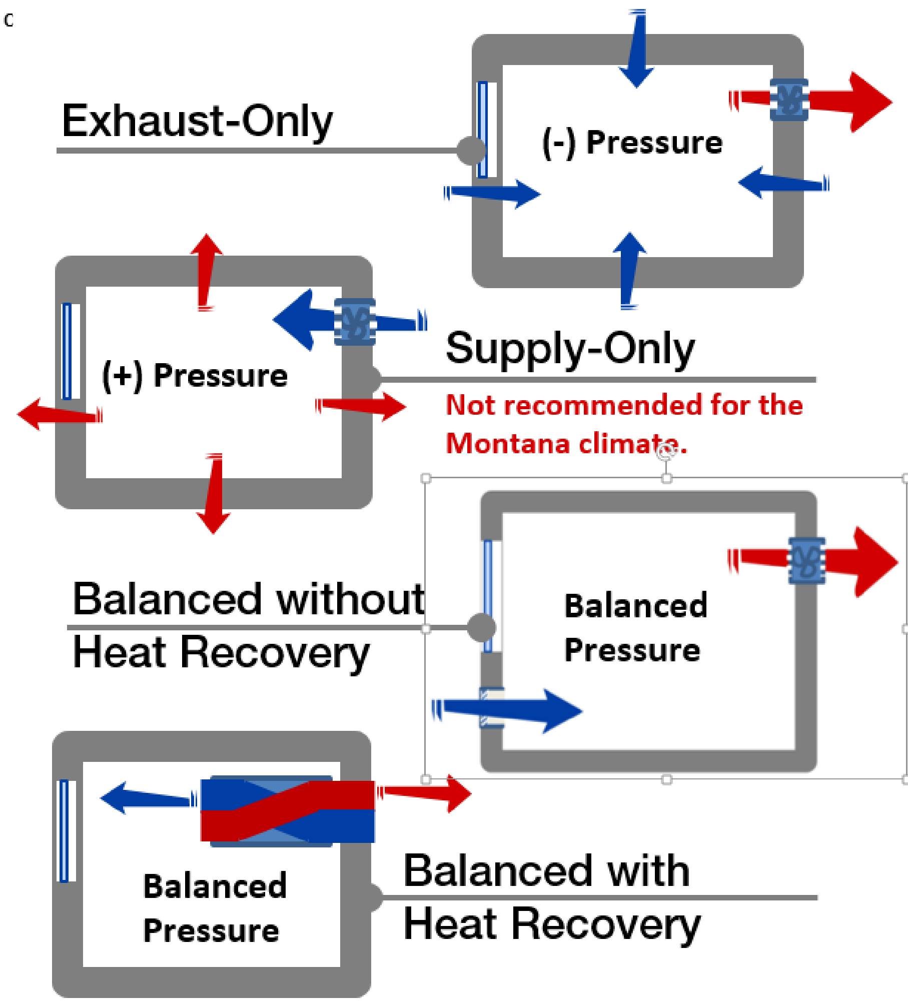
A fundamental building science principle is that if one cfm of air leaves a building, then one cfm must enter the building.

The four most common types of ventilation system are exhaust-only, supply-only, balanced, and balanced with heat recovery. *Exhaust-only ventilation systems* are the most common and often least expensive. The make-up air for exhaust-only systems is supplied by the various air leaks in the building envelope. Exhaust-only systems usually consist of simple exhaust fans in the bathrooms or kitchen. Exhaust-only systems depressurize the house without providing planned pathways for make-up air. This often results in very uneven distribution of fresh air throughout the home. Exhaust-only systems can contribute to depressurization in the combustion appliance zone, which can lead to backdrafting of atmospherically vented appliances.

Supply-only ventilation systems pressurize the house without providing planned pathways for exhaust air. 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 such as Montana.

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 can minimize problems of over-pressurizing and under-pressurizing spaces within the home. A balanced ventilation system is more likely to provide design air quantities. Since make-up air is provided through planned pathways air quality may be improved. Simple balanced ventilation systems may use *trickle* or *passive* fresh air inlets installed as through-the-wall units or in window frames. Unfortunately a recent study conducted by Washington State University Energy Extension found that these units were no more effective than basic exhaust only systems without air inlets.

Many balanced ventilation systems utilize local exhaust fans that are interconnected with a central air handler. The exhaust fans, central air-handler fan, and a motorized damper on a fresh air duct connected to the air handler return duct are coordinated. The motorized damper in the make-up air duct establishes a fixed amount of outside air that enters the central system. This approach allows the central air-handler 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° F in order to control condensation of combustion gases on the heat exchanger surfaces.

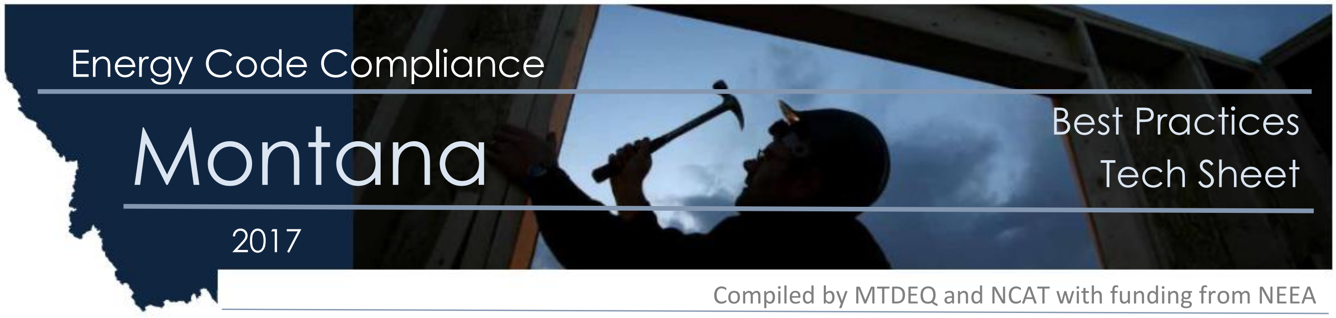
Balanced ventilation systems with heat recovery are designed to provide heat recovery. Typically, an HRV will transfer 60% to 90% of the heat in the stale air being exhausted from the home to the fresh air entering the home. Heat recovery ventilators (HRV) have the potential to provide energy savings and effective ventilation but only if designed and installed properly. 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. An HRV transfers heat from the exhaust air to the intake (outside) 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. Outside air is supplied by the central ventilation system to one or more spaces.

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. While it is possible to integrate an HRV with a central air handler, it is difficult to balance the HRV in this configuration because of the ducting and operating conditions of the central air distribution system.

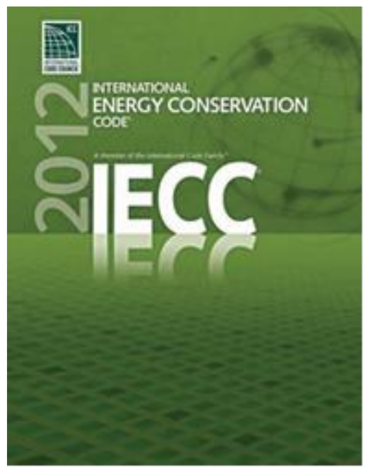
Ventilation Effectiveness

While the codes set important minimal whole house mechanical ventilation requirements, the code provisions alone do not assure that the installed system will provide effective and energy efficient ventilation to occupants of new homes. To the contrary, it takes thoughtful design, proper installation, and appropriate behavior of the occupants to provide the ventilation necessary to provide healthy, comfortable, and energy efficient ventilation. This newsletter is too brief to provide a comprehensive discussion of ventilation system design, but following are some design and operation considerations that improve the effectiveness and energy efficiency of whole-house ventilation systems.

- 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 but 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.
- 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.



Residential Energy Code Checklist



On November 7, 2014, Montana adopted the 2012 International Energy Efficiency Code (IECC) with a number of amendments. The previous state energy code was based on the 2009 IECC. The differences are significant. The family of building codes are developed by the ICC to work together. There are many energy-related aspects of residential construction that are contained in the IRC and the International Mechanical Code (IMC). Montana adopts chapters 1 through 10, 15, and 44 of the IRC, along with the IECC and IMC with amendments. The following table points out that important energy-related topics such as foam insulation properties, vapor retarders, crawlspace ventilation, and continuous whole-house ventilation are found in the IRC or the mechanical code.

Montana Energy Code Is Applicable Statewide

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.

How the Codes Overlap for Energy-Related Topics

Topic	IECC	IRC	IMC
HVAC Sizing	■		
Insulation Values	■		
Window/Skylight U-Factors	■		
House Tightening	■		
Duct Sealing and Tightening	■		■
Lighting Efficiency	■		
Foam Thermal Properties		■	
Vapor Retarders		■	
Crawlspace Ventilation		■	
Mechanical Ventilation		■	■

The following pages are a checklist to the Montana residential energy code that was adopted in November 2014. The blower door requirement did not take effect until November of 2015.

Montana Builder's Energy Code Checklist (2012 IECC)

*** Indicates Montana Energy Code value that was amended from the 2012 IECC.**

Date	Builder	
House Address		City
☐ New Construction	☐ Addition to Existing Building	☐ Existing Building Renovation

☑ ☒ N/A	Component	Code Provision	Presc. Code Value	RESChk Tradeoff Value	2012 IECC Code Section
	Pre-Inspection/Plan Review				
☐ ☐ ☐	Construction Documents	Construction drawings sufficiently demonstrates energy code compliance			R103.2
☐ ☐ ☐	HVAC Load Calculations	HVAC loads sized according to ACCA Manual J			R403.6
	Foundation				
☐ ☐ ☐	Slab	Unheated slab edge insulation R-value	R-10		R402.1.1 R402.2.9
☐ ☐ ☐		Heated slab edge insulation R-value	R-15		
☐ ☐ ☐		Depth/length from top of slab	4 ft		
☐ ☐ ☐	Basement Wall Exterior Insulation	Continuous exterior insulation	R-15		R402.1.1
☐ ☐ ☐		Insulation depth (or to basement floor)	10 ft		R402.2.8
☐ ☐ ☐	Crawl Space	Continuous, Exterior	R-15		
	Framing/Rough-in				
☐ ☐ ☐	Windows & Doors	Area weighted average (maximum value)	U-0.32		R402.1.1
☐ ☐ ☐	Skylight	U-factor (maximum value)	U-0.55		R402.1.1
☐ ☐ ☐	Mass Wall	More than 50% of insulation on interior	R-20		R402.1.1
☐ ☐ ☐		Less than 50% of insulation on interior	R-15		R402.1.1
☐ ☐ ☐	Duct Insulation	Supply ducts in unconditioned attic	R-8		R403.2.1
☐ ☐ ☐		All other ducts outside thermal envelope	R-6		
☐ ☐ ☐	Ducts	Sealed with approved tapes, mastics, and gaskets			R403.2.2
☐ ☐ ☐		Building cavities not used for supply ducts			R403.2.3

House Address				City		
☑ ☒ N/A	Component	Code Provision	Presc. Code Value	RESChk Tradeoff Value	2012 IECC Code Section
	Insulation				
☐ ☐ ☐	Crawl Space	Cavity Insulation	R-19		R402.1.1 R402.2.10
☐ ☐ ☐		Continuous, Interior	R-15		
☐ ☐ ☐		Continuous Class 1 vapor retarder, joints overlapped 6" and sealed, extending 6" up the stem wall			
☐ ☐ ☐	Basement Wall Interior Insulation	Continuous Insulation	R-15		R402.1.1
☐ ☐ ☐		Framed wall	R-19		R402.1.1
☐ ☐ ☐	Floor Insulation	Must be in contact with floor sheathing	R-30		R402.1.1
☐ ☐ ☐	Exterior Walls	Framed wall	R-21*		R402.1.1
☐ ☐ ☐		Framed wall + continuous	R-13+R-10		R402.1.1
☐ ☐ ☐	Air Sealing	Tested by blower door (ACH50)	≤4*		R402.4.2.1
☐ ☐ ☐		Air Barrier and Insulation Installation			R402.4.1.1
☐ ☐ ☐	Ceiling Insulation	Insulation R-value	R-49		R402.1.1
☐ ☐ ☐		If full thickness over wall top plates	R-38		R402.1.1
☐ ☐ ☐	Attic Access Hatch	Hatch door insulation	R-49		R402.2.3
☐ ☐ ☐	Duct Tightness Test (Not required if all ducts and air handler are within conditioned space)	**Postconstruction** total leakage or leakage to outside (CFM per 100 ft^2)*	≤4 CFM		R403.2.2
☐ ☐ ☐		**Rough-in** total duct leakage test (CFM per 100 ft^2)	≤4 CFM		R403.2.2
☐ ☐ ☐	Lighting	% of lamps that must be high-efficacy	75%		R404.1
☐ ☐ ☐	Wood Fireplace	Gasketed doors, outdoor combustion air			R402.4.2
☐ ☐ ☐	Forced Air Furnace	Programmable thermostat installed			R403.1.1
☐ ☐ ☐	Heat Pump	Heat pump thermostat installed			R403.1.2
☐ ☐ ☐	Certificate Posted	Permanent energy label posted on electrical panel			R401.3
	Sunroom with thermal isolation				
☐ ☐ ☐		Glazing U-factor	U-0.45		R402.3.5
☐ ☐ ☐		Skylight U-factor	U-0.70		
☐ ☐ ☐		Wall insulation	R-13		R402.2.12

House Address		City			
☑ ☒ N/A	**Component**	**Code Provision**	**Presc. Code Value**	**RESChk Tradeoff Value**	**2012 IECC Code Section**
	Other Provisions				
☐ ☐ ☐	All Components	All materials, systems and equipment Installed per manufacturer's instructions and building code			R303.2
☐ ☐ ☐	Basement Wall Exterior Insulation	Exposed insulation protected			R303.2.1
☐ ☐ ☐	Snowmelt	Snow-melt controls			R403.8
☐ ☐ ☐	U-factor Labeling	Windows, doors, and skylights certified and labeled			R303.1.3
☐ ☐ ☐	Insulation Labeling	Installed insulation labeled and observable for inspection			R303.1
☐ ☐ ☐		Ceiling insulation	R-24		R402.2.12
☐ ☐ ☐	Recessed Light Fixtures	IC-rated fixtures that meet infiltration criteria			R402.4.4
☐ ☐ ☐	Hot Water	HW piping insulation under specific conditions	R-3		R403.4
☐ ☐ ☐		Circulating HW systems have automatic or accessible manual controls			R403.4.1
☐ ☐ ☐	Mech Sys Piping Insul	Carrying fluids $\geq$ 105 degrees F or $\leq$ 55 degrees F	R-3		R403.5
☐ ☐ ☐	Exhaust Openings	Dampers on all outdoor intake & exhaust openings			R403.5
☐ ☐ ☐	Fenestration Air Leakage	Infiltration rate maximum for windows, skylights, and sliding doors	0.3 CFM/ft^2		R402.4.3
☐ ☐ ☐		Infiltration rate maximum for swinging doors	0.5 CFM/ft^2		
☐ ☐ ☐		Windows, doors, and skylights air leakage listed and labeled			
☐ ☐ ☐	Pools and In-ground Spas	Heater accessible manual controls + time switch + cover			R403.9

Duct Tightness Test Results		
Test Date:	House Floor Area Ft^2:	Leakage CFM25:
Rough-in Test: Total duct leakage in CFM per 100 ft^2 of conditioned floor area:		
Postconstruction Test: **Leakage to outdoors** in CFM per 100 ft^2 of conditioned floor area:		
Postconstruction Test: **Total duct leakage** in CFM per 100 ft^2 of conditioned floor area:		

Blower Door Test Results		
Test Date:	Houser Volume Ft^3:	House Floor Area Ft^2:
Measured airflow at 50 Pascals (CFM50):		
Air Change at 50 Pascals (ACH50 = (CFM50 x 60)/Volume):		

House Address		City
	Air Barrier and Insulation Installation	
☑ ☒ N/A	**Component**	**Criteria**
☐ ☐ ☐	**Air barrier and thermal barrier**	A continuous air barrier installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier sealed. Air-permeable insulation not be used as a sealing material.
☐ ☐ ☐	**Ceiling/attic**	The air barrier in any dropped ceiling/soffit aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop-down stair, or knee wall doors to unconditioned attic spaces sealed.
☐ ☐ ☐	**Walls**	Corners and headers insulated and the junction of the foundation and sill plate sealed. The junction of the top plate and top of exterior walls sealed. Exterior thermal envelope insulation for framed walls installed in substantial contact and continuous alignment with the air barrier. Knee walls sealed.
☐ ☐ ☐	**Windows, skylights, and doors**	The space between window/door jambs and framing and skylights and framing sealed.
☐ ☐ ☐	**Rim joists**	Rim joists insulated and include the air barrier.
☐ ☐ ☐	**Floors (above-garage and cantilevered floors)**	Insulation installed to maintain permanent contact with underside of subfloor decking.
☐ ☐ ☐	**Crawl space walls**	Where provided in lieu of floor insulation, insulation permanently attached to the crawlspace walls. Exposed earth in unvented crawl spaces covered with a Class I vapor retarder with overlapping joints taped.
☐ ☐ ☐	**Shafts, penetrations**	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space sealed.
☐ ☐ ☐	**Narrow cavities**	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
☐ ☐ ☐	**Garage separation**	Air sealing shall be provided between the garage and conditioned spaces.
☐ ☐ ☐	**Recessed lighting**	Recessed light fixtures installed in the building thermal envelope shall be air-tight, IC-rated, and sealed to the drywall.
☐ ☐ ☐	**Plumbing and wiring**	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
☐ ☐ ☐	**Shower/tub on exterior wall**	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
☐ ☐ ☐	**Electrical/phone box on exterior walls**	The air barrier installed behind electrical or communication boxes or air sealed boxes installed.
☐ ☐ ☐	**HVAC register boots**	HVAC register boots that penetrate building thermal envelope sealed to the subfloor or drywall.
☐ ☐ ☐	**Fireplace**	An air barrier installed on fireplace walls. Fireplaces have gasketed doors.