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Your Resource Guide to the 2018 Virginia Residential Energy Code

On behalf of Viridiant, the Virginia Department of Housing and Community Development (DHCD) and the Southeast Energy Efficiency Alliance, we are pleased to distribute the following resources as part of the Circuit Rider Program to aid in the Virginia Residential Energy Code implementation.

Thank you to the following jurisdictions for their participation in the Circuit Rider Program: City of Alexandria, Fairfax County, Franklin County, City of Hampton, James City County, Montgomery County, City of Norfolk, Roanoke County, Southampton County, and Warren County. Their unique perspectives were crucial in compiling information to guide resource development. Additional thanks to DHCD Division of Building and Fire Regulation.

Notable energy-related changes in the 2018 update include the requirement that homes obtain a blower door test, increased attic insulation performance, provision of an energy certificate in the home, and a minimum 90% of installed lighting meeting high-efficiency criteria.

- Unvented Crawl Spaces Guide
- Energy Certificate
- Insulation & Air Barrier Guide
- Insulation Installation Details
- Insulation Installation Tips
- Insulation, Air Barrier, & Air Sealing Inspection Checklist
- Blower Door Test Training Video*
- Blower Door Test Report Form
- Slab Edge Insulation Guide
- Manual J, D, & S Brochures
- Understanding and Using the HVAC Design Review Form
- Understanding Select Fields on the Residential Plans Examiner Review Form for HVAC System Design
- HVAC Installation Tips
- Duct Sealing and Testing Inspection Guide
- Duct Test Report Form
- Duct Blaster Test Training Video*
- Buried Ducts Guide
- Whole-House Fresh Air Ventilation Guide
- Indoor Air Quality, Code and COVID Guide
- Hot Water Pipe Insulation Guide
- Lighting Tips
- Jack A. Proctor Virginia Building Code Academy*
- Recommended Practices for Remote Virtual Inspection*

As some resources can only be accessed digitally (denoted with an *), please visit https://www.viridiant.org/2018-virginia-residential-energy-code-resources/or scan the QR code on the back of this binder with your phone.

These resources are intended to support and provide deeper context and understanding of the implementation of the 2018 Virginia Residential Energy Code (Energy Code). Should there be a conflict between these resources and the Energy Code, the Energy Code takes precedence. These resources and tools are for training purposes only and DHCD is not intending to endorse and/or promote one product over another.

For more information or questions, please contact Viridiant at admin@viridiant.org or 804.225.9843.

Acknowledgement: This material is based upon work supported by the Southeast Energy Efficiency Alliance, the Department of Energy and Pacific Northwest National Labs.

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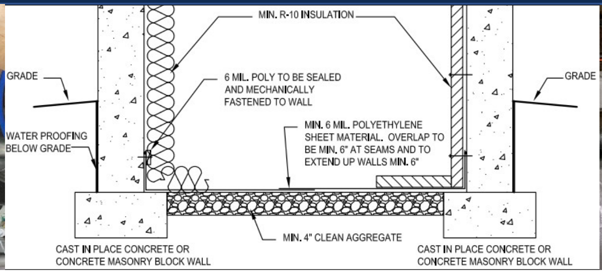
2018 Virginia Residential Energy Code Resource Guide

Resources denoted with an * can be accessed digitally at https://www.viridiant.org/2018-virginia-residential-energy-code-resources/

Unvented Crawl Spaces

2018 VRC/VECC Review Guide



Unvented Crawl Spaces:

Summary: The 2018 Virginia Residential Code provides several options for ensuring that unvented crawl spaces maintain acceptable humidity levels. Chapter 4, Foundations (R408.3) and Chapter 11, Energy Efficiency (N1102.2.11 or VECC Table R402.1.2) provide requirements for vapor barriers, perimeter insulation, and humidity control strategies when the home's air barrier and insulation layer is constructed to include the crawl space.

Why: Unvented crawl space details have been included in Chapter 4 of the IRC going back at least to the 2000 edition. Extensive research by NC State University, Oak Ridge National Lab, and others has shown that venting permits the crawl space to track exterior moisture levels. This can create elevated *relative humidity* during portions of the year which can cause condensation, mold, and rot in crawl spaces. It's a particular risk in summer months when traditional practice has dictated that operable vents should be opened.

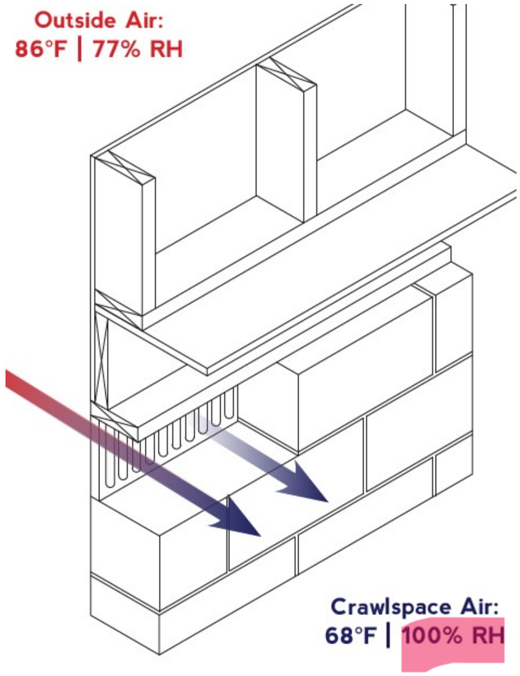


Image: Pennsylvania Housing Research Center

Key Components of an Unvented Crawl Space:

The Vapor Barrier. As with vented crawl spaces, the first and most important element is an effective vapor barrier covering the earth. Joints in the vapor barrier material must overlap and be sealed or taped. Edges of the vapor barrier must extend at least 6 inches up stem walls and be attached and sealed to the stem wall or to insulation on that wall. Best practice advises that the vapor barrier extend at least 6 inches above the level of the exterior grade.

Perimeter Insulation. The walls separating unvented crawl spaces from the exterior must be insulated to a minimum of either R-10 continuous (interior or exterior) or R-13 cavity (interior only). The insulation must be permanently fastened to the wall and extend downward from the floor to the finished grade elevation <u>and</u> then vertically or horizontally (as applicable) for at least another 2 feet.

In locations where termites are a risk, the vertical face of the sill plate plus the first 1 to 2 inches of the foundation wall below the sill plate must be uncovered by insulation. These areas may be covered if the insulation is easily removable or if another approved means of inspection is provided. Access doors from the exterior into an unvented crawl space must have a minimum of R-5 insulation and effective weatherstripping.

Humidity Management Strategy. The home must utilize one of the options listed below.

1. A continuously operating exhaust fan pulling conditioned air (1 CFM per 50 SF of crawl space floor area) from the home via a transfer grille or duct, through the crawl, and exiting the perimeter wall
2. Provision of conditioned air (1 CFM per 50 SF of crawl space floor area) to the crawl space with a permanent open pathway to a return grille of the HVAC system
3. Dedicated dehumidification of the crawl space (with moisture removal capacity of not less than 70 pints/day per 1000 SF of crawl floor area). While not stated in the code, for effective moisture removal, the equipment should not require manual emptying of condensate. Many systems drain into the same reservoir and pump that manages condensate from the AC coil.
4. (*Prohibited in new structures; allowable only as a modification or repair to an existing under-floor plenum*) Receives conditioned air because the crawl space is a return plenum.

Radon:

Crawl spaces utilizing a passive submembrane depressurization strategy to manage radon may not be unvented unless "an *approved* mechanical crawl space ventilation system or other equivalent system is installed."

2018 VRC/VECC Code References:

R408.3 Unvented crawl space. For unvented under-floor spaces, the following items shall be provided:

1. Exposed earth shall be covered with a continuous Class I vapor retarder. Joints of the vapor retarder shall overlap by 6 inches (152 mm) and shall be sealed or taped. The edges of the vapor retarder shall extend not less than 6 inches (152 mm) up the stem wall and shall be attached and sealed to the stem wall or insulation.
2. One of the following shall be provided for the under-floor space:
   - 2.1. Continuously operated mechanical exhaust ventilation at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m2) of crawl space floor area, including an air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2.11 of this code.
   - 2.2. Conditioned air supply sized to deliver at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m2) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2.11 of this code.
   - 2.3. Plenum in existing structures complying with Section M1601.5 if under-floor space is used as a plenum.
   - 2.4. Dehumidification sized to provide 70 pints (33 liters) of moisture removal per day for every 1,000 square feet (93 m2) of crawl space floor area.

R408.3.1 Termite inspection. Where an unvented crawl space is installed and meets the criteria in Section R408, the vertical face of the sill plate shall be clear and unobstructed and an inspection gap shall be provided below the sill plate along the top of any interior foundation wall covering. The gap shall be a minimum of 1 inch (25.4 mm) and a maximum of 2 inches (50.8 mm) in width and shall extend throughout all parts of any foundation that is enclosed. Joints between the sill plate and the top of any interior wall covering may be sealed. **Exception:** In areas not subject to damage by termites as indicated

by Table R301.2(1). **Exception:** Where other approved means are provided to inspect for potential damage.
Where pier and curtain foundations are installed as depicted in Figure R404.1.5(1) [double rim joists], the inside face of the rim joist and sill plate shall be clear and unobstructed except for construction joints, which may be sealed. **Exception:** Fiberglass or similar insulation may be installed if easily removable.

TABLE N1102.1.2 (R402.1.2)

Climate Zone	3	4 Except Marine	5 and Marine 4
Crawl Space Wall R-Value	5/13	10/13	10/13

"10/13" means R-10 continuous insulation on the interior or exterior of the home or R-13 cavity insulation on the interior of the basement wall.

N1102.2.11 (R402.2.11) Crawl space walls.
As an alternative to insulating floors over crawl spaces, crawl space walls shall be insulated provided that the crawl space is not vented to the outdoors. Crawl space wall insulation shall be permanently fastened to the wall and shall extend downward from the floor to the finished grade elevation and then vertically or horizontally for not less than an additional 24 inches (610 mm). Exposed earth in unvented crawl space foundations shall be covered with a continuous Class I vapor retarder in accordance with this code. Joints of the vapor retarder shall overlap by 6 inches (153 mm) and be sealed or taped. The edges of the vapor retarder shall extend not less than 6 inches (153 mm) up the stem walls and shall be attached to the stem walls.

M1601.5 Under-floor plenums.
Under-floor plenums shall be prohibited in new structures. Modification or repairs to under-floor plenums in existing structures shall conform to the requirements of this section. The space shall be cleaned of loose combustible materials and scrap and shall be tightly enclosed. The ground surface of the space shall be covered with a moisture barrier having a thickness of not less than 4 mils (0.1 mm). Plumbing waste cleanouts shall not be located within the space. **Exception:** Plumbing waste cleanouts shall be permitted to be located in unvented crawl spaces that receive conditioned air in accordance with Section R408.3.

N1102.2.4 (R402.2.4) Access hatches and doors. Access doors from *conditioned spaces* to *unconditioned spaces* (e.g., attics and crawl spaces) shall be weather-stripped and insulated in accordance with the following values: Hinged vertical doors shall have a minimum overall R-5 insulation value.

AF103.5 Passive submembrane depressurization system. In buildings with crawl space foundations, the following components of a passive submembrane depressurization system shall be installed during construction. Exception: Buildings in which an approved mechanical crawl space ventilation system or other equivalent system is installed.
AF103.5.1 Ventilation. Crawl spaces shall be provided with vents to the exterior of the building. The minimum net area of ventilation openings shall comply with Section R408.1.

Energy Specification Certificate

Street Address: City: State: VA

Building Envelope			
Insulation R-values			
Ceiling:		Above Grade Walls:	
Foundation Walls:		Floor Over Unconditioned Space:	
Slab:			
Infiltration:	ACH50:		CFM50:	

Windows and Doors				
Windows:	U-value:		SHGC:	
Doors with Glazing:	U-value:		SHGC:	
Opaque Doors:	U-value:			

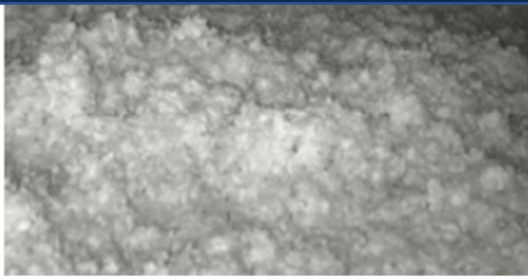
Mechanical Equipment						
HVAC System 1						
Heating:	Type:		Efficiency:		Fuel:	
Cooling:	Type:		Efficiency:			
Ducts:	Insulation:		Total Duct Leakage %:		CFM25:	
HVAC System 2						
Heating:	Type:		Efficiency:		Fuel:	
Cooling:	Type:		Efficiency:			
Ducts:	Insulation:		Total Duct Leakage %:		CFM25:	
Water Heater	Type:		Efficiency:		Fuel:	

Builder or Design Professional			
Name:		Date:	
Signature:			

2018 Virginia Energy Conservation Code R401.3: A permanent certificate shall be completed by the builder or other approved party and posted on a wall in the space where the furnace is located, a utility room or an approved location inside the building. Where located on an electrical panel, the certificate shall not cover or obstruct the visibility of the circuit directory label, service disconnect label, or other required labels.
Where approved, certificates for multifamily dwelling units shall be permitted to be located off-site at an identified location. The certificate shall indicate the predominant R-values of insulation installed in or on ceilings, roofs, walls, foundation components such as slabs, basement walls, crawl space walls and floors, and ducts outside conditioned spaces; U-factors of fenestration and the solar heat gain coefficient (SHGC) of fenestration; and the results from any required duct system and building envelope air leakage testing performed on the building. Where there is more than one value for each component, the certificate shall indicate the value covering the largest area. The certificate shall indicate the types and efficiencies of heating, cooling, and service water heating equipment. Where a gas-fired unvented room heater, electric furnace, or baseboard electric heater is installed in the residence, the certificate shall indicate "gas-fired unvented room heater," "electric furnace," or "baseboard electric heater," as appropriate. An efficiency shall not be indicated for gas-fired unvented room heaters, electric furnaces, and electric baseboard heaters.

Insulation & Air Barriers

2018 VRC/VECC Inspection Guide



Insulation and Air Barriers:

Summary: The thermal envelope is the most important system relating to the performance of the home. Properly aligned air barrier and thermal insulation systems provide long lasting benefits to both the home and its occupants. Thermal components of the building's thermal envelope may be required by the building official to be represented on the construction drawings.

Why: Poorly installed insulation can result in higher heating and cooling costs, comfort problems, mold, and other moisture related issues including long-term durability and structural issues. Professionally installed insulation should follow the manufacturer's installation instructions. These typically stipulate no gaps, voids, compression of the insulation material; alignment of the insulation with the continuous air barrier; complete air barriers; and minimal thermal bridging. Best practices for insulation installation lead to conditioned spaces that require less heating and cooling, have even temperatures, and a quieter environment throughout the house.[1]

Notes:

- *Specific blown fiberglass systems, high-density fiberglass/mineral wool batts, and spray foam insulation are materials that can achieve R-15 in a 2x4 stud cavity. Most other products will need to be installed in conjunction with exterior continuous insulation and/or in a 2x6 wall assembly.*
- *In order to be effective, insulation must be <u>continuous and contiguous</u>. All insulated surfaces – ceilings, walls, and floors – must be insulated and in contact with one another and the continuous air barrier.*
- *Most common insulation materials work primarily by slowing conductive heat flow and--to a lesser extent--convective heat flow. Radiant barriers and reflective insulation systems reduce radiant heat transfer. To be effective, the reflective surface must face an air space and stay clean.*[2]
- *Heat flows from hot to cold and will do so until there is no longer a temperature difference. In practice, this means that in winter, heat flows directly from heated living spaces to adjacent unheated attics, garages, basements, and the outdoors. Heat flow can also move indirectly through interior ceilings, walls, and floors--wherever there is a difference in temperature. Poor insulation installation will lead to increased heat flow into/out of the building.*

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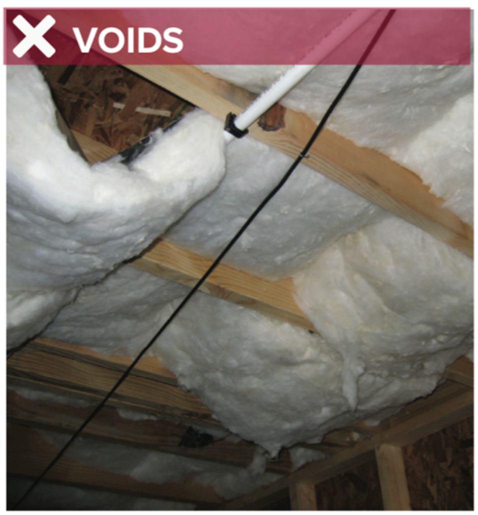
[1] https://basc.pnnl.gov/building-science-measures/insulation-quality-installation

[2] https://www.energy.gov/energysaver/weatherize/insulation#:~:text=Insulation%20in%20your%20home%20provides,costs%2C%20but%20also%20improves%20comfort.

2018 VECC TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	GLAZED FENESTRATION SHGC	CEILING R-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE	FLOOR *R*-VALUE	BASEMENT WALL *R*-VALUE	SLAB *R*-VALUE & DEPTH	CRAWL SPACE WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.4	0.65	0.25	38	13	4/6	13	0	0	0
3	0.32	0.55	0.25	38	20 or 13+5	8/13	19	5/13[f]	0	5/13
4 except Marine	**0.32**	**0.55**	**0.4**	**49**	**15 or 13+1**	**8/13**	**19**	**10/13**	**10, 2 ft**	**10/13**
5 and Marine 4	0.3	0.55	NR	49	20 or 13+5	13/17	30g	15/19	10, 2 ft	15/19
6	0.3	0.55	NR	49	20+5h or 13+10	15/20	30g	15/19	10, 4 ft	15/19
7 and 8	0.3	0.55	NR	49	20+5h or 13+10	19/21	38g	15/19	10, 4 ft	15/19

Best Practice: Install insulation to completely fill floor framing cavity or to maintain permanent contact with the subfloor without voids or compression.

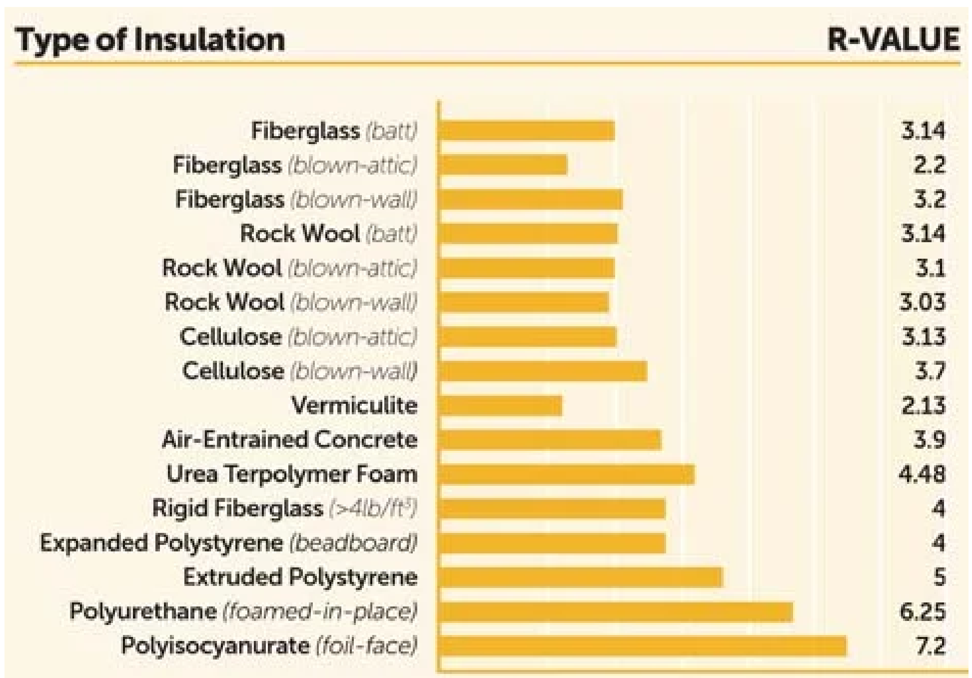


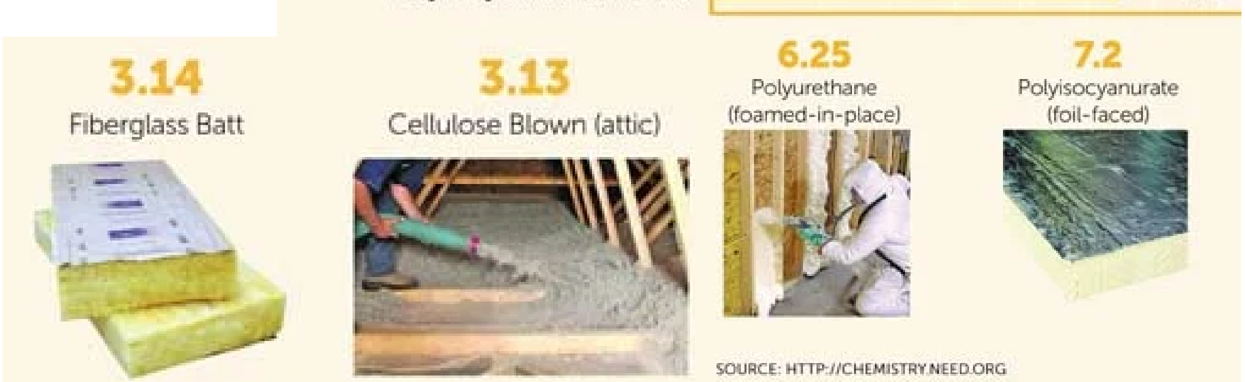
Best Practice: Cut and split insulation around all blocking, plumbing, HVAC, and electrical components to obtain a completely full framing cavity.

Figure 2: Insulated floor over garage

Figure 3: Damp-spray cellulose insulation in wall

Figure 4: R-Value per inch table





2018 VECC and VRC Insulation Installation Code References:

Section R402.4.1/N1102.4.1 Building Thermal Envelope. The building thermal envelope shall comply with Sections R402.4.1.1 and R402.4.1.2. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

Section R402.4.1.1/N1102.4.1.1 Installation (Mandatory). The components of the building thermal envelope as listed in Table R402.2.1.1(N1102.4.1.1) shall be installed in accordance with the manufacturer's instruction and the criteria listed in Table R402.2.1.1 (N1102.4.1.1), as applicable to the method of construction. Where required by the code official, an approved third party shall inspect all components and verify compliance.

Section R402.4.1.2/N1102.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding five air changes per hour in Climate Zone 4. Testing shall be conducted in accordance with RESNET/ICC 380, ASTM E779, or ASTM E1827 and reported at a pressure of 0.2 inch w.g. (50 Pascals). A written report of the results of the test shall be signed by the party conducting the test and provided to the building official. Testing shall be conducted by a Virginia licensed general contractor, a Virginia licensed HVAC contractor, a Virginia licensed home inspector, a Virginia registered design professional, a certified BPI Envelope Professional, a certified HERS rater, or a certified duct and envelope tightness rater. The party conducting the test shall have been trained on the equipment used to perform the test. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope.

Section R303.1.1/N1101.10.1 An R-value identification mark shall be applied by the manufacturer to each piece of building thermal envelope insulation 12 inches or greater in width. Alternately, the insulation installers shall provide a certification listing the type, manufacturer and R-Value of insulation installed in each element of the building thermal envelope.

Section R303.1.1.1/N1101.10.1.1 Blown or sprayed roof/ceiling insulation. The thickness of blown-in or sprayed roof/ceiling insulation (fiberglass or cellulose) shall be written in inches on markers that are installed at least one for every 300 square feet throughout the attic space.

Section R303.2/N1101.11 Installation. Materials, systems, and equipment shall be installed in accordance with the manufacturer's instruction and this code.

Section R303.2.1/N1101.11.1 Protection of exposed foundation insulation. Insulation applied to the exterior of basement walls, crawl space walls and the perimeter of slab-on-grade floors shall have a rigid, opaque, and weather-resistant protective covering to prevent the degradation of the insulation's thermal performance. The protective covering shall cover the exposed exterior insulation and extend not less than 6 inches (153 mm) below grade.

Insulation Installation Field Inspection Focus:

Inspections should provide verification in the following areas:[3]

1. Cavity insulation, as indicated in approved construction documents, completely fills ALL wall cavities with no compression or gaps, the manufacturer's R-value mark is readily available, and meets the approved R-value per construction documents.
2. Continuous insulation (if applicable) is installed in accordance with manufacturer's installation instructions, the manufacturer's R-value mark is readily available, and meets the approved R-value per construction documents.
3. Batt insulation is cut neatly around any wiring and plumbing, or insulation readily conforms to available space and extends behind piping and wiring.
4. Joints, seams, holes, and penetrations are caulked, gasketed, weather-stripped, or otherwise sealed.
5. Continuous air barrier is properly installed as indicated in approved construction documents.
   Confirm the insulation is installed in substantial contact and continuous alignment with the air barrier.
6. The junction where the rafters meet the exterior wall top plates and/or the attic floor are sealed.

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[3] basc.pnnl.gov/code-compliance/air-sealing-and-insulating-attic-knee-walls-code-compliance-brief

Success with the 2018 Virginia Energy Conservation Code:
Tech Tips for Builders

INSULATION

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IECC Tech Tips
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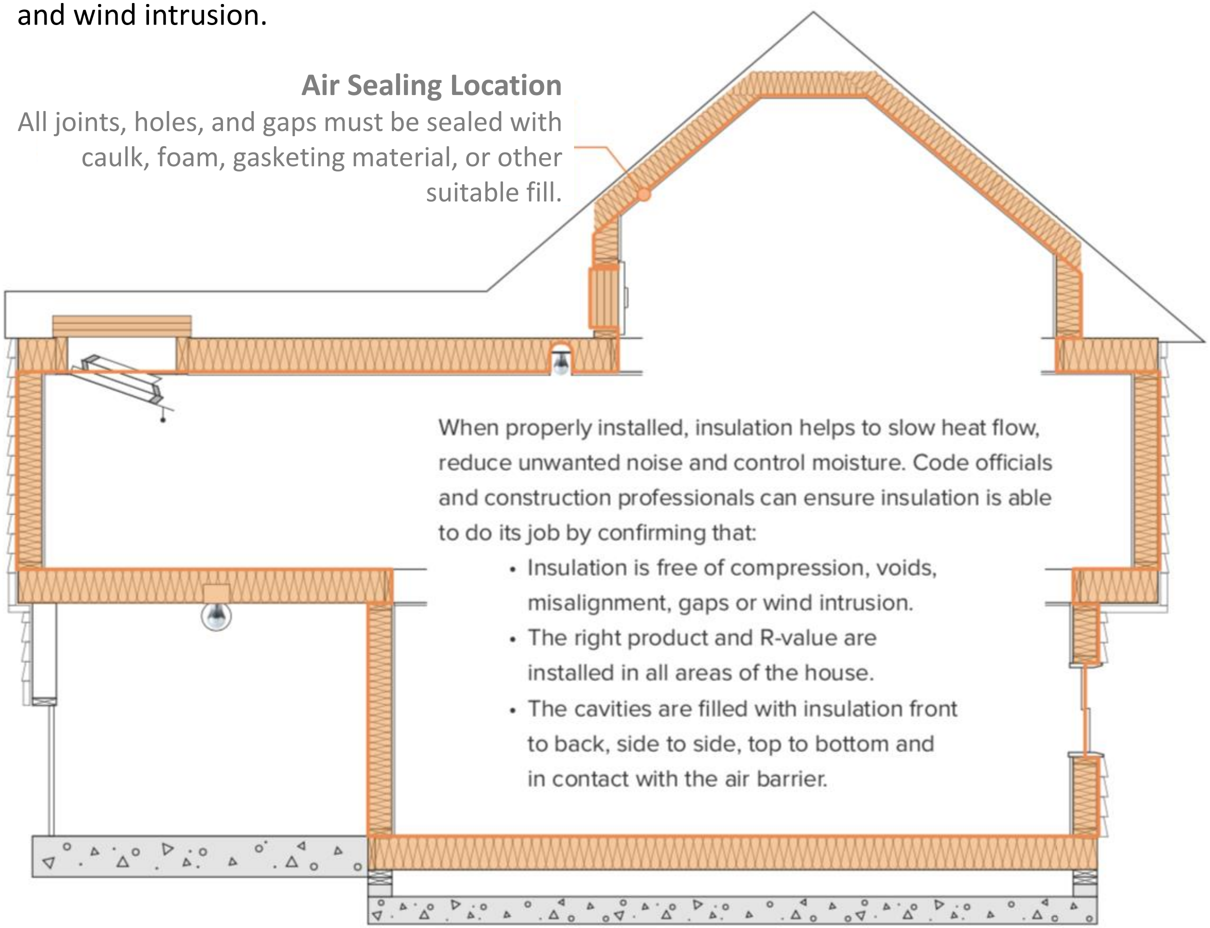
INSULATION INSTALLATION

Tips for Meeting the 2018 VRC/VECC

To obtain the code-required R-values in the 2018 VRC Table N1102.1.2 (R402.1.2), insulation "shall be installed in accordance with the manufacturer's instructions" (N1101.11 (R303.2)). All manufacturers require that insulation be free of gaps, voids, misalignment, compression, and wind intrusion.



Insulation

The 2017-2018 Virginia Residential "Field Study" gauged energy code enforcement. www.energycodes.gov/residential-energy-code-field-studies

Ceiling Insulation *R-Value*

- 2015 VA Code: R-38
- Study results: 96% COMPLIANT

Ceiling Insulation *Quality*

- Study results : 69% COMPLIANT

69%	25%	6%
Grade I	Grade II	Grade III

Wall Insulation *R-Value*

- 2015 VA Code required R-15 or R-13 + 1
- Study results : 100% COMPLIANT

Wall Insulation *Quality*

- 2015 VA Code required per manufacturer's instructions
- Study results : 37% COMPLIANT

37%	59%	4%
Grade I	Grade II	Grade III

Grade 1: almost no gaps; Grade II: up to 2% gaps, compression or voids; Grade III: 2-5% gaps, compression or voids

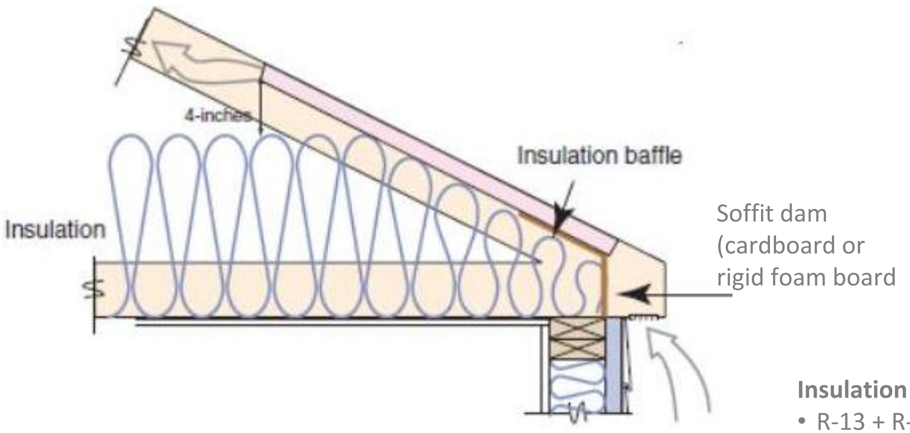
See the Insulation, Air Barrier, and Air Sealing Inspection Checklist to make sure code-compliance is achieved.

Example Details

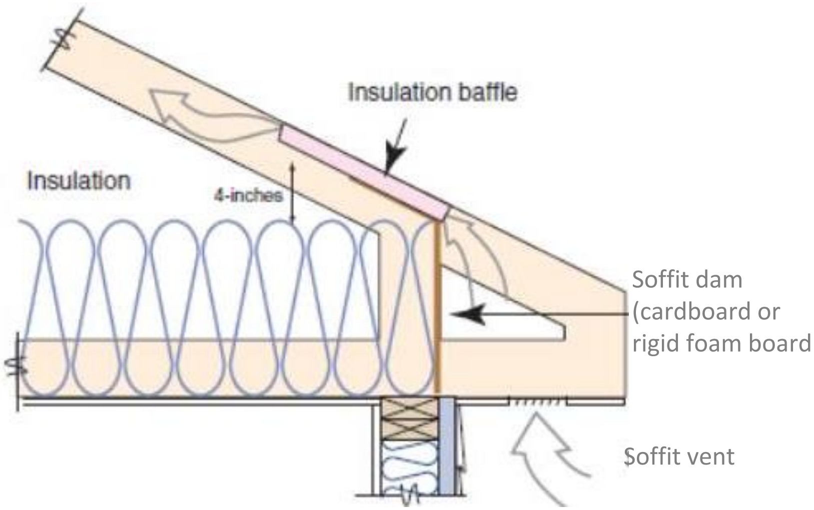
Images: basc.pnnl.gov/resource-guides

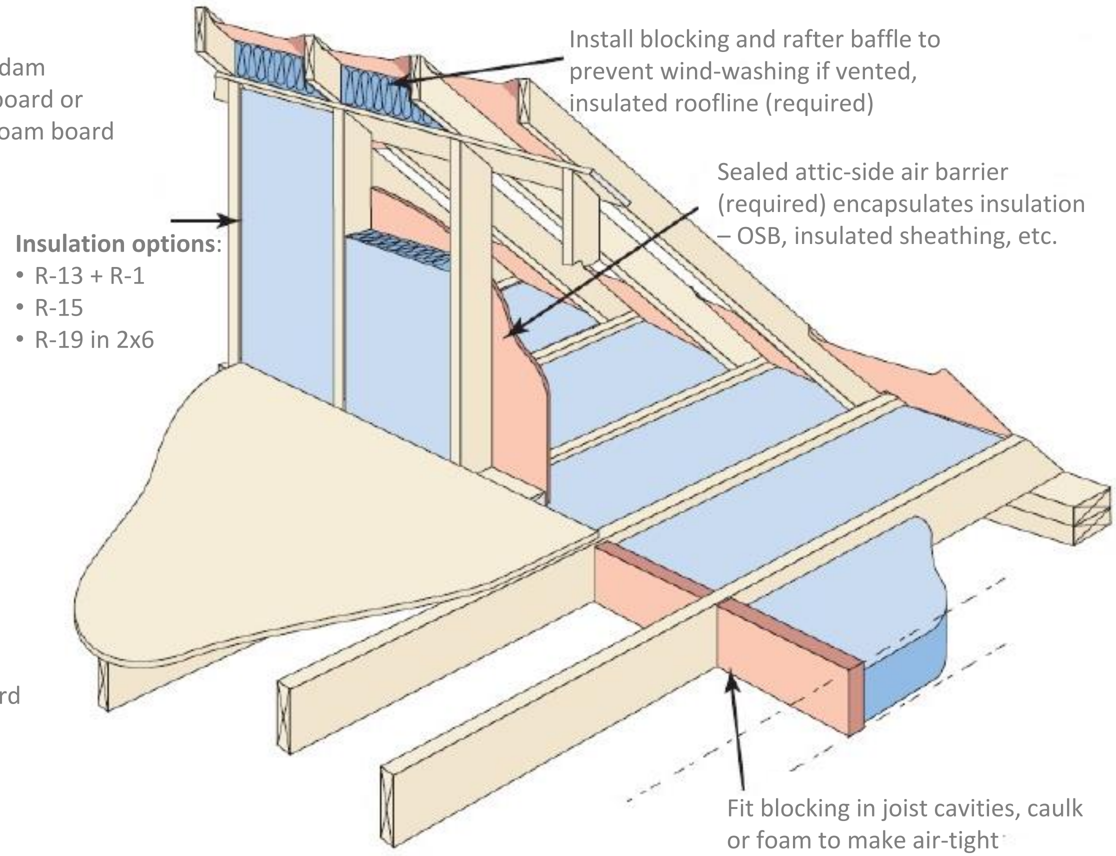
Inspecting Insulation
- Air sealing
- Baffling
- Obstructions
- Odd-sized cavities

Standard Truss with tapered insulation depth



Energy Truss with full height insulation (recommended)





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See the Insulation, Air Barrier, and Air Sealing Inspection Checklist to make sure code-compliance is achieved.

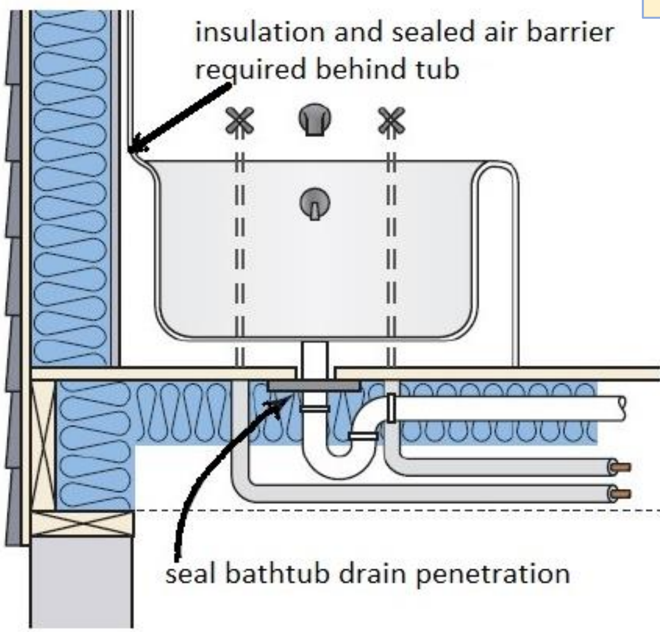
Example Details

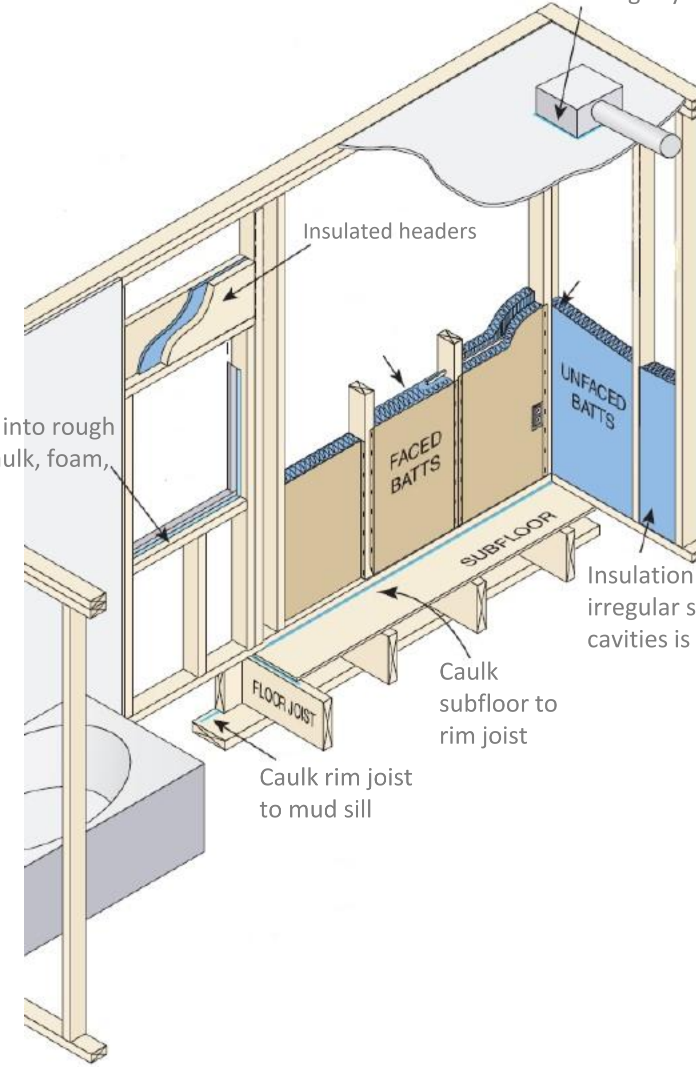
Images: basc.pnnl.gov/resource-guides

Inspecting Insulation

- Tubs
- Showers
- Fireplaces
- Attic knee walls

Tubs on exterior walls: Ensure insulation is fully encapsulated and air barrier is continuous





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IECC Tech Tips
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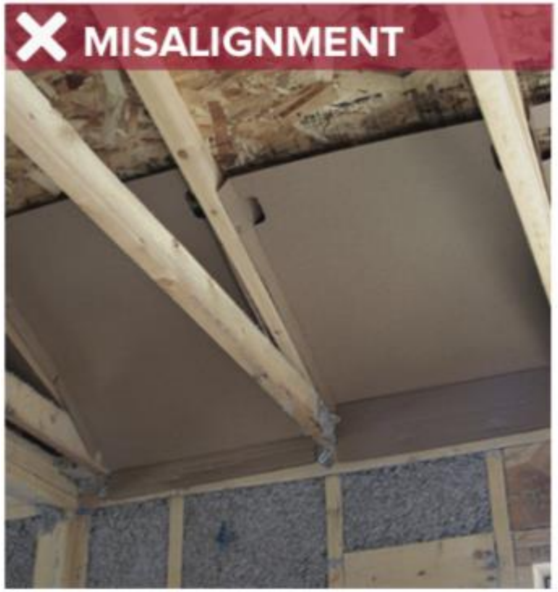
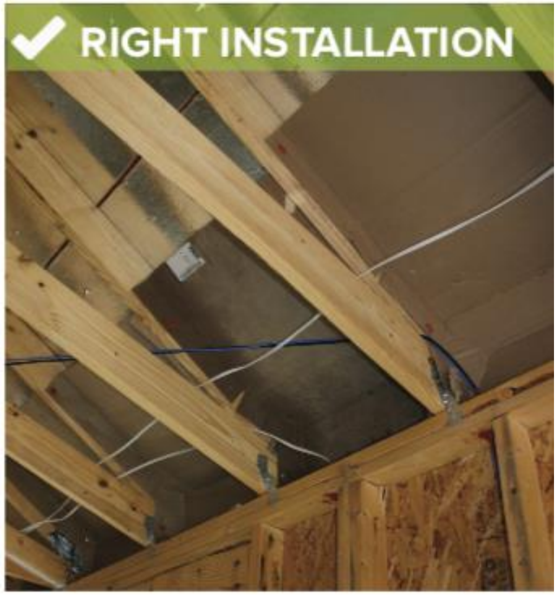
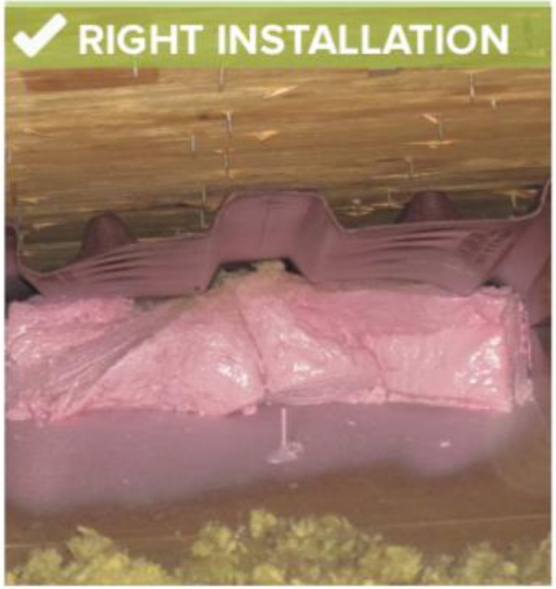
TECH TIPS:
INSULATION

1. For vented attics, install wind baffles on top of all exterior walls, leaving room for at least 4 inches of insulation over top plates and ventilation above.







TECH TIPS:
INSULATION

2. Install insulation to meet Virginia's 2018 R-value requirements[a]. Insulation shall be installed in accordance with the manufacturer's instructions.

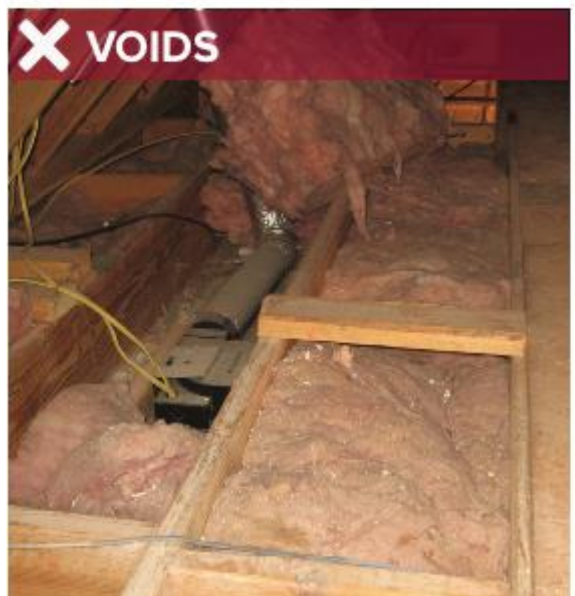
Climate Zone	Ceiling[b]	Frame Wall[c]	Slab	Basement/ Crawl Wall[d,e]	Mass Wall[f]	Floor[g]
Zone 4	R-49	R-15 or 13+1	R-10, 2 ft	R-10/13	R-8/13	R-19

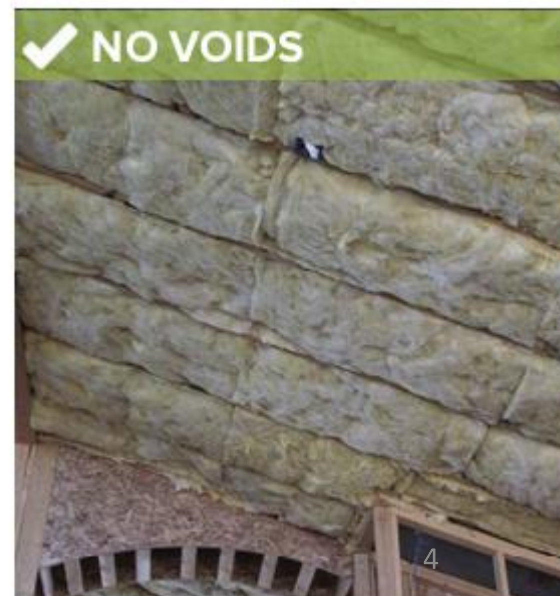
a. R-values are minimums. When insulation is installed in a cavity which is less than the label or design thickness of the insulation, the installed R-value shall not be less than the R-value specified in the table.
b. For air-permeable insulation in vented attics, a baffle shall be installed adjacent to the soffit and eave vents. The baffle shall maintain an opening equal or greater than the size of the vent and extend over the top of the attic insulation.
c. R-values noted are for wood framed walls. R-13 cavity + R-1 insulated sheathing or R-15 cavity will meet the requirement. For kneewalls, the attic side shall have a sealed air barrier.
d. R-10 is continuous and R-13 is cavity.
e. Basement walls shall be insulated from the top of the basement wall down to 10 feet below grade or the basement floor, whichever is less.
f. The second R-value applies when more than half the insulation is on the interior side of the mass wall.
g. Floor insulation shall be installed to maintain continuous permanent contact with the underside of the subfloor decking, and insulation ends shall have air barriers.

IECC Tech Tips
VIRGINIA

TECH TIPS:
INSULATION

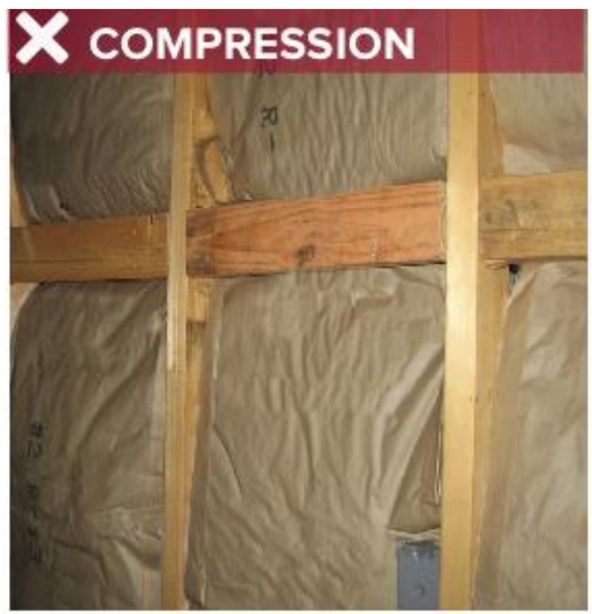
3. Install insulation to fill the cavity between conditioned and unconditioned space without gaps, voids, misalignments or compression.





TECH TIPS:
INSULATION

3. (continued) Install insulation to fill the cavity between conditioned and unconditioned space without gaps, voids, misalignments, or compression.



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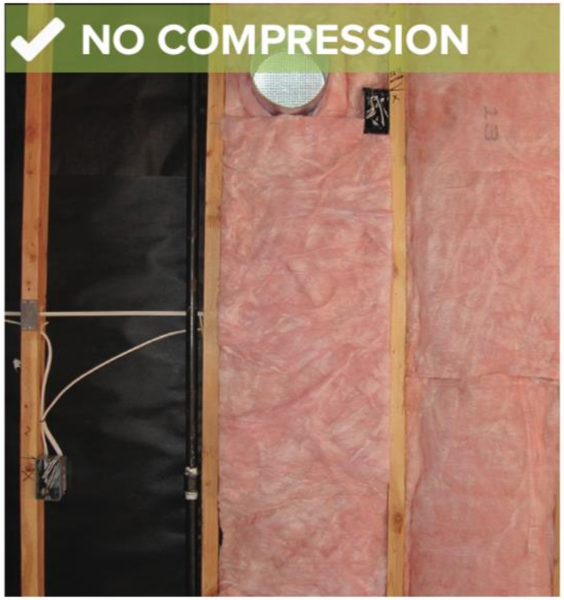
INSULATION

4. Cut and split insulation around all blocking, plumbing, HVAC, and electrical components to obtain a completely full framing cavity.



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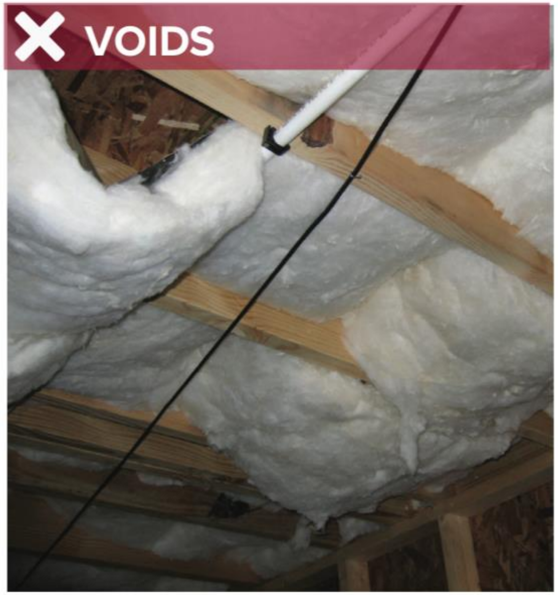
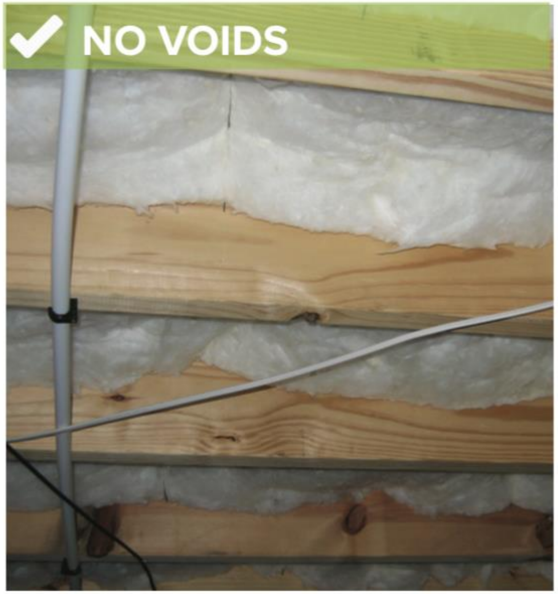
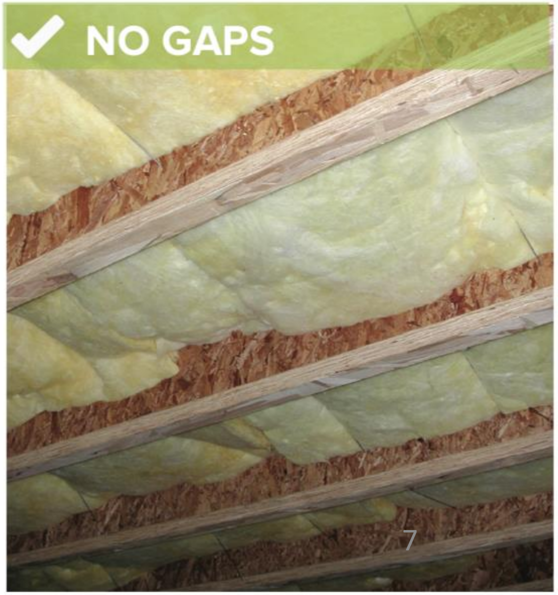
TECH TIPS:
INSULATION

5. Install insulation to completely fill floor framing cavity or to maintain permanent contact with the subfloor without voids or compression.







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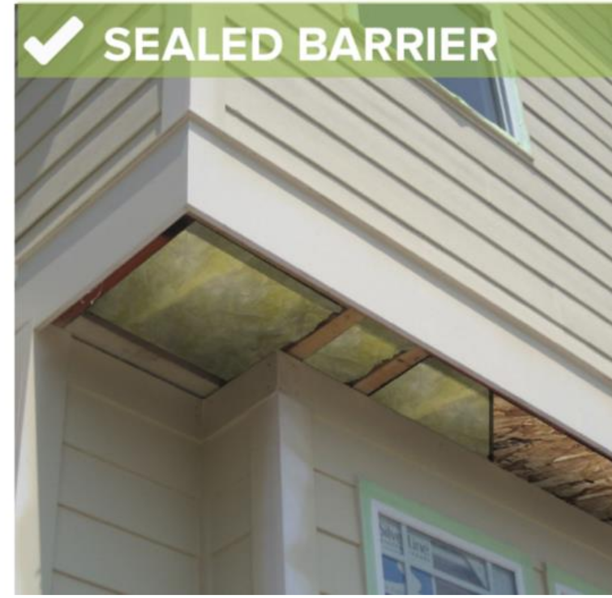
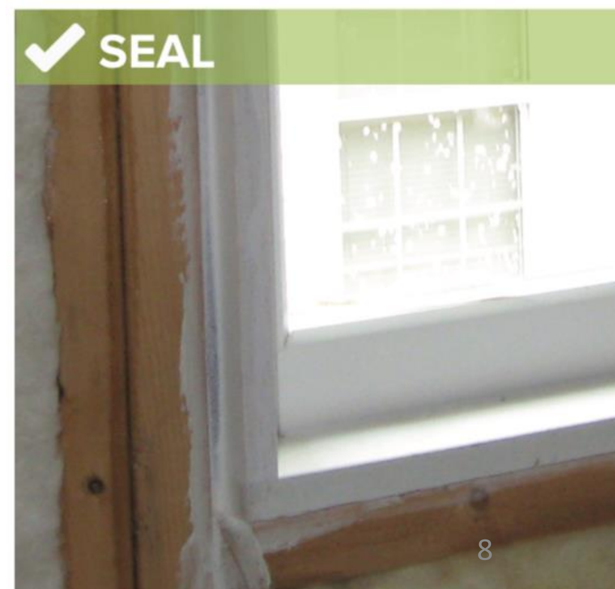
TECH TIPS:
INSULATION

6. For cantilever floors, frame to allow for at least R-19 and encapsulated with an exterior rigid air barrier and air sealing.

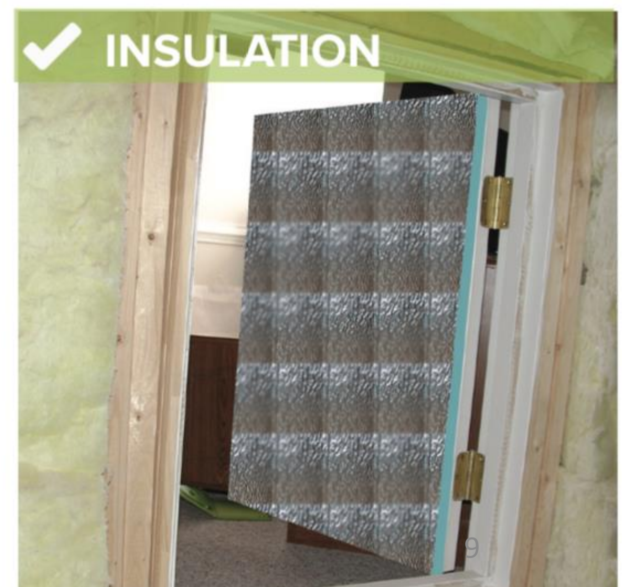


7. Air seal around windows and doors using backer rod, caulk or low expansion foam.



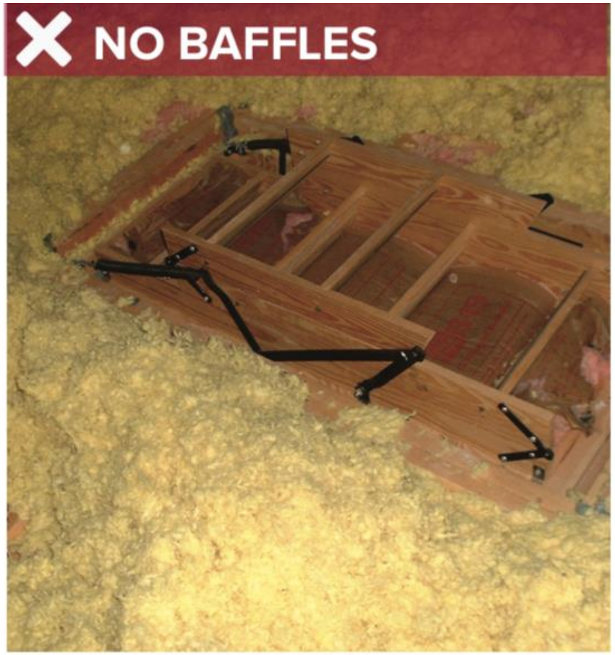
TECH TIPS:
INSULATION

8. Insulate all attic access doors and install weather stripping to make them air-tight.



TECH TIPS:
INSULATION

9. For attics with loose fill insulation, install baffles/dam around the attic access opening to hold insulation in place.



Insulation, Air Barrier and Air Sealing Inspection Checklist

2018 VRC/VECC Inspection Guide

Address: ______________________ Permit #: __________

Inspector: ______________________ Date: __________

Builder: ______________________

Complete	Air Sealing: Component/Inspection Point	N/A	Notes:
☐	All gaps, cracks, seams, and penetrations between conditioned and unconditioned space (i.e. gaps around lighting fixtures, HVAC duct boots, electric wiring, plumbing pipes, and flues) shall be sealed with sealants alone (e.g., caulk, foam, aerosol sealant) or, for larger gaps, with rigid blocking material (e.g. backer rod) sealed in place with sealants, per sealant manufacturer's instructions. Fibrous insulation is NOT an air barrier and shall not be used for air sealing	☐	
☐	The space between window/door jambs and framing, and skylights and framing shall be sealed. Fibrous insulation is not an air barrier and shall not be used for air sealing	☐	
☐	The junction of the foundation and sill plate shall be sealed	☐	
☐	The junction of the top plate and the top of exterior walls shall be sealed	☐	
☐	Seams where drywall attaches to the top plate at all interior and exterior walls shall be sealed from the attic side with a caulk, spray foam, or sprayer-applied sealant	☐	
☐	Larger gaps and openings (such as uncovered dropped soffits and openings under knee walls or at the tops of balloon-framed gable walls) shall be closed off using a solid material such as rigid foam or OSB that is sealed at the edges with caulk, sealant, or mastic	☐	
☐	Gaps around masonry chimneys or gas appliance vents shall be sealed with high-temperature-rated caulk or foam in accordance with building code requirements	☐	
☐	A continuous gasket, such as weather stripping, shall be installed around all exterior door openings	☐	
☐	Recessed lighting fixtures installed in the building thermal envelope shall be air tight and IC rated	☐	
☐	Air sealing shall be provided between the garage and conditioned spaces	☐	
Notes:			

Complete	Wall Insulation, Air Barrier and Air Sealing	N/A	Notes:
☐	A continuous air barrier shall be installed in the building envelope. The exterior thermal envelope contains a continuous air barrier	☐	
☐	Insulation installed to be in full contact with the air barrier (the drywall to the inside and the sheathing or weather resistant barrier to the outside). If air-permeable insulation is not encapsulated by an air barrier on all six sides, it WILL NOT insulate properly	☐	
☐	Insulation is installed to fill 100 percent of cavity	☐	
☐	If batts are installed, the batt is cut to fit around all plumbing, heating and electrical penetrations and other obstacles. It is split to go behind and in front of wires and plumbing. This is done in such a way as to fill all cavity spaces and gaps, while *not* compressing the insulation	☐	
☐	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	☐	
☐	Walls are framed to allow the corner to be insulated or continuous insulation is/will be installed	☐	
☐	Exterior walls adjacent to showers and tubs shall be insulated	☐	
☐	The air barrier installed at exterior walls adjacent showers and tubs shall separate the tub/shower from the exterior wall and be air sealed	☐	
☐	The air barrier shall be installed behind electrical or communication boxes or air-sealed boxes shall be installed	☐	
☐	Crawl space walls: Where provided instead of floor insulation, insulation shall be permanently attached to crawlspace walls	☐	
☐	Rim joists: Rim joists shall be insulated	☐	

☐	When utilized: exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier	☐	
Notes:			
Complete	Attic Insulation, Air Barrier and Air Sealing	N/A	Notes:
☐	Before installing fibrous attic floor insulation, baffles shall be installed at all attic eaves adjoining vented soffits to prevent air flow through the insulation and to provide a path for ventilation air from the soffit vents to the ridge vents. The baffles shall extend at least 6 inches above the height of the attic insulation	☐	
☐	Attic insulation extends all of the way to the exterior edge of the top plate of the wall below without compression. Roof-framing details, such as raised-heel trusses or oversized trusses, must allow for this	☐	
☐	R-15 or R-13+1 insulation shall be installed at attic knee walls, skylight shaft walls, vertical portions of all dropped ceilings, and any other vertical wall adjoining conditioned space	☐	
☐	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed	☐	
☐	All joints, cracks, and penetrations in the wall air barrier shall be fully sealed with caulk, foam, or equivalent	☐	
☐	Attic insulation shall be installed at all flat and sloped surfaces adjoining the conditioned space with no gaps, voids, or compression and at levels that meet or exceed prescriptive levels specified by the 2018 Virginia Energy Conservation Code	☐	
☐	All blown-in or sprayed fiberglass or cellulose attic insulation shall be uniform and conform to manufacturer-specified density with attic rulers to verify full depth	☐	
☐	Attic hinged vertical doors insulated to a minimum of R-5, drop-down stairs insulated with a minimum of R-5 rigid insulation on 75% of the panel, and hatches to a level equivalent to the surrounding surfaces. All shall be weatherstripped (not caulked) to provide a continuous air seal when closed.	☐	
☐	All non-ICAT recessed light fixtures shall be boxed with a solid material, such as drywall or rigid foam, that is sealed at all seams with a sealant such as caulk, mastic, or spray foam	☐	
☐	Sprinklers: When required to be sealed, concealed fire sprinklers shall only be sealed in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.	☐	
Complete	Floor Insulation, Air Barrier and Air Sealing		
☐	Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing, or continuous insulation installed on the underside of floor framing and extends from the bottom to the top of all perimeter floor framing members	☐	
☐	Air barrier shall be installed at any exposed edge of insulation	☐	
☐	Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped	☐	
Notes:			

Blower Door Test Report

House

Home Address	Permit Number	GPIN

Tester

Testing Company	Name of Tester	Signature

Qualification Held:

- ☐ Virginia licensed general contractor
- ☐ Virginia licensed HVAC contractor
- ☐ Virginia licensed home inspector
- ☐ Virginia registered design professional
- ☐ Certified BPI Envelope Professional
- ☐ Certified HERS rater
- ☐ Certified duct and envelope tightness rater

Test Results

Date: **Test Procedure:** ☐ RESNET/ICC 380 ☐ ASTM E779 ☐ ASTM E1827

Volume of House (cubic feet)	Maximum Allowed (ACH50)	Maximum Allowed (CFM50)	Compliance Status
	5	0.0	Fail
Test Results (CFM50)	**Test Results (ACH50)**	*Attach supporting documentation (software generated report, picture, or similar)*	

During Testing (from N1102.4.1.2 (R402.4.1.2))

1. *Exterior windows and doors and fireplace and stove doors shall be closed, but not sealed beyond the intended weatherstripping or other infiltration control measures;*
2. *Dampers, including exhaust, intake, makeup air, backdraft, and flue dampers shall be closed, but not sealed beyond intended infiltration control measures;*
3. *Interior doors, if installed at the time of the test, shall be open;*
4. *Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed;*
5. *Heating and cooling systems, if installed at the time of the test, shall be turned off; and*
6. *Supply and return registers, if installed at the time of the test, shall be fully open.*

Slab Edge Insulation

2018 VRC/VECC Review Guide

Slab Edge Insulation:

Though the requirements have remained the same in the International Energy Conservation Code (IECC) and International Residential Code (IRC) since 2009, misunderstandings persist regarding placement of insulation, depth of insulation, thermal breaks between conditioned and unconditioned spaces, and how additions or retrofits to existing homes should be handled.

Slabs lose energy primarily as a result of heat conducted outward and through the perimeter of the slab. Installing insulation around the perimeter of the slab edge properly will significantly reduce heat loss and gain through the exposed concrete. *Insulation is included in slab-on-grade construction for two purposes:*

1. *Insulation prevents heat loss in winter and heat gain in summer. This effect is most pronounced at the slab perimeter, where the slab edge often comes in direct contact with outdoor air/ambient conditions as it is placed above grade.*
2. *Even in climates and locations on the slab (perimeter vs. middle) where slab insulation may not confer large energy benefits, thermal isolation of the slab can prevent cool slab temperatures that can cause condensation inside the house. This condensation can lead to mold and other moisture-related problems, especially if the slab is carpeted.*[1]

Items of Note:

- *Typical insulation products used below grade include extruded polystyrene, expanded polystyrene, and rigid mineral fiber panels (Baechler et al. 2005). Extruded polystyrene (XPS) is nominally R-5 per inch. Expanded polystyrene (EPS) is nominally R-4 per inch and can be less expensive. Below-grade foams can be at risk for moisture accumulation under certain conditions.*[2]
  1. *All of the products listed would require 2 inches or more of insulation to achieve R-10.*
  2. *Depth of insulation in relation to wall assemblies can be of concern. Code allows the insulation to be cut away from the wall at a 45 degree angle for this reason.*
- *XPS has a higher initial insulating R-value than does a similar thickness and density of EPS, but the R-value of XPS degrades over time. EPS does not experience as much "thermal drift," and the*

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[1] https://foundationhandbook.ornl.gov/handbook/section4-1.shtml

[2] https://foundationhandbook.ornl.gov/handbook/section4-1.shtml

reported R-value remains the same throughout its lifespan. EPS also has better drying capabilities than XPS, allowing it to perform better below grade in locations that can remain wet for large parts of the year.

* *For durability and insulation efficacy, final grade must be sloped away from the building. Long-term moisture degrades insulating value of slab insulations. Proper compressive strength and ground contact rated insulations should be specified.*

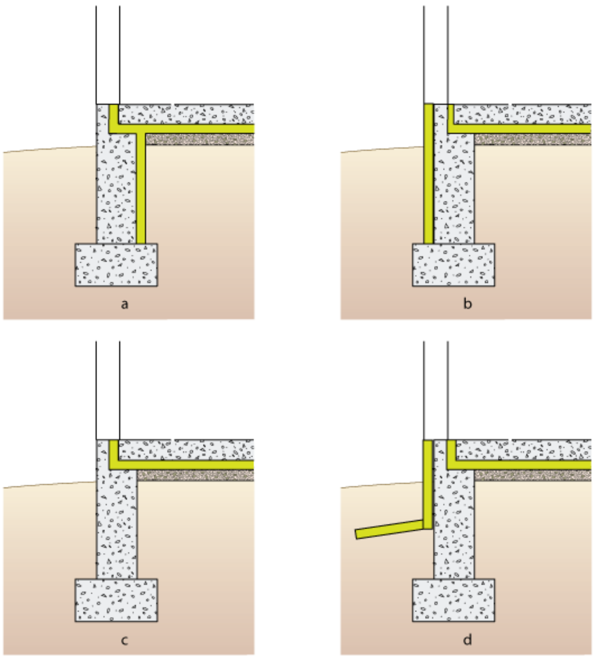

Figure 1: Common slab edge insulation locations[3]

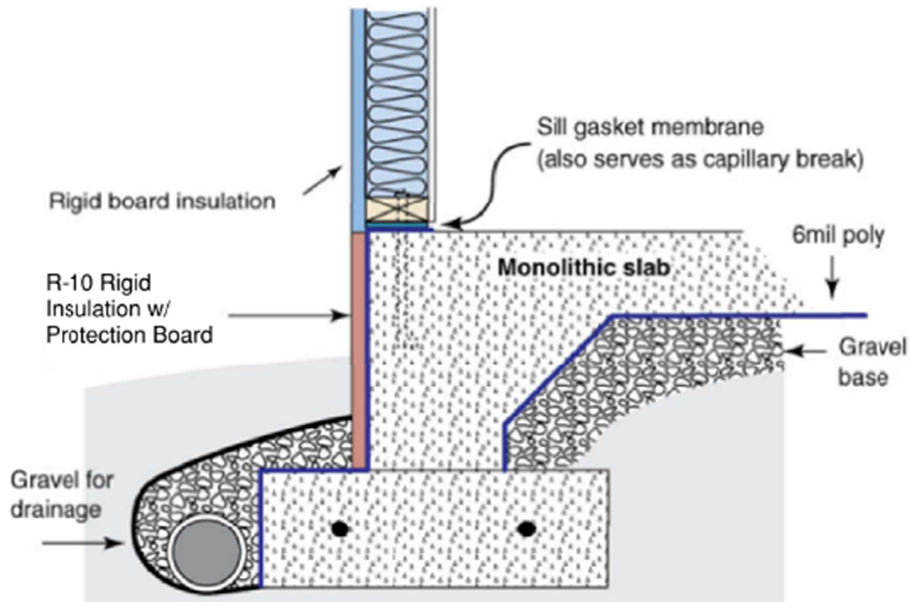

Figure 2: Example of monolithic pour with slab edge insulation

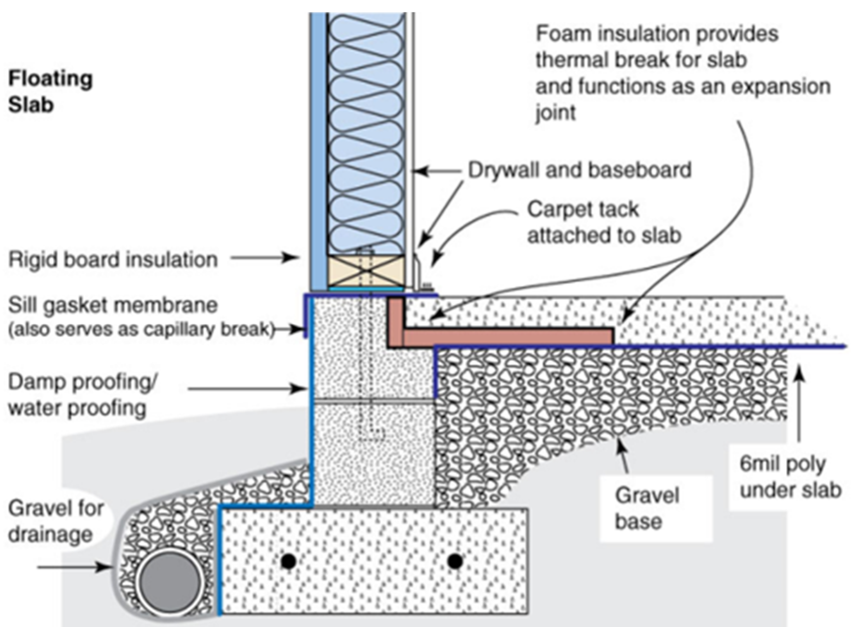

Figure 3: Slab and stem wall configuration

[3] https://foundationhandbook.ornl.gov/handbook/chapter4.shtml

Figure 4: Stem Wall insulated to height of Slab. Insulation to be cut at 45 degree angle away from wall (2018 VRC Code Section **N1102.2.10** (**R402.2.10**))

Figure 5: Slab Edge insulation with flashing and protection.

Plan Review Focus:

Construction Documentation: Review the construction documents for the details describing slab insulation installation and construction techniques.

Vapor Barrier and Under-slab Fill: Ensure that a vapor barrier is specified with all seams overlapped and taped. #57 stone under slabs is recommended as a moisture control strategy but not required by code.

R-Value/Depth: Ensure R-value is denoted in drawings and current details achieve a full thermal break at the slab edge from the top of the slab to 2’ below grade. Ensure thermal envelope is completed leaving no gaps between wall and slab edge insulation coverage.

Insulation Protection: Confirm that the construction documents specify proper insulation protection if applicable. Rigid foam board is typically used for insulating slabs and requires protection if exposed.

Flashing: Confirm that the construction documents specify the proper location for installing flashing and flashing material.

2018 VRC/VECC Code References:

Table N1102.1.2/ R402.1.2

Climate Zone	4 except Marine
Slab R-Value	R-10
Depth	2 ft

Insulation to R-5 should be added to the required slab edge R-values for heated slabs… A heated slab is a type of construction that has a slab-on-grade concrete floor with a heating system embedded in or beneath the slab floor. Building additions that include a slab-on-grade construction also are subject to the slab edge requirements listed in the VRC/VECC.

Section N1101.5/R103.2 Information on Construction Documents. Construction documents shall be of sufficient clarity to indicate the location, nature and extent of the work proposed and show in sufficient detail pertinent data and features of the building, systems and equipment...Details shall include but are not limited to, as applicable:

1. Insulation materials and R-values. (*Items 2-8 not shown, see Chapter 11 of Virginia Residential Code)

Section N1101.10.1/R303.1.1 Building thermal envelope insulation. An R-value identification mark shall be applied by the manufacturer to each piece of building thermal envelope insulation 12" or greater in width. Alternately, the insulation installers shall provide a certification listing the type, manufacturer, and R-value of insulation installed in each element of the building thermal envelope. For blown or sprayed insulation (fiberglass and cellulose), the initial installed thickness, settled thickness, settled R-value, installed density, coverage area, and number of bags installed shall be listed on the certification.

Section N1102.2.10/R402.2.10 Slab-On-Grade Floors. Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table N1102.1.2. The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall. Insulation located below grade shall be extended the distance provided in Table N1102.1.2 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the building. Insulation extending away from the building shall be protected by pavement or by not less than 10 inches (254 mm) of soil. The top edge of the insulation installed between the exterior wall and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.79 rad) angle away from the exterior wall. Slab-edge insulation is not required in jurisdictions designated by the building official as having a very heavy termite infestation.

Section N1101.11.1/R303.2.1 Protection of exposed foundation insulation. Insulation applied to the exterior of basement walls, crawlspace walls, and the perimeter of slab-on-grade floors shall have a rigid, opaque, and weather-resistant protective covering to prevent degradation of the insulation's thermal performance. The protective covering shall cover the exposed exterior insulation and extend not less than 6 inches below grade.

VRC Section R703.4 Flashing. Approved corrosion resistant flashing should be applied in shingle fashion to prevent entry of water into the wall cavity or penetration of water to the building structural framing components.

VRC Section R703.8.5 Flashing. Flashing should be located beneath the first course of masonry above the finished ground level, **above the foundation wall or slab**, and at other points of support including structural floors.

Definitions:

Above-Grade Wall: A wall more than 50 percent above grade and enclosing conditioned space. This includes between-floor spandrels, peripheral edges of floors, roof and basement knee walls, dormer walls, gable end walls, walls enclosing a mansard roof and skylight shafts.

Air Barrier: One or more materials joined together in a continuous manner to restrict or prevent the passage of air through the building thermal envelope and its assemblies.

Building Thermal Envelope: The basement walls, exterior walls, floors, ceilings, roofs and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

Conditioned Space: An area, room, or space that is enclosed within the building thermal envelope and that is directly heated or cooled or indirectly heated or cooled

Heated Slab: Slab-on-grade construction in which the heating elements, hydronic tubing, or hot air distribution system is in contact with, or placed within or under, the slab.

Infiltration: The uncontrolled inward air leakage into a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both.

R-Value: The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area ($h \cdot ft^2 \cdot °F/Btu$) [($m^2 \cdot K)/W$]. **Note: In more general terms, resistance to heat flow of a single material, expressed as a whole number. Higher numbers denote higher resistance to heat flow*

Slab-on-Grade: Slab floor less than 12" below grade requiring insulation

U-Value: The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films (Btu/h • ft^2 • °F) [W/(m^2 • K)]. **Note: In more general terms, resistance to heat flow of multiple materials expressed as a decimal point. Lower numbers denote higher resistance to heat flow*

Vapor Retarder Class: A measure of the ability of a material or assembly to limit the amount of moisture that passes through that material or assembly. Vapor retarder class shall be defined using the desiccant method with Procedure A of ASTM E96 as follows:

- Class I: ≤0.1 perm rating
- Class II: > 0.1 to ≤ 1.0 perm rating
- Class III: > 1.0 to ≤ 10 perm rating

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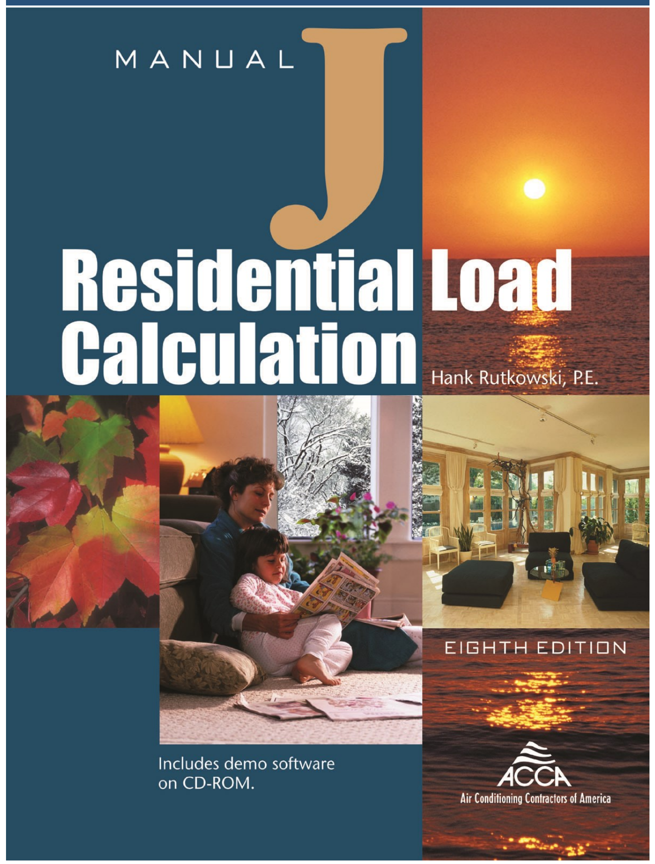
The Air Conditioning Contractors of America (ACCA) is dedicated to excellence in the heating, ventilation, air conditioning and refrigeration (HVACR) industry. As the largest HVACR contractor organization, ACCA is committed to helping its members succeed. Some of the fundamental ways in which our efforts are seen, are in the technical resources and industry standards, that guarantee quality HVACR design, installation and maintenance.

Sponsored by the ACCA Code Committee

The ACCA Code Committee was formed to address code issues and in particular, *to advise and assist ACCA in beneficially representing the contractors in the code processes that affect the HVACR industry.* This information has been provided for entities, seeking to verify that load calculations for an HVACR application have been correctly performed. For more information, contact:

Surumi Hudacsko
Phone: 703-824-8847
Fax: 703-575-9147

Verifying ACCA Manual J® Procedures



Includes load calculation checklist

ACCA
AIR CONDITIONING CONTRACTORS OF AMERICA

WHY ARE HEAT LOSS AND HEAT GAIN CALCULATIONS IMPORTANT

Achieving occupant satisfaction is the principal goal of any HVAC design. Primary factors impacting occupant satisfaction include: filtration, temperature and humidity control, air motion in the room, adequate ventilation, interior zoning needs and energy efficient operation. Occupant satisfaction is maximized when the heating and cooling system and equipment are the correct type and size and the air distribution system is properly designed and installed.

For residential applications, ACCA's Manual J, Eighth Edition (MJ8™) is the only procedure recognized by the American National Standards Institute (ANSI) and specifically required by residential building codes. Methods not based on actual construction details, nor founded on relevant physical laws and engineering principles, are unlikely to result in correct equipment sizing.

PROBLEMS WITH OVERSIZED EQUIPMENT

Oversized equipment results in marginal part load temperature control. While the temperature control at the thermostat may be satisfactory, equipment cycling may cause noticeable temperature swings in other rooms and larger temperature differences between rooms. Oversized equipment may cause degraded humidity control and increase the potential for mold growth, allergic reactions and respiratory problems. In these unfavorable conditions, occupants may experience additional discomfort and dissatisfaction. Other negative effects are higher installed costs, increased operating expenses, and increased maintenance costs. Furthermore, oversized equipment generally requires larger ducts, poses additional requirements on the power grid and may lead to more service calls.

REASONS FOR OVERSIZED EQUIPMENT

Three main reasons for oversized equipment are: (1) a guess is made on the load; (2) mistakes are made in the load calculation; (3) the equipment is selected for either unusual/extreme conditions such as abnormal temperatures or unusual occupancy loads (i.e. gatherings/parties). Other reasons include the use of inappropriate and inadequate "rules of thumb" such as '500ft^2/ton', '400CFM/ton', or 'total cooling capacity = 1.3 x sensible cooling capacity'. Furthermore, seemingly trivial mistakes such as ignoring building efficiency upgrades and assuming that the original design and installation are correct, all contribute towards inappropriate equipment sizing.

MANUAL J® VERIFICATION

While it is not practical to verify every aspect of a submitted MJ8 calculation, it is a good practice to review key elements that indicate general integrity of the calculations i.e. the contractor has made a good faith effort to provide reasonably accurate loads.

ITEMS TO VERIFY

The key load elements, grouped in roughly decreasing levels of impact on the overall contribution to the loads, are:

IMPACT ON LOAD

HIGH	✓ Design Temperatures (Indoor and Outdoor) ✓ Windows, Glass Doors and Large Skylights (shading, overhangs, etc.) ✓ Ducts (location, leakage and duct wall R-values) ✓ Ceilings under an attic (R-values, roof material, roof color)
MEDIUM	✓ Small Skylights ✓ Infiltration ✓ Ventilation
LOW	✓ Appropriately Insulated Floors ✓ Appropriately Insulated Walls ✓ Internal Gains

It is also worth noting some unusual items that also contribute to the load. These include:

- Hot Tubs
- Whirlpool Tubs
- Three-season Porches

A NOTE ON UNDERSTANDING THE DESIGN PROCESS

Manual J allows contractors to perform a load calculation on a residential building/home. Apart from the load calculation being performed, the ducts must be sized and the correct size equipment must be selected. ANSI-recognized ACCA Manual D® for duct sizing and ACCA Manual S® for residential equipment selection provide guidance here.

The order of this checklist follows Form J1 of ACCA Manual J8®.

#	Key Item	Check	Questions to Ask	Circle Answer*		
1	Design Temperatures	✓ Indoor Design Temperatures	Is the indoor design temperature for *Heating*: per Local Code OR 70°F (21°C) at 30% RH?	YES	NO	-----
			Is the indoor design temperature for *Cooling*: per Local Code OR 75°F (24°C) at 50% RH? [or 55% for humid climate, 45% for dry climate?]	YES	NO	-----
		✓ Outdoor Design Temperatures	Is the outdoor design temperature per Table 1 of MJ8 or Local Code?	YES	NO	-----
2	Windows & Glass Doors	✓ U-values and SHGC values	Are the SHGC and U-values reasonable for the window types and frame constructions? (see Table 2 of MJ8)	YES	NO	-----
		✓ Shading Adjustments	Have window shading (curtains, drapes, insect screens, tinting, etc.) adjustments been made?	YES	NO	-----
		✓ Overhang Adjustments	Have roof overhang adjustments been made?	YES	NO	-----
		✓ Total Area	Is the total area for the windows & glass doors roughly equal to the area shown on the drawing plans?	YES	NO	-----
		✓ Exposure Directions	Do the exposure directions [North (N), North-East (NE), etc.] appear correct?	YES	NO	-----
3	Skylights	✓ U-values and SHGC values	Are the SHGC and U-values appropriate for the skylight types and frame constructions? (see Table 2 of MJ8)	YES	NO	N/A
		✓ Shading Adjustments	Have adjustments been made for drapes, tinting and reflective coatings?	YES	NO	N/A
		✓ Total Area	Is the total area for the skylights roughly equal to the area shown on the drawing plans?	YES	NO	N/A
		✓ Exposure Directions	Do the exposure directions [North (N), North-East (NE), etc.] appear correct?	YES	NO	N/A
4	Doors | Wood, Metal	✓ *None*	--	-----	-----	-----
5	Walls | Above Grade, Below Grade	✓ Insulation	Are correct wall insulation R-values taken into account when the wall loads are calculated?	YES	NO	-----
		✓ Total Area	Is the total area for the walls equal to the area shown on the drawing plans?	YES	NO	-----
6	Ceilings	✓ Insulation	Is correct ceiling insulation R-value taken into account when the ceiling load is calculated?	YES	NO	N/A
		✓ Radiant Barrier	If applicable, does the load calculation take credit for a radiant barrier?	YES	NO	N/A
		✓ Roof color and material	Is correct roof color and material taken into account when the ceiling load is calculated?	YES	NO	-----
		✓ Total Area	Is the total area for the ceilings equal to the area shown on the drawing plans?	YES	NO	-----
7	Floors	✓ Insulation	Is the floor insulation and type of construction representative of what is built/planned?	YES	NO	-----
8	Infiltration	✓ Envelope Tightness	Is the listed envelope tightness (tight, semi-tight, average, semi-loose, loose) appropriate?	YES	NO	-----
		✓ Above grade volume	Is the total above grade volume equal to what is shown on the drawing plans?	YES	NO	-----
9	Internal Gains	✓ Appliances	Are the appliance gains 1200 Btuh, 2400 Btuh or a value recommended by MJ8?	YES	NO	-----
		✓ Occupants	*Is Maximum Number of Occupants = Number of Bedrooms + 1?*	YES	NO	-----
			- Is Btuh (sensible) = 230 x Number of Occupants? - Is Btuh (latent) = 200 x Number of Occupants?	YES	NO	-----
10	Ducts	✓ Duct Location	If located in an unconditioned space, are the ducts insulated (appropriate R-value)?	YES	NO	N/A
		✓ Duct Tightness	Is the duct tightness category 'average sealed' or higher (i.e. notably sealed, extremely sealed)?	YES	NO	-----
11	Ventilation	✓ Intermittent Fans	Are intermittent bathroom and kitchen fans <u>excluded</u> from the infiltration calculations?	YES	NO	N/A
		✓ Continuous Exhaust Fans	Are dedicated exhaust fans (continuous) <u>included</u> in the calculations?	YES	NO	N/A
		✓ Heat Recovery Equipment	Are the heat recovery equipment and/or a ventilating dehumidifier included in the calculations (if applicable)?	YES	NO	N/A

*Questions should be answered 'YES' (where applicable) to achieve representative load calculation.

Friction Rate Worksheet

Step 1) Manufacturer's Blower Data

External Static Pressure (ESP) = 0.70 IWC CFM= 1200 CFM

Step 2) Device Pressure Losses (DPL)

Direct expansion refrigerant coil………	0.23 IWC
Electric heat resistance coil……………	
Hot water coil…………………………	
Filter………………………………….	0.18 IWC
Humidifier…………………………….	
Supply outlet…………………………	0.03 IWC
Return grille………………………….	0.03 IWC
Balancing dampers……………………	0.03 IWC
Other device………………………….	
Total device losses ………..............	0.50 IWC

Step 3) Available Static Pressure (ASP)

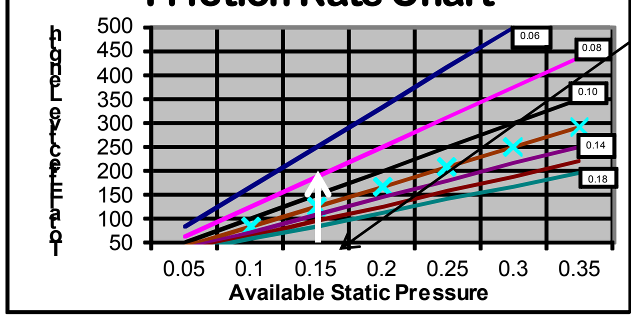
ASP = ESP – DPL (Step 1 – Step 2) 0.20 IWC

Step 4) Total Effective Length (TEL)

Supply side TEL + Return side TEL = 200 ft TEL

Step 5) **Friction Rate** Design Value [FR= (ASPx100)÷TEL] 0.10 IWC from chart below

Friction Rate Chart



A — From manufacturer's data—equipment CFM at rated capacity

B — From Manufacture's Blower Performance Data corresponding to the CFM (#1)

C — From Manufacturer's Performance Data

D — **Total Effective Length** ≈ loss from duct lengths, reducers, elbows and other fittings

E — **Friction Rate** is found by reading bottom scale to 0.20 and up the side scale to 200 feet the intersecting line is the 0.10. That is the design friction rate. This example, 0.10, is within the acceptable friction rate range.

F — The **Design CFM** for each room is based on the larger of the Cooling or Heating CFM. Those heat and cool CFM come from the allocation of the system's capacity based on each room's heating and cooling needs.

G — The **Friction Rate** is used to determine the duct size.

H — The **return duct size** is based on the friction rate and then may be adjusted to a larger size to meet recommended velocity.

I — **Grille and register sizes** should be selected to ensure the velocities are acceptable.

Recommended Velocity (FPM) (Manual D, Table 3-1)

	Supply				Return			
	Recommended		Maximum		Recommended		Maximum	
	Rigid	Flex	Rigid	Flex	Rigid	Flex	Rigid	Flex
Trunk Ducts	700	600	900	700	600	600	700	700
Branch Ducts	600	600	900	700	400	400	700	700
Supply Outlet Face Velocity	Size for Throw		700					
Return Grille Face Velocity								500
Filter Grille Face Velocity								300

Table of Useful Air Distribution System Design Information

Zone:	One	Design Friction Rate	0.10	Type of System:	Trunk and Branch
Construction Material	Supply Air Trunk	Metal	Supply Air Branch	Flex	
Construction Material	Return Air Trunk	Duct board	Return Air Branch	Flex	
R-Value of Insulation	Supply	R6	Return	R6	

Room	Design CFM	Supply Duct Size(s)	Supply Grille(s) Size, and Velocity	Return Duct Size(s)	Return Grille Size and Velocity
Bedroom 1	150	1 – 8”	1 - 14x6, 600fpm	(9”)- 12”	14x14, 300fpm
Walk-in-Closet	15	1 – 4”	1 - 8x4, 450fpm		
Bedroom 2	100	2 – 6”	2 - 10x4, 600fpm	(7”) - 8”	14x8, 275fpm
Bedroom 3	100	1 – 7”	1 - 12x4, 600fpm	(7”) - 8”	14x8, 275fpm
Living Room	275	2 – 8”	2 - 14x6, 575fpm	(16”)- 18”	24x24, 350fpm
Den	125	1 – 8”	1 - 14x6, 600fpm		
Dining	125	2 – 6”	2 - 10x4, 600fpm		
Foyer	80	1 – 6”	1 - 10x4, 600fpm		
Kitchen	125	2 – 6”	2 - 10x4, 625fpm	ACCA does not recommend installing return ducts in kitchens, baths, laundry, or utility rooms	
Bath 1	65	1 – 6”	1 - 10x4, 600fpm		
Bath 2	40	1 – 5”	1 - 8x4, 500fpm		
Bath 3					
TOTALS	1200				

Notes:

Types of Supply System: Trunk and Branch, Perimeter Loop, Radial

Construction Materials: Sheet metal, Fiberglass Ductboard, Rigid Round Fiberglass, Flexible Vinyl Duct, Fiberglass Duct Liner w/ Facing, Flexible Metal Duct

Verifying ACCA Manual D® Procedures

Why are duct design calculations important?

Achieving occupant satisfaction is the principal goal of any HVAC design. For residential air duct designs ACCA's Manual D is the procedure recognized by the American National Standards Institute (ANSI) and specifically required by residential building codes. Air is the first word in air conditioning. If the network of ducts carrying the air is not properly designed then the health and safety of the occupant are at risk, the equipment could fail more quickly, the energy costs could rise, and occupant comfort might be sacrificed.

What problems come from wrong sized ducts?

In order for home owners to be comfortable a duct system must be designed to carry the right amount of air, at the right speed, into the right room. If the ducts are the wrong size then the wrong amount of air will enter the room and may cause:

- The room to be too warm or too cool
- The air to be too drafty and disturb people while they sleep, eat, read, etc...
- The air to be too noisy and drown out conversations, TV or radio programs, etc...
- The air to be too slow – the conditioned air will not circulate or mix well in the room.
- The fan to work harder, possibly fail sooner, and use more energy to move air
- The furnace or air conditioner safety devices to stop equipment operation
- Pressure differentials that may increase energy costs by pushing out conditioned air or drawing in unwanted air

For a more detailed analysis on the design process

visit www.acca.org for

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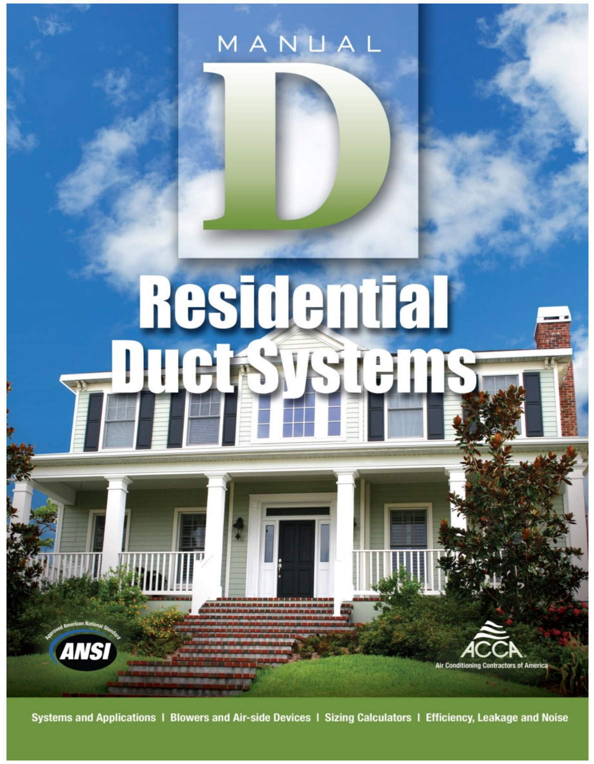
Verifying ACCA Manual D®



Includes Duct Inspection Checklist

AIR CONDITIONING CONTRACTORS OF AMERICA®

2800 Shirlington Road, Suite 300
Arlington, VA 22206

Phone 703-824-4477
Fax 703575-4449

ACCA's Manual D Residential Duct Design Checklist

Key Item	Check	Questions to Ask
Information from load calculation	CFM for each room	Does each room have a heating and cooling CFM assigned? (Proportioned air supply based on Manual J8 room-by-room load calculations) (F)
Manufacturer's Data	Manufacturer's External Static Pressure (ESP)	According to the manufacturer's data will the fan produce the specified airflow at the specified static pressure? (Manufacturers produce a graph that relates air flow and static pressure) (A) (B)
	Accessory and device pressure losses	Did the contractor submit the manufacturer's data specifying the pressure drop for any item in the air stream like a high efficiency filter or a hot water coil? (C)
Manual D Friction Worksheet	Available Static Pressure (ASP)	Are supply outlets, return grilles, and balancing dampers listed at a standard 0.03?
		Are the pressure drops listed for other external devices: filters, coils, etc...? (C)
	Total Effective Length (TEL)	Did the contractor calculate the TEL by adding the longest Supply Total Effective Length and the longest Return Total Effective Length? (Total Effective Length = the length of the duct from outlet back to unit + the effective length for all fittings, i.e., elbows, reducers, take-offs, etc…) (D)
	Friction Rate design value	Did the contractor use the Friction Rate Chart or calculate Friction Rate [FR = ASP x 100 / TEL] (E)
Air Distribution System Design	Branch Lead Size	Did the contractor size the ducts based on the design CFM, friction rate, and the duct material used? (G)
	Trunk Size	Did the contractor select a supply trunk duct large enough to accommodate all the supply branch leads?
	Return Trunk Duct Velocities	Did the contractor select the return trunk duct large enough to meet the lower return air velocity requirements? (H)
	Return air path	Verify each occupied room has an open air path (ACCA recommends a ducted return for each bedroom, den, library, etc…)
Manual T	Register and Grille Face Velocities	Does the air velocity across the register or grille exceed the Recommended Velocity Chart? (Grille manufacturers list the face velocity for grilles and registers at a given CFM, e.g., 12 x 4 - Model XYZ, 500fpm at 120cfm (I)

Sponsored by the ACCA
Codes Committee

2800 Shirlington Road
Suite 300
Arlington, VA 22206

Phone: 703-575-4477
Fax: 703-575-9147

ACCA (Air Conditioning Contractors of America) is dedicated to excellence in the HVACR industry. As the largest HVACR contractor organization, ACCA is committed to helping its members succeed. Some of the fundamental ways in which our efforts are seen, are in the technical resources and industry standards, that guarantee quality HVACR design, installation and maintenance.

The ACCA Codes Committee was formed to address code issues and in particular, *to advise and assist ACCA in beneficially representing the contractors in the code processes that affect the HVAC industry*. This document has been written for code officials, seeking to verify that HVAC equipment has been selected in order to meet the home's load requirements.

For a more detailed analysis on the design process
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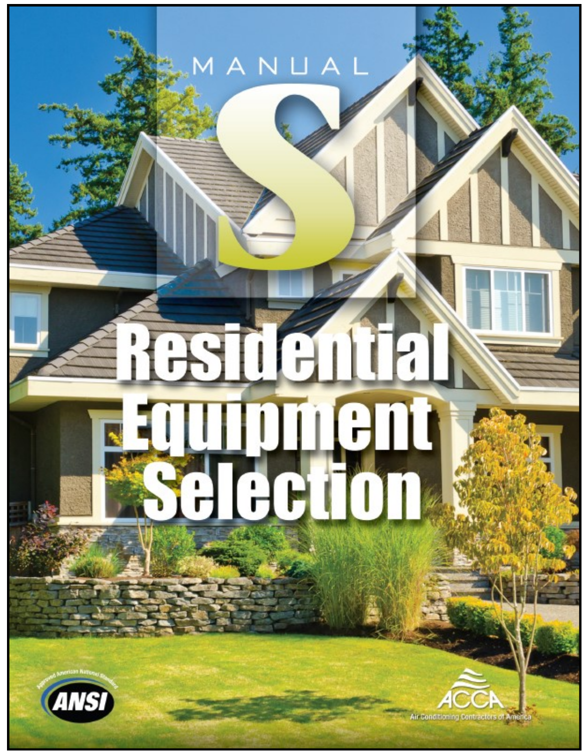


Includes Equipment Selection Checklist & Example

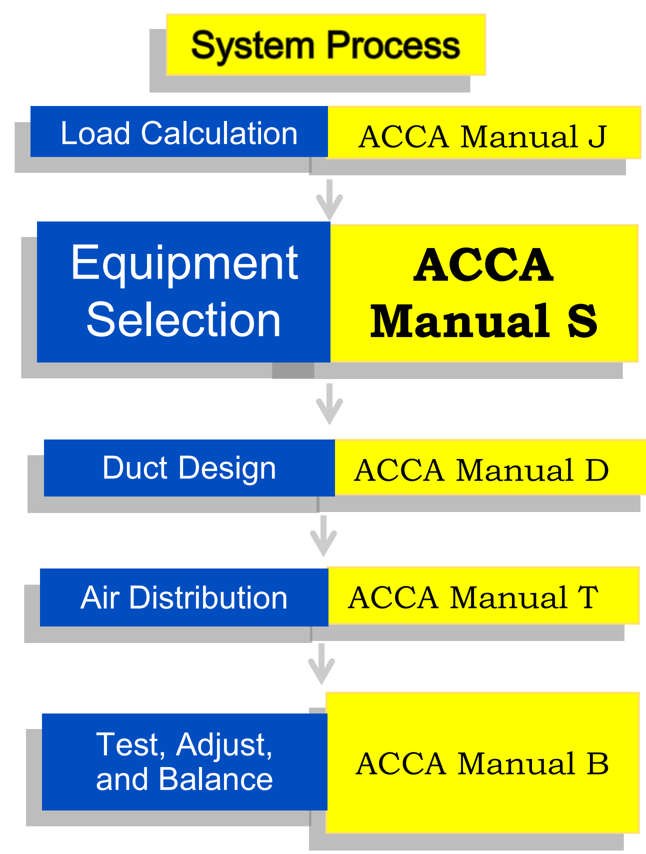
Verifying ACCA Manual S® Procedures

Why is proper equipment selection important?

Achieving occupant satisfaction is the principal goal of any HVAC design. Occupant satisfaction is maximized when the heating and cooling equipment are the correct type and size to meet the capacity requirements from the Manual J load calculation.

For residential equipment selections, ACCA's Manual S®, is the only procedure recognized by the American National Standards Institute (ANSI). If the Manual J load calculation is done then the next step is to select the equipment that will deliver the necessary heating and cooling.

ACCA'S Residential Design Manuals



What problems come from the wrong size equipment?

Undersized equipment will not meet the customer's comfort requirements at the design specifications.

Oversized equipment will create other problems:

- Degraded humidity control in the summer.
- Occupants may suffer the effects of an increased potential for mold growth. These same conditions also may contribute to asthma and other respiratory conditions.
- The temperature may feel right at the thermostat but the temperature in other rooms will suffer from the oversized equipment going through short operation cycles. Short cycles can cause temperature swings as the equipment over-conditions, stops, then over-conditions, etc…
- Hot and cold spots between rooms because the thermostat is satisfied but the room is not.
- Oversized equipment generally requires larger ducts, increased electrical circuit sizing and larger refrigeration tubing. These cause higher installed costs and increased operating expenses.
- The equipment starts and stops more frequently, this causes excessive wear and can increase maintenance costs / service calls.

In these unfavorable conditions occupants will experience discomfort and dissatisfaction.

What are some reasons for oversized equipment?

Manufacturers take great care in measuring and testing how well their equipment performs at different operating conditions.

When contractors use this data to select the equipment they will meet the heating and cooling needs of their customers.

Two main reasons for oversized equipment are either that: (1) a guess was made on the equipment's capacity at the design conditions or (2) mistakes were made in the selection process.

Equipment Selection Checklist

#	Key Item	Verify	Verification Questions
1	Design Conditions	The design conditions fall within specifications.	Do the design conditions fall within the minimum standards for this region as found in Manual J8 Table 1A or 1B? (A)
		The information from the Manual J load calculation was transferred accurately.	Was the Total Heat Gain / Loss information used to evaluate equipment candidates? (B)
2	OEM's Performance Data	The equipment manufacturer's performance parameters match the design parameters used to calculate the heat load.	Does the manufacturer's performance parameters match the design parameters used to calculate the home's heat load (i.e., outdoor dry-bulb, indoor dry-bulb, and indoor wet-bulb)?
			If the performance data parameters are more than 5% greater or less than the design parameters then did the contractor interpolate the equipment manufacturer's performance parameters to match the design parameters used to calculate the heat load?
3	Equipment Performance	Estimated Cooling – CFM based on Temperature Difference	Was the Sensible Heat Ratio calculated? (Sensible Load / Total Load)? (C)
			Was the SHR used to find the proper air flow? (D)
		Equipment selected satisfies Total Btus (for cooling the Sensible and **Latent** load)	Is the total heating capacity of the selected equipment ≤140% of the designed total heating load? (If not reduce equipment size) (E)
			Is the total cooling capacity of the selected equipment ≤115% of the designed total cooling load ? (If not reduce equipment size) (F)
			Does the "Sensible" and/or "Latent" capacities of the selected equipment meet the load's requirements? (G)
			If a heat pump in a very cold climate (heating is primary concern) does the total cooling capacity of the selected equipment exceed 125% of the designed total cooling load?
4	Auxiliary Heat	Heat Pump Balance Point	Does the electric auxiliary heat provide the necessary BTUs to makeup difference in capacity from the heat pump's balance point to the design load conditions? (H)

Equipment Selection using an ExampleChecklist

Design

Winter Design Conditions		
Outdoor °F:	27°F (A)	From Manual J8 Table 1A or 1B
Indoor °F:	70°F	Manual J8 §3-6 defaults to 70°F
Total Calculated Heat Loss	50,981Btu/h (B)	Determined by Manual J8 load calculation

Summer Design Conditions		
Outdoor°F:	85°F (A)	From Manual J8 Table 1A or 1B
Indoor °F:	75°F	Manual J8 §3-6 defaults to 75°F
Entering Wet Bulb (EWB):	63°F	Manual J8 §3-6 defaults to 63°F EWB (≈ 75°F / 50% RH)
Total Heat Gain	27,543Btu/h (B)	Determined by Manual J8 load calculation
Sensible Heat Gain	23,321Btu/h (G)	
Latent Heat Gain	4,222Btu/h (G)	
Sensible Heat Ratio (SHR)	85% (C)	See formula below
Design Air Flow	1,116 CFM (D)	The "*TARGET*" airflow, we look for equipment that operates in this range ($^{+}$/- 10%), on **medium** fan speed

$$SHR = \frac{\text{Sensible Heat}}{\text{Total Heat Gain}} \quad (C)$$

$$\frac{23{,}321\text{Btu/h}}{27{,}543\text{Btu/h}} = .85 \quad (D)$$

Sensible Heat Ratio versus Temperature Design Value	
SHR	Recommended Temp. Design
Below 0.80	21°F
0.80 – 0.85	19°F
Above 0.85	17°F

85% ≈ 19° Design Temp

$$CFM = \frac{\text{Sensible Heat Gain}}{\text{Design Temp x 1.1}}$$

$$1{,}116\ CFM = \frac{23{,}321\ \text{Btu/h}}{19 \times 1.1}$$

Application Data: Equipment Capacity

A furnace was selected for comparing "heating only" design and performance. Other types of equipment may be used.

Furnace Model Number:	FU600300	Fictitious furnace
Output BTUH:	52,000Btu/h (E)	Furnace Btu/h Output: (≤ 140% of calculated loss)

A heat pump was selected for comparing cooling and heating design and performance. Other types of equipment may be used.

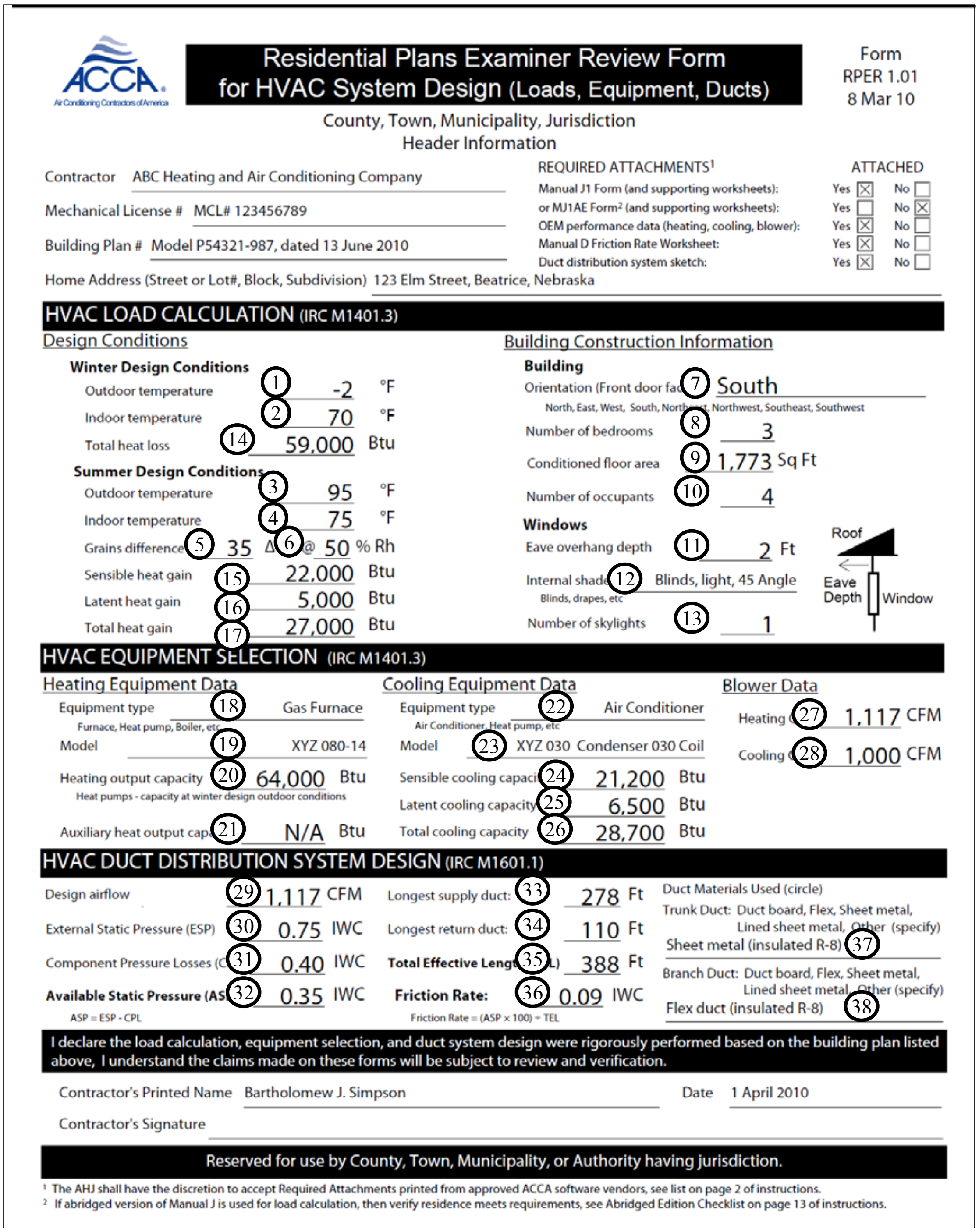
Outdoor Unit Model Number:	HP-030	Fictitious heat pump
Total Cooling Capacity (≤ 115%)	28,400Btu/h (F)	These capacities are from manufacturer's performance data at the **DESIGN CONDITIONS:** 85°F ODT, 1,000CFM, and 63°F EWB
Sensible Cooling Capacity (≈ Sensible Gain)	21,600Btu/h (G)	
Latent Cooling Capacity (≈ Latent Gain)	6,800Btu/h (G)	
Indoor Unit Model Number:	AH-030	Fictitious air handler
Indoor Blower CFM (CFM in manufacturer's performance data at rated capacity-medium fan speed):	1,000 (D)	The actual equipment rated airflow, (medium fan speed optimal) should fall within target CFM,($^{+}$/ - 15%)
Btuh Difference between Heat Pump Balance Point and Total Heat Loss	30,281 Btu/h (H)	This heat pump can only produce 20,700Btu/h at design conditions. More capacity is required. (Air Conditioners do not have a balance point.)
Auxiliary Heat (Circle): Electric Gas Oil	10 KW (H)	In this example the auxiliary heat is electric, the formula for electric heat is KW= Btu/h ÷ 3.413

From Manual J8 Tables	From Manual J8 Load Calculation	From Equip. Performance Data

Understanding and Using the HVAC Design review Form

Each of the 38 points of requested information is discussed, and references to the supporting manual are given to substantiate the requirement.

Table of Contents



Residential Plans Examiner Review Form for HVAC System Design (Loads, Equipment, Ducts)

Form RPER 1.01 8 Mar 10

County, Town, Municipality, Jurisdiction

Header Information

Contractor: ABC Heating and Air Conditioning Company

Mechanical License #: MCL# 123456789

Building Plan #: Model P54321-987, dated 13 June 2010

Home Address (Street or Lot#, Block, Subdivision): 123 Elm Street, Beatrice, Nebraska

REQUIRED ATTACHMENTS[1]	ATTACHED	
Manual J1 Form (and supporting worksheets):	Yes ☒	No ☐
or MJ1AE Form[2] (and supporting worksheets):	Yes ☐	No ☒
OEM performance data (heating, cooling, blower):	Yes ☒	No ☐
Manual D Friction Rate Worksheet:	Yes ☒	No ☐
Duct distribution system sketch:	Yes ☒	No ☐

HVAC LOAD CALCULATION (IRC M1401.3)

Design Conditions

Winter Design Conditions

- Outdoor temperature (1) -2 °F
- Indoor temperature (2) 70 °F
- Total heat loss (14) 59,000 Btu

Summer Design Conditions

- Outdoor temperature (3) 95 °F
- Indoor temperature (4) 75 °F
- Grains difference (5) 35 Δ (6) @ 50 % Rh
- Sensible heat gain (15) 22,000 Btu
- Latent heat gain (16) 5,000 Btu
- Total heat gain (17) 27,000 Btu

Building Construction Information

Building

- Orientation (Front door faces) (7) South (North, East, West, South, Northeast, Northwest, Southeast, Southwest)
- Number of bedrooms (8) 3
- Conditioned floor area (9) 1,773 Sq Ft
- Number of occupants (10) 4

Windows

- Eave overhang depth (11) 2 Ft
- Internal shade (12) Blinds, light, 45 Angle (Blinds, drapes, etc)
- Number of skylights (13) 1

HVAC EQUIPMENT SELECTION (IRC M1401.3)

Heating Equipment Data

- Equipment type (18) Gas Furnace (Furnace, Heat pump, Boiler, etc)
- Model (19) XYZ 080-14
- Heating output capacity (20) 64,000 Btu (Heat pumps - capacity at winter design outdoor conditions)
- Auxiliary heat output capacity (21) N/A Btu

Cooling Equipment Data

- Equipment type (22) Air Conditioner (Air Conditioner, Heat pump, etc)
- Model (23) XYZ 030 Condenser 030 Coil
- Sensible cooling capacity (24) 21,200 Btu
- Latent cooling capacity (25) 6,500 Btu
- Total cooling capacity (26) 28,700 Btu

Blower Data

- Heating CFM (27) 1,117 CFM
- Cooling CFM (28) 1,000 CFM

HVAC DUCT DISTRIBUTION SYSTEM DESIGN (IRC M1601.1)

- Design airflow (29) 1,117 CFM
- External Static Pressure (ESP) (30) 0.75 IWC
- Component Pressure Losses (CPL) (31) 0.40 IWC
- **Available Static Pressure (ASP)** (32) 0.35 IWC (ASP = ESP - CPL)
- Longest supply duct: (33) 278 Ft
- Longest return duct: (34) 110 Ft
- **Total Effective Length (TEL)** (35) 388 Ft
- **Friction Rate:** (36) 0.09 IWC (Friction Rate = (ASP × 100) ÷ TEL)

Duct Materials Used (circle)

Trunk Duct: Duct board, Flex, Sheet metal, Lined sheet metal, Other (specify) Sheet metal (insulated R-8) (37)

Branch Duct: Duct board, Flex, Sheet metal, Lined sheet metal, Other (specify) Flex duct (insulated R-8) (38)

I declare the load calculation, equipment selection, and duct system design were rigorously performed based on the building plan listed above. I understand the claims made on these forms will be subject to review and verification.

Contractor's Printed Name: Bartholomew J. Simpson Date: 1 April 2010

Contractor's Signature:

Reserved for use by County, Town, Municipality, or Authority having jurisdiction.

[1] The AHJ shall have the discretion to accept Required Attachments printed from approved ACCA software vendors, see list on page 2 of instructions.

[2] If abridged version of Manual J is used for load calculation, then verify residence meets requirements, see Abridged Edition Checklist on page 13 of instructions.

SECTION I: HVAC LOAD CALCULATION:

These instructions use standard forms and worksheets found in Manual J and Manual D. The AHJ shall have the discretion to accept information generated by software companies that have demonstrated their software follows the procedures in ACCA design manuals. The current list of approved software vendors, listed alphabetically, is:

Manual J

Adtek (www.adteksoft.com)
Elite (www.elitesoft.com))
Florida Solar Energy Center (Florida only)
Nitek (www.hvaccomputer.com)
Wrightsoft (www.wrightsoft.com)

Manual D

Elite (www.elitesoft.com
Wrightsoft (www.wrightsoft.com)

1. Winter OD Temp: Ensure this value comes from MJ8 Table 1A or 1B. Manual J8 §A5-1: "Use of this set of conditions (from Table 1A or 1B) is mandatory, unless a code or regulation specifies another set of conditions." See Figure 1 below, the Winter OD Temperature is -2°F.

Table 1A

Outdoor Design Conditions for the United States

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)
Nebraska									
Beatrice	1323	40	-2	95	74	28	35	41	M

Figure 1: Table 1A of Manual J

2. Winter Indoor temperature: 70°F. Manual J8 §A5-3: "Heating and cooling load estimates shall be based on the indoor design conditions listed below. Use of this set of conditions is mandatory, unless superseded by a code, regulation, or documented health requirement." See Figure 2: Indoor Design Conditions.

Indoor Design Condition Manual J §A5-3	Stated Value
Heating indoor dry bulb temperature	70°F
Cooling indoor dry bulb temperature	75°F

Figure 2: Indoor Design Conditions

3. Summer OD Temp: See #1. In Figure 1 above, the Summer OD Temperature is 95°F.
4. Summer Indoor temperature: 75°F. See #2 and Figure 2.
5. Summer Design Grains: See #1. In Figure 1 above, the Summer Design Grains are 35 at 50% RH.
6. Relative Humidity: Design Grains correspond to an RH (Relative Humidity). In Figure 1 above, the Summer Design Grains were selected at 50% RH. The HVAC system designer has the discretion to select the 55%, or 50%, or 45% value for this design element. Code Officials may wish to refer to IECC Figure 301.1 Climate Zones.
7. Orientation (e.g., North, South…): Verify that the orientation of the home's windows/doors/skylights correspond to the orientation of the plan. Manual J8 §A5-4 Plans, Sketches, and Notes states, "Sketches and notes shall provide the following information. Sketches based on plan take-off or field observation: An arrow or directional rosette that points north." Using Figure 3 as an example, the front door and skylight should be listed as facing South. The cooling loads for windows and skylights are very dependent on direction.
8. Number of Bedrooms: Verify the number of bedrooms match the plan. Using Figure 3 as an example, the number of bedrooms should equal 3.
9. Floor area: Ensure floor area listed is approximate to home's floor plan.

10. Occupants: Ensure this value equals the number of bedrooms plus one. Manual J8: §3.11, Occupants produce sensible and latent loads. The number of occupants shall equal the number of bedrooms plus one. Using Figure 3 as an example, the number of occupants should equal 4.

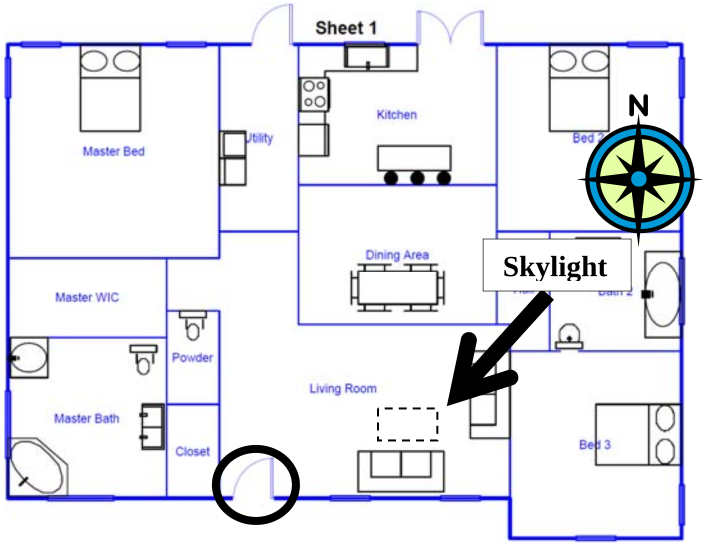


Figure 3: Example Home

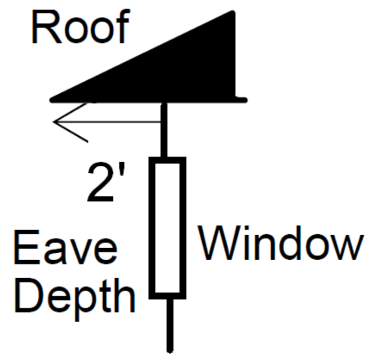


Figure 4: Window

11. Windows Overhang: This value shall represent the deepest overhang. The house may have overhangs of many depths, only the deepest overhang value is recorded. Manual J8: §2-3 (Manual J Mandatory Requirements) item 6, "…overhang adjustments shall be applied to all windows and glass doors, including purpose-built day-lighting windows." Figure 4 illustrates a window overhang of two feet.

12. Windows Internal Shade: For an *existing* home this entry must describe the predominate type of internal shading, in a *new* home it describes the expected shading that will be predominate. Manual J8: §2-3 (Manual J Do's – Mandatory Requirements) item 7: "Take credit for internal shade (the default is a medium color blind with slats at 45 degrees, or use the actual device – this applies to all vertical glass – this does not apply to purpose-built day-light windows)." Unless there is contrary evidence, HVAC system designers shall default to a "medium color blind with slats at 45 degrees".

Figure 5: Example of Internal Window Shading

13. Skylights (Number): Skylights have a large impact on the heating and cooling load calculations. Ensure the number of skylights on the building plan is represented accurately, Figure 3 has one skylight in the Living Room.

14. Total Heat Loss: This value is used to select the heating system, a code official may wish to verify the total represents the sum of the individual loads.

15. Sensible Heat Gain: This value represents the amount of dry heat the cooling system must remove.

16. Latent Heat Gain: This value represents the amount of moist heat the cooling system must remove.

17. Total Heat Gain: This value is used to size cooling systems; the total cooling capacity shall equal the sensible and latent heat gains.

SECTION II: HVAC EQUIPMENT SELECTION:

The purpose of this portion of the form is to ensure the equipment selected meets the heating or cooling requirements calculated in Section I for the home. Ensure the HVAC designer used the manufacturer's performance data, and did not exceed the limits prescribed by the recognized national standard.

Equipment sizing requirements (2018 IRC, Section M1401.3) from Manual S:

Manual S Equipment Selection Sizing Limitations		
Equipment	Sizing Limits	Reference
Furnaces	100% - 140% of total heating load	Section 2-2
Boilers	100% - 140% of total heating load	Section 2-2
Air conditioners	115% of total cooling load*	Section 3-4
Heat pumps (cooling dominant climates)	115% of total cooling load*	Section 4-4
Heat pumps (heating dominant climates)	125% of total cooling load*	Section 4-4
Supplemental heat (heat pumps)		
• Electric	Based on equipment balance point	Section 4-8
• Dual fuel	100% - 140% of total heating load	Section 6-8
Emergency Heat (heat pumps)	Based on local codes	Section 4-9
Manual S Input for Design Air Flow (Manual D)		
• Heating	Temperature rise requirement	Section 2-6
• Cooling	Air flow associated with the selected equipment's capacity	Section 3-11
* The size of the cooling equipment must be based on the same temperature and humidity conditions that were used to calculate the Manual J loads.		

Figure 6: Manual S Sizing Limitations

Heating Equipment Data

18. Equipment Type: A description of the type of heat source used: furnace, boiler. If a heat pump is used list the fan coil/air handler and supplemental heater size.
19. Model: The model of heater that will be installed. In Figure 7, the model is a 080-14.
20. Heating output capacity: The amount of maximum OUTPUT heating capacity available from the heater shall be equal to, but not exceed 140% of the heat loss (value from item #14); in Figure 7 the output capacity is 64,000 Btu/h. Manual S §2-2 states, "…the output capacity of the furnace or boiler must be greater than the design heating load, but no more than 40 percent larger than the design heating load." Manual S further states in §2-3, "Always use the output capacity value to size the heating equipment."

XYZ Furnace Company

MODEL	060 - 14	080 - 14	080 - 16
TYPE	Downflow / Horizontal	Downflow / Horizontal	Downflow / Horizontal
RATINGS			
Input BTUH	60,000	80,000	80,000
Capacity BTUH (ICS)	48,000	64,000	64,000
AFUE	80.0	80.0	80.0
Temp. rise (Min.-Max.) °F.	30 - 60	35 - 65	35 - 65

Figure 7: Example Heating Performance Data

Multi-Stage equipment: Heaters (furnaces, boilers, etc.) may have more than one capacity level. The maximum heater capacity shall not exceed the heat loss (item #14) by more than 40%. For example, if a home has a heat loss of 59,000, the HVAC contractor could install a two stage furnace with a high fire output capacity of 73,000Btu (XYZ 080-16, see Figure 8) and meet the sizing limit. However, a furnace with a low fire output capacity were 60,000Btu and the high fire output capacity were 93,000Btu (XYZ 100-16, see Figure 8), would exceed the home's heating needs by more than 40%.

XYZ Furnace Company - 2 Stage Furnace

MODEL	060 - 14	080 - 16	100 - 16	120 - 18
RATINGS				
1st Stage Input BTUH	39000	52000	65000	72000
1st Stage Capacity BTUH (ICS)	36000	48000	60000	66600
2nd Stage Input BTUH	60000	80000	100000	120000
2nd Stage Capacity BTUH (ICS)	56000	73000	93000	112000
AFUE (ICS)	93.0	92.5	93.0	92.5
Temp. Rise (Min.-Max.) °F.	30 - 60	35 - 65	35 - 65	40 - 70

Figure 8: Example of 2 Stage Furnace Performance Data

Heat pumps are different; the equipment's heating capacity diminishes as the outdoor temperature gets colder. Heat pumps usually lack the capacity to meet the total heating requirement at the design outdoor temperature used in the heat loss calculations (item #1). Therefore, for heat pumps this value shall be the heat pump's heating capacity at the winter OD temperature.

As an alternate example, the heat pump in Figure 9 can provide 10,700 Btu/h at an OD temperature of 12°F. The capacity of the supplemental heat source will be discussed next. For further illustration, see www.acca.org/codes/reviewform, Example #2.

XYZ 030 Heating Performance Data

O.D. TEMP. F.	HEATING CAPACITY MBH AT INDOOR DRY BULB TEMP. 70	75	80	TOTAL POWER IN KILOWATTS AT INDOOR DRY BULB TEMP. 70	75	80
2	7.7	7.6	7.6	1.39	1.43	1.47
7	9.2	9.1	9.0	1.42	1.47	1.51
12	10.7	10.5	10.5	1.46	1.50	1.55
17	12.1	12.0	11.9	1.50	1.54	1.59
22	13.3	13.1	13.0	1.54	1.58	1.63
27	14.4	14.2	14.1	1.57	1.62	1.67
32	15.5	15.4	15.2	1.61	1.66	1.71
37	17.0	16.8	16.7	1.65	1.70	1.75
42	19.0	18.8	18.6	1.68	1.73	1.78
47	21.0	20.8	20.6	1.71	1.76	1.81
52	22.5	22.3	22.1	1.75	1.80	1.85
57	24.0	23.7	23.5	1.78	1.83	1.89
62	25.4	25.2	24.9	1.82	1.87	1.93
67	26.9	26.6	26.4	1.85	1.91	1.96
72	28.4	28.1	27.8	1.89	1.94	2.00

CORRECTION FACTORS FOR OTHER AIRFLOWS (MULTIPLY DATA BY FACTOR)

	AIRFLOW	TOTAL CAPACITY	SENSIBLE CAPACITY
LOW	700	0.98	0.97
HIGH	900	1.01	1.02

Figure 9: Example: Heat Pump - Heating Performance Data

21. Supplemental heating output capacity: The auxiliary heat source that supplements the heat pump, see 20.b. above. Manual S §4-8 states that the supplemental heat is based on, "…the difference between the winter design heating load and the capacity the heat pump will have when it operates at the winter design temperature." Therefore, when auxiliary heat is used, it shall be based on the difference between the homes heat loss (line #14) and the heat pump's capacity (line #20).

    Supplemental heat may also be required by code for circumstances when the heat pump has failed, for example if the compressor in the heat pump fails, then the emergency heat would provide some heating. Manual S states in §4-8 that emergency heat sizing shall be in compliance with local codes.

Cooling Equipment Data

22. Equipment Type: A description of the cooling equipment that will be installed: air conditioner, heat pump, etc.
23. Model: The model of cooling equipment that will be installed. In Figure 11, the model is an AC -030.
24. Sensible cooling capacity: The sensible cooling capacity of the equipment should satisfy the sensible cooling requirement (line #15). If the sensible capacity is insufficient, Manual S §3-10 (Step 4) states that the HVAC system designer is permitted to, "Add half of the *excess* latent capacity to the sensible capacity…"
25. Latent cooling capacity: Latent capacity is rarely listed in the manufacturers' performance data. However, it can be derived by subtracting the sensible from the total cooling capacities. The latent cooling capacity is crucial to proper health and safety. When the cooling equipment lacks the latent capacity, moisture related problems arise: affects to framing, growth of harmful compounds, and organisms.
26. Total cooling capacity: The amount of maximum cooling capacity available from the equipment shall not exceed 115% of the heat gain (value from Line #17). The air conditioner in Figure 11 has a total cooling capacity of 28,700 Btu/h. Manual S §3-4 states,:
    a. "Cooling equipment shall be sized so that the total cooling capacity does not exceed the total cooling load by more than 15 percent."
    b. "…heat pump equipment (air source or water source) is installed in a warm or moderate climate, the total cooling capacity shall not exceed the total cooling load by more than 15 percent."
    c. "…heat pump equipment (air source or water source) is installed in a cold climate (where heating costs are a primary concern), the total cooling capacity can exceed the total cooling load by 25 percent."

    Each equipment manufacturer presents their expanded performance data in a unique manner. Figure 11 is one example of the expanded performance data from a fictitious original equipment manufacturer (OEM). In this example, the Total cooling capacity is 28,700 Btu/h. The key elements considered are:

Key Element	Information Source
Outdoor drybulb temperature	This value shall be within 5°F of the Summer OD design temperature (item #3)
Indoor wet bulb (I.D. W.B) temperature	75°F @ 45% RH ≈ 62°F WB 75°F @ 50% RH ≈ 63°F WB 75°F @ 55% RH ≈ 64°F WB
Indoor dry bulb temperature	This shall match the indoor design temperature in cell on the front of the form
CFM	The airflow required to achieve this capacity. This value is used on item # 28.

Figure 10: Information for Manufacturer's Cooling Performance Data

XYZ Performance Data						
Model 030 with Coil AC030 and Furnace FR 080-14 @ 1,000 CFM						
OD Dry Bulb (F)	Indoor Entering Wet Bulb (F)	Total Capacity	Sensible Capacity at Entering Dry Bulb Temperature (F)			
			72	75	78	80
85	59	28,400	22,600	25,300	27,800	29,400
	63	29,900	18,800	21,600	24,300	26,100
	67	32,100	15,100	17,900	20,700	22,600
	71	34,700	11,400	14,200	17,000	18,900
95	59	27,300	22,200	24,900	27,400	28,300
	63	28,700	18,500	21,200	23,900	25,700
	67	30,800	14,700	17,500	20,400	22,200
	71	33,300	11,000	13,700	16,600	18,500
105	59	26,200	21,900	24,500	27,100	27,200
	63	27,600	18,100	20,900	23,600	25,400
	67	29,700	14,300	17,200	20,000	21,800
	71	32,100	10,600	13,300	16,200	18,100

OD Dry Bulb – Outdoor Dry Bulb, the outdoor temperature.

Correction Factors for other Airflows			
	Airflow	Total Capacity	Sensible Capacity
Low	875	0.98	0.93
High	1125	1.02	1.06
Multiply rated capacity data by factor.			

Figure 11: Sample I Equipment Performance Data

A similar unit from a different manufacturer, uses the same basic information is presented another way, with different cooling capacities.

ABC Air Conditioners – Detailed Cooling Capacities Model AC-30 with Coil AC-030							
Evaporator Air		Condenser Entering Air Temp – DB (F)					
CFM	EWB (F)	85		95		105	
		Capacity		Capacity		Capacity	
		Total	Sensible	Total	Sensible	Total	Sensible
875	72	34,610	18,190	33,100	17,620	31,520	17,020
	67	31,400	22,240	30,000	21,650	28,520	21,040
	63	28,620	26,290	27,350	25,680	26,020	25,040
	57	27,840	27,840	26,820	26,820	25,740	25,740
1000	72	35,250	19,090	33,680	18,500	32,030	17,890
	67	31,990	23,660	30,530	23,060	29,000	22,440
	63	29,300	27,220	28,020	26,560	26,770	26,770
	57	29,020	29,020	27,930	27,930	26,780	26,780
1125	72	35,720	19,920	34,110	19,330	32,410	18,710
	67	32,430	25,010	30,930	24,410	29,360	23,780
	63	29,970	29,970	28,850	28,850	27,630	27,630
	57	30,000	30,000	28,850	28,850	27,640	27,640

Figure 12: Sample II Equipment Performance Data

Some cooling equipment is available with two speeds or stages, other cooling equipment can scale its capacity to meet peak and part-load conditions. These types of cooling equipment, generally, are produced in limited sizes. Due to the sizing limitations, in these circumstances, the designer should choose the smallest equipment that will meet the total cooling load. For example, this home has a cooling load of 27,000. Figure 13 shows the available units, from these, the 3 ton A/C unit should be chosen because it is the smallest unit that can meet the total cooling load.

2 Ton A/C Unit		3 Ton A/C Unit		4 Ton A/C Unit	
1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage
12,000	24,000	18,000	36,000	24,000	48,000

Figure 13: Example Two Stage Equipment Selection

Blower Data:

27. Heating CFM: The volume of air required to deliver the heating Btu for the home.
   a. Furnaces: The airflow calculated from the heating capacity and temperature range required by the manufacturer. The XYZ 80-14 and -16 (Figures 7 & 8) must have a temperature difference (TD) of no less than 35°F, and no more than 65°F. The airflow formula is CFM = Btuh ÷ (TD × 1.08 × ACF) where:
      - CFM: Cubic Feet per Minute, the volume of air moving through the equipment
      - Btu/h: The heating capacity of the furnace or other heat source.
      - TD: Temperature Difference, e.g., the difference between 35°F and 65°F[1].
      - 1.08: A physics constant that converts the weight of air into a volume of air.
      - ACF: Altitude Correction Factor, for homes at elevations above 1,000 feet.

      In this example, the airflow is CFM = 64,000Btuh ÷ (50°F × 1.08 × 1.0) = 1,185 CFM
   b. Heat pumps: The air flow associated with the heating capacity for the equipment selected. If Figures 11 and 12 were performance data for a heat pump, the heating and cooling airflow would be 1,000 CFM. Ensure you read and apply any footnotes added by the OEM. In addition, this airflow must also meet the supplemental heater's requirements.
28. Cooling CFM: The air flow associated with the total cooling capacity for the equipment selected in Figures 11 and 12 the airflow is 1,000 CFM.

Adjusting Design Airflow: For forced air systems, the HVAC system designer must carefully evaluate blower assembly performance in the selected equipment, e.g., furnace, air handler, fan coil, etc. In this example, the design *heating* airflow is 1,185 CFM; the design *cooling* airflow is 1,000 CFM. Evaluating the furnace in Figure 14, the designer determines that on Med-Low fan speed, the blower assembly can deliver about 1,117 CFM, and on Low fan speed 1,000 CFM. Both airflows are at the same external static pressure (ESP, see item #29). The HVAC system can be designed at this common ESP, and the equipment's fan speed can be set on Med-Low for heating, and Low for cooling.

However, before the designer may alter the heating CFM, they must ensure the TD through the equipment remains within the boundaries set by the OEM. 1,117 CFM will provide a TD of 53°F. The TD formula is TD = Btu/h ÷ (CFM × 1.08 × ACF) where:

- TD: Temperature Difference the design airflow should achieve.
- Btu/h: The heating capacity of the furnace or other heat source.
- CFM: Cubic Feet per Minute, the volume of air moved by the blower
- 1.08: A physics constant that converts the weight of air into a volume of air.
- ACF: Altitude Correction Factor, for homes at elevations above 1,000 feet.

In this example, the TD = 64,000Btuh ÷ (1,117CFM × 1.08 × 1.0) = 53°F. A 53°F temperature difference falls safely within the range of 35°F to 65°F.

[1] Any temperature between 35°F and 65°F would be acceptable to the OEM. However, a low TD promotes condensation damage and a high TD can decreases the heat exchanger life cycle. To find the middle ground (50°F), take the difference between 35°F and 65°F, which is 30°F. Half of 30°F is 15°F. 30°F + 15°F = 50°F or another way is 65°F - 15°F = 50°F.

SECTION III: HVAC DUCT DISTRIBUTION SYSTEM DESIGN:

The purpose of this section is to ensure the air moving values and capabilities of the equipment selected in Section II are sufficient to meet the resistance offered by additional components and the duct distribution system. Ensure these values are accurately transcribed from the Manual D Friction Rate Worksheet.

29. Design airflow: The volume of air delivered by a piece of equipment at a given fan speed, voltage, and amount of pressure (the larger of Heating or Cooling CFM, item 27 or 28). When selecting a blower assembly, the design airflow will be the higher of the two, 1,117 CFM.
30. Static Pressure: The design static pressure from the air moving equipment's blower performance table.

XYZ Furnace Company Blower Data										
Air Delivery – CFM (with filter)										
Unit Size	Return Air Entry	Fan Speed	External Static Pressure (inches water column)							
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
FR 060-14	1 side or bottom	High	1100	1065	1005	945	900	805	730	610
		Med-Low	890	865	810	765	705	620	540	475
		Low	745	710	670	625	565	505	425	360
FR 080-14	1 side or bottom	High	1740	1705	1660	1615	1570	1500	1425	1355
		Med-High	1500	1470	1445	1410	1375	1330	1280	1210
		Med-Low	1340	1315	1300	1270	1235	1200	1140	1095
		Low	1195	1175	1165	1130	1100	1070	1030	975
FR 080-16	1 side or bottom	High	2250	2175	2090	2020	1930	1855	1760	1670
		Med-High	2020	1950	1900	1840	1790	1710	1640	1545
		Med-Low	1725	1690	1660	1630	1575	1520	1460	1370
		Low	1490	1480	1460	1440	1380	1340	1295	1230
‡ • Airflow shown is for bottom only return-air supply with factory supplied 1-in. washable filter (0.05 IWC).										

Figure 14: Example Blower Performance Data

A similar unit from a different OEM, presents the same basic information in another format, with different static pressure values (note the special clarification of test conditions in both examples).

Airflow Performance ABC 080-036 : Wet coil, No Heaters												
EXTERNAL STATIC PRESSURE (in.w.g.)	AIRFLOW (CFM)											
	VERTICAL						HORIZONTAL					
	230 VOLTS			208 VOLTS			230 VOLTS			208 VOLTS		
	HI	MED	LO	HI	MED	LO	HI	MED	LO	HI	MED	LO
0	1484	1282	1077	1402	1200	963	1402	1265	1069	1349	1165	947
0.1	1412	1268	1082	1352	1166	948	1350	1228	1048	1298	1131	915
0.2	1344	1226	1055	1292	1130	924	1289	1180	1015	1243	1090	890
0.3	1277	1171	1013	1227	1089	893	1225	1127	976	1185	1047	866
0.4	1209	1110	965	1163	1040	856	1163	1073	933	1127	1001	836
0.5	1139	1049	915	1098	982	814	1104	1019	887	1066	953	795
0.6	1065	987	862	1031	915	764	1043	962	835	1001	898	743
0.7	988	916	799	957	839	703	977	897	771	929	829	677
0.8	907	827	713	870	757	624	894	815	689	846	736	599
0.9	823	702	584	760	671	521	783	707	579	745	609	513
NOTES:	With filter, no horizontal drip tray Small apex baffle Subtract 0.06" W.G. for downflow						As shipped except without filter Subtract 0.05"" W.G. for horizontal left					

Figure 15: Sample Blower Performance Data

The static pressure is the amount of pressure in inches water column (IWC) the blower can "push" against and still deliver the stated volume of air. For example, in Figure14, on Med-Low fan speed the FR 80-14 furnace can push 1,117 CFM (interpolated[2] between 1,140 CFM and 1,095 CFM) against a constant or "static" pressure of 0.75 (interpolated between 0.7 and 0.8). This value should not be confused with the Friction Rate which will be discussed later.

31. Component Pressure Losses (CPL): The total resistance or pressure created by accessories like filters, refrigeration coils, grilles, registers, dampers, and others. For example, in Figure 16 the component pressure loss is 0.40.

32. Available Static Pressure (ASP): The difference between the external static pressure (item 31) and the component pressure losses (item 32). This number represents the amount of resistance (or pressure) the ducts can create and still allow the fan to deliver the correct airflow. This is a major factor in determining the friction rate which will be used to size the ducts. For example, in Figure 16 the ASP is 0.35.

Step 1) Manufacturer's Blower Data

External static pressure (ESP) = 0.75 IWC   Cfm = 1,117

Step 2) Component Pressure Losses (CPL)

Direct expansion refrigerant coil	0.18
Electric resistance heating coil	
Hot water coil	
Heat exchanger	
Low efficiency filter	
High or mid-efficiency filter	0.13
Electronic filter	
Humidifier	
Supply outlet	0.03
Return grille	0.03
Balancing damper	0.03
UV lights or other device	
Total component losses (CPL)	0.40 IWC

Step 3) Available Static Pressure (ASP)

ASP = (ESP - CPL) = (0.75 - 0.40) = 0.35 IWC

Figure 16: Friction Rate Worksheet - Top Section

33. Longest SUPPLY duct: The "effective" length of the longest supply (conditioned air) duct run. Different duct fittings create different amounts of resistance, the resistance of a 90° elbow may be one foot long, but that elbow may offer as much resistance as thirty feet of straight pipe. A duct runout may look short, but because of elbows and other fittings it may actually have a long effective length. For example, in Figure 17 the supply side total effective length (TEL) is 278.

34. Longest RETURN duct: The same properties apply to return ducts (that bring room air back to the furnace, fan coil, or air handler). For example, in Figure 17 the return side TEL is 110.

35. Total Effective Length (TEL): The sum total of the supply and return effective lengths. In Figure 17 the total effective length is 388.

[2] Interpolation is the process of determining a value between two known, prescribed values.

Step 4) Total Effective Length (TEL)

Supply-side TEL + Return-side TEL = (278 + 110) = 388 Feet

Step 5) Friction Rate Design Value (FR)

FR value from friction rate chart = 0.09 IWC/100

Figure 17: Friction Rate Worksheet - Mid Section

36. Friction Rate *(ASP x 100) ÷ TEL = FR*]: The value used to determine the size of duct required to carry a certain volume of air. It is important to ensure the FR is greater than 0.06 and less than 0.18 to control air velocity. If the FR is outside this boundary the contractor should justify their design. In Figure 18, the friction rate is 0.09. The FR is one value used to size the ducts; the other factor in duct sizing is the duct material.

Step 5) Friction Rate Design Value (FR)

FR value from friction rate chart = 0.09 IWC/100

$$FR = \frac{ASP \times 100}{TEL}$$

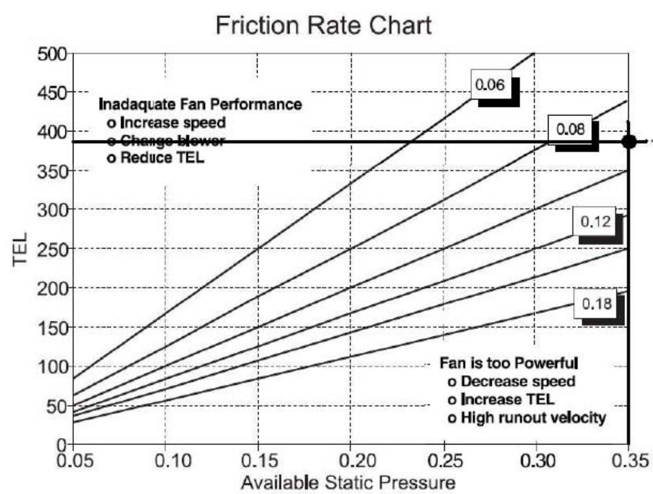


Figure 18: Friction Rate Worksheet - Bottom Section

Duct Materials Used:

37. Trunk duct: Ensure the planned materials are listed: Metal pipe, fiberglass duct board, flexible duct, or other. Use a friction chart or duct calculator (Figure 20) to verify the size of the ducts considering the friction rate and the duct material. Do not use a "sheet metal" duct calculator to size flexible ducts.
38. Branch duct: See item 378.

Examine Duct Distribution Sketch: Verify duct sizes with a duct calculator like the one in Figure 20, and ensure all isolated rooms (like bedrooms) have a low resistance air path (cross over duct / transfer grille) or a ducted return. Ensure the duct calculator used has the appropriate scale for the duct material used.

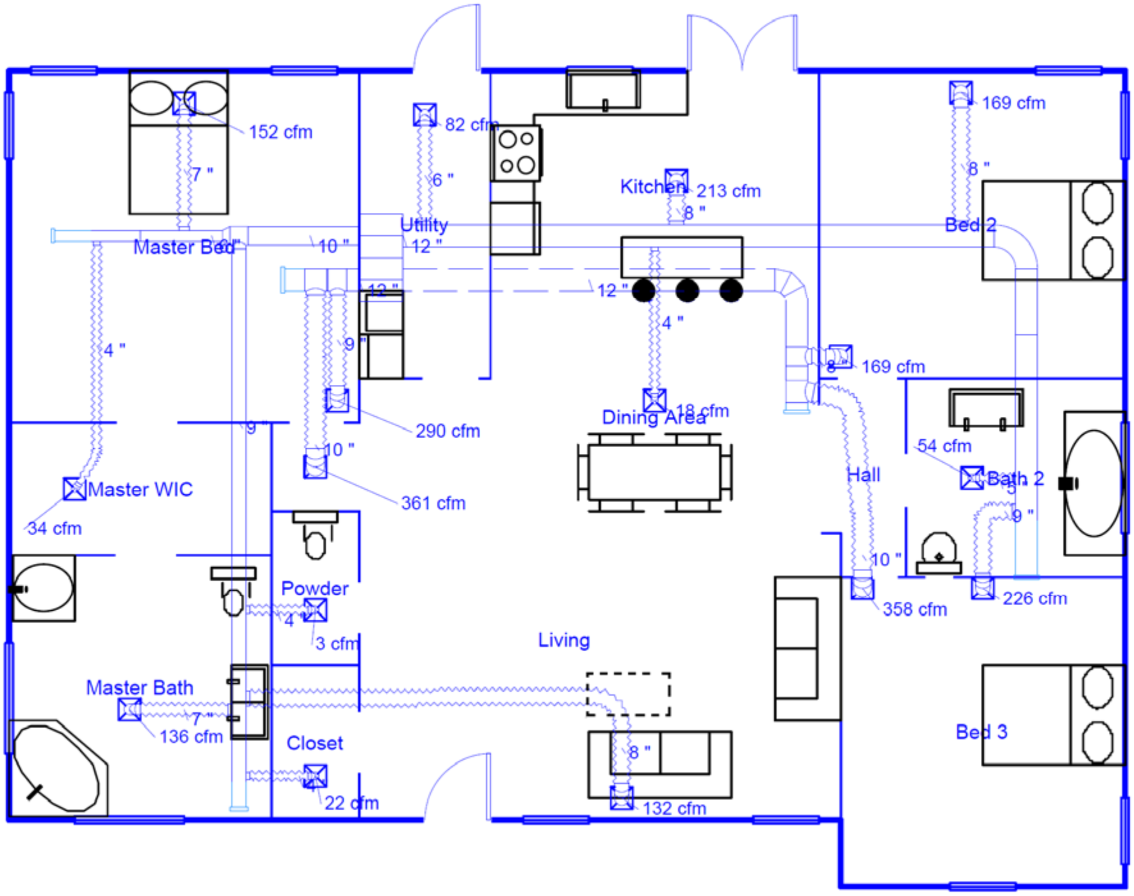


Figure 19: Example Duct Sketch

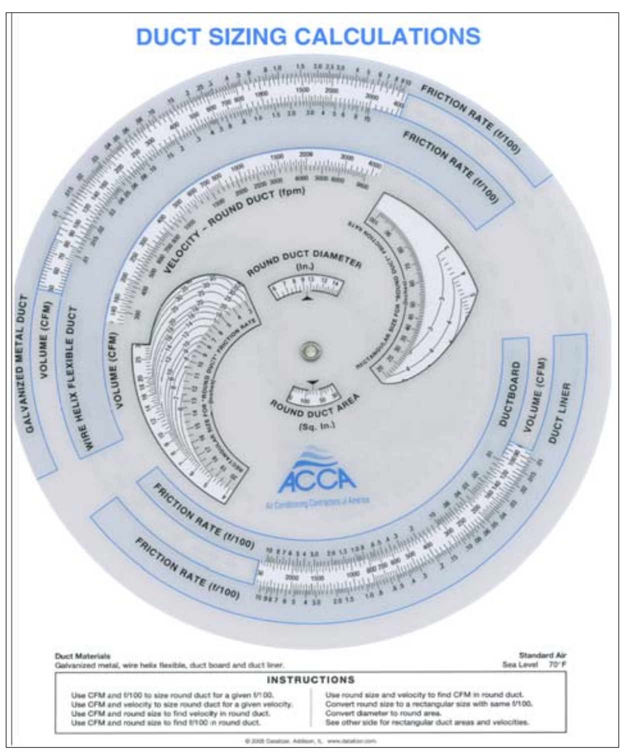


Figure 20: ACCA Duct Calculator

Manual J Abridged Edition Checklist	
The abridged procedure was used, I have initialed next to each block to indicate this dwelling meets each criteria.	
	ONLY a single family detached dwelling.
	HVAC system is a central, single-zone, constant volume system.
	NO radiant heating system.
	NO ventilation heat exchanger (ERV or HRV) or a ventilating dehumidifier.
	ONLY engineered ventilation allowed is provided by piping outdoor air to the return side of the duct sys tem (pressurization effect on infiltration is ignored).
	The indoor design conditions are: Heating 70 °F; Cooling 75 db °F and 45%, 50% or 55% RH.
	ONLY outdoor design conditions equal to the values in Table 1A were used.
	TOTAL window area (including glass doors and skylight area) does not exceed 15 percent of the associated floor area.
	The windows are equitably distributed around all sides of the dwelling - the dwelling has adequate exposure diversity (AED).
	NO Low-e, tinted, reflective, or special glass (All windows, skylights, and glass doors must be clear 1-pane, 2-pane or 3-pane glass)
	ALL skylights are flat. NO skylight light shafts or internal shade.
	ALL windows' internal shade factor is a medium-color blind with slats at 45 degrees.
	ALL U-values and SHGC values for all windows, skylights, and glass doors are from Table 3A and 3C.
	ALL purpose-built daylight windows and skylights have no internal shade.
	ALL windows and glass doors are calculated with applicable bug screen, French door, and projection adjustments.
	NO glass external sun screens.
	ALL windows and glass doors are calculated with applicable overhang adjustments.
	ALL above grade walls are wood frame walls or empty-core block walls (no metal framing, no filled core block).
	ALL exterior finish is brick, stucco, or siding.
	ONLY gypsum board was used for the interior finish.
	ALL below grade walls are empty-core block walls (board insulation; framing and blanket insulation).
	ALL framing is wood (not metal).
	ONLY a dark shingle roof over an attic, a beam ceiling or a roof-joist ceiling.
	ONLY attic or attic knee wall space (when applicable) vented to FHA standards, with no radiant barrier.
	ONLY slab floors with no edge insulation (or 3 feet of vertical insulation that covers the edge). NO insulation below basement floors slab, no sensitivity to width.
	NO insulation under floors over a closed space or on the walls of the closed space.
	Floors over a closed space are insensitive to the tightness of the closed space.
	ONLY infiltration load estimates based on Table 5A (three or four exposures, class 4 wind shielding, no blower door test or component leakage estimate).
	ONLY a sensible appliance load of 1,200 or 2,400 Btuh
	ONLY number of occupants is the number of bedrooms plus one.
	ONLY allowed duct systems (when applicable) are: a. installed in one horizontal plane; b. entirely in a conditioned
	ONLY one of the following duct runs were used: a. An attic installed radial or spider pattern supply system (supplies in room centers) and returns (large return close to air handler or return in closet door); OR b. A trunk and branch supply system in the attic (supplies near inside walls; return riser in floor to ceiling chase); OR c. A trunk and branch supply system in a closed crawlspace or unconditioned basement.
	ONLY the duct leakage rate of R/A=0.12 S./A = 0.24 was used, unless proven by a leakage test.
	ONLY the following duct insulation: R-2, R-4, R-6, or R-8.
	ONLY blower heat adjustment is 500 Watts, if manufacturer's performance data is not discounted for blower heat.
Note: The abridged edition of ***Manual J*** (MJ8ae) shall ONLY be used to estimate heating and cooling loads for dwellings which are totally compatible (100 percent) with this checklist and the descriptions and caveats provided by Appendix 2 and 3. The full version of ***Manual J*** will be used for all other scenarios.	

Understanding Select Fields on the Residential Plans Examiner Review Form for HVAC System Design

Residential HVAC

Tips for Enforcing the 2018 Virginia Code

The ***Residential Plans Examiner Review Form for HVAC System Design*** is a standardized template provided by Air Conditioning Contractors of America (ACCA). It provides key information about the load calculations that were performed.

This form can be generated and pre-populated from the common software programs that are used to perform HVAC load calculations in accordance with ACCA Manual J.

This guide will cover best practices for reviewing the information on this form for accuracy.

ACCA Air Conditioning Contractors of America

Residential Plans Examiner Review Form for HVAC System Design (Loads, Equipment, Ducts)

Form RPER 1.01 8 Mar 10

County, Town, Municipality, Jurisdiction

Header Information

Contractor ______

Mechanical License # ______

Building Plan # ______

REQUIRED ATTACHMENTS[1]	ATTACHED	
Manual J1 Form (and supporting worksheets):	Yes ☐	No ☐
or MJ1AE Form[2] (and supporting worksheets):	Yes ☐	No ☐
OEM performance data (heating, cooling, blower):	Yes ☐	No ☐
Manual D Friction Rate Worksheet:	Yes ☐	No ☐
Duct distribution system sketch:	Yes ☐	No ☐

Home Address (Street or Lot#, Block, Subdivision) ______

HVAC LOAD CALCULATION (IRC M1401.3)

Design Conditions

Winter Design Conditions

Outdoor temperature ______ °F

Indoor temperature ______ °F

Total heat loss ______ Btu

Summer Design Conditions

Outdoor temperature ______ °F

Indoor temperature ______ °F

Grains difference ______ Δ Gr @ ______ % Rh

Sensible heat gain ______ Btu

Latent heat gain ______ Btu

Total heat gain ______ Btu

Building Construction Information

Building

Orientation (Front door faces) ______

North, East, West, South, Northeast, Northwest, Southeast, Southwest

Number of bedrooms ______

Conditioned floor area ______ Sq Ft

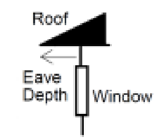
Number of occupants ______

Windows

Eave overhang depth ______ Ft

Internal shade ______
Blinds, drapes, etc

Number of skylights ______



HVAC EQUIPMENT SELECTION (IRC M1401.3)

Heating Equipment Data

Equipment type ______
Furnace, Heat pump, Boiler, etc.

Model ______

Heating output capacity ______ Btu
Heat pumps - capacity at winter design outdoor conditions

Auxiliary heat output capacity ______ Btu

Cooling Equipment Data

Equipment type ______
Air Conditioner, Heat pump, etc

Model ______

Sensible cooling capacity ______ Btu

Latent cooling capacity ______ Btu

Total cooling capacity ______ Btu

Blower Data

Heating CFM ______ CFM

Cooling CFM ______ CFM

HVAC DUCT DISTRIBUTION SYSTEM DESIGN (IRC M1601.1)

Design airflow ______ CFM

External Static Pressure (ESP) ______ IWC

Component Pressure Losses (CPL) ______ IWC

Available Static Pressure (ASP) ______ IWC
ASP = ESP - CPL

Longest supply duct: ______ Ft

Longest return duct: ______ Ft

Total Effective Length (TEL) ______ Ft

Friction Rate: ______ IWC
Friction Rate = (ASP × 100) ÷ TEL

Duct Materials Used (circle)

Trunk Duct: Duct board, Flex, Sheet metal, Lined sheet metal, Other (specify) ______

Branch Duct: Duct board, Flex, Sheet metal, Lined sheet metal, Other (specify) ______

I declare the load calculation, equipment selection, and duct system design were rigorously performed based on the building plan listed above, I understand the claims made on these forms will be subject to review and verification.

Contractor's Printed Name ______ Date ______

Contractor's Signature ______

Reserved for use by County, Town, Municipality, or Authority having jurisdiction.

[1] The AHJ shall have the discretion to accept Required Attachments printed from approved ACCA software vendors, see list on page 2 of instructions.

[2] If abridged version of Manual J is used for load calculation, then verify residence meets requirements, see Abridged Edition Checklist on page 13 of instructions.

HVAC Load Calculation – Design Conditions

Tips for Enforcing the 2018 Virginia Code

Design Conditions

Winter Design Conditions

Outdoor temperature ______ °F

Indoor temperature ______ °F

Total heat loss ______ Btu

Summer Design Conditions

Outdoor temperature ______ °F

Indoor temperature ______ °F

MANUAL J DESIGN CRITERIA[n]							
Elevation	Latitude	Winter heating	Summer cooling	Altitude correction factor	Indoor design temperature	Design temperature cooling	Heating temperature difference
—	—	—	—	—	—	—	—
Cooling temperature difference	Wind velocity heating	Wind velocity cooling	Coincident wet bulb	Daily range	Winter humidity	Summer humidity	—
—	—	—	—	—	—	—	—

New in the 2018 Virginia Residential Code is the addition of the Manual J Design Criteria table to Table R301.2(1).

Now each jurisdiction will provide the design criteria that all contractors should use in their Manual J calculations.

HVAC Load Calculation – Design Conditions

Tips for Enforcing the 2018 Virginia Code

Design Conditions

Winter Design Conditions

Outdoor temperature		°F
Indoor temperature		°F
Total heat loss		Btu

Summer Design Conditions

Outdoor temperature		°F
Indoor temperature		°F
Grains difference	Δ Gr @	% Rh
Sensible heat gain		Btu
Latent heat gain		Btu
Total heat gain		Btu

Total Heat Loss describes the amount of heat that will be lost from the building during the coldest hours of the winter. This heat loss needs to be made up by a heating source. The combined capacity of the heating equipment and any supplemental heat sources should meet or exceed this value.

Cooling is described by **Sensible Gain** and **Latent Gain**, as well as **Total Heat Gain**, which is the sum of the Sensible and Latent loads. Sensible gain is the heat gained by the building in the summer. Latent gain is the moisture gain.

HVAC Load Calculation – Building Construction Information

Tips for Enforcing the 2018 Virginia Code

Building Construction Information

Building

Orientation (Front door faces) ______

North, East, West, South, Northeast, Northwest, Southeast, Southwest

Number of bedrooms ______

Conditioned floor area ______ Sq Ft

Number of occupants ______

The **Orientation** should match the home's actual orientation and can be confirmed against the site plan.

The **Conditioned Floor Area** is the area served by the HVAC system. If there is a single system in the home, it should match the conditioned floor area of the whole home. If there are multiple HVAC systems, the combined value across all systems should match the conditioned floor area of the whole home.

The **Number of Bedrooms** should match the number of bedrooms in the plans. The **Number of Occupants** should equal the Number of Bedrooms + 1 (this assumes two people in the main bedroom).

If there are multiple HVAC systems in a home, combine the Number of Occupants values provided on each ***Residential Plans Examiner Review Form for HVAC System Design*** form provided for the home and check the total value for compliance. This will account for the whole house.

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Success with the 2018 Virginia Energy Conservation Code

HVAC INSTALLATION

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IECC Tech Tips
VIRGINIA

TECH TIPS:
HVAC Installation

1. Seal all duct terminations to adjacent drywall and/or subfloor. Seal all HVAC penetrations in the building envelope with foam, caulk, or mastic. Use fire-rated sealants where required. (R402.4.1.1 Installation (Mandatory) and elsewhere)

TECH TIPS:

HVAC Installation

2. Seal all HVAC components at all joints, seams, and corners. (R403.3.2 Sealing (Mandatory))

3. Mechanically fasten all metal duct work with screws. For flexible duct, attach the inner liner with plastic straps and tighten with a manufacturer-approved tool. (M1601.4 Installation)

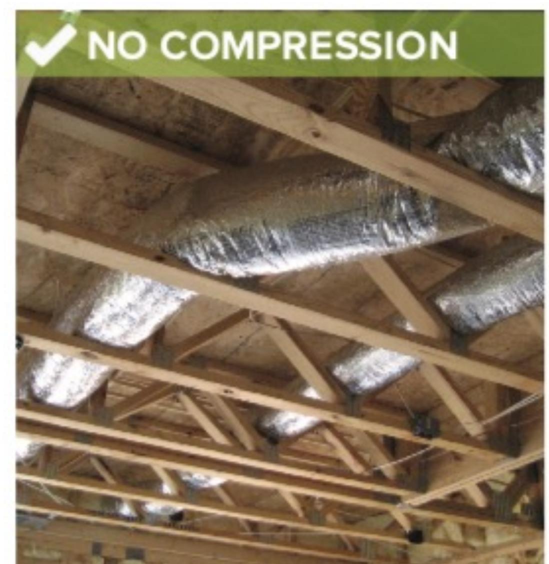
IECC Tech Tips
VIRGINIA

TECH TIPS:

HVAC Installation

4. Insulate all ducts outside of conditioned space to at least R-8. (R403.3.1 Insulation (Prescriptive))

5. Do not compress insulated flexible ducts more than the thickness of the insulation. (Manufacturer's instructions)



IECC Tech Tips
VIRGINIA

TECH TIPS:
HVAC Installation

6. Support flexible ducts (including those for ventilation) at least every 4 feet. Do not bend more than 90 degrees. (Manufacturer's instructions)

TECH TIPS:

HVAC Installation

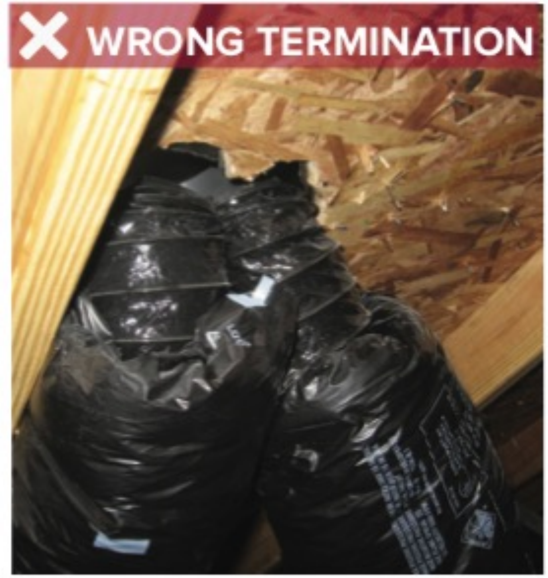
7. Install outside air ventilation intakes at least 10 feet from any exhaust vent or stack. (M1504.3 Exhaust openings)

8. Coordinate bath fan exhaust duct direction with electrical contractor (or other fan installer) to ensure ductwork is as short and straight as possible.

TECH TIPS:

HVAC Installation

9. Terminate exhaust ventilation duct work to the outside and install a screen over the termination.



10. For heat pumps, install a heat strip outdoor temperature lockout that prevents supplemental heat operation. Set it to an appropriate balance point based on local climate. (R403.1.2 Heat pump supplementary heat (Mandatory))

IECC Tech Tips
VIRGINIA

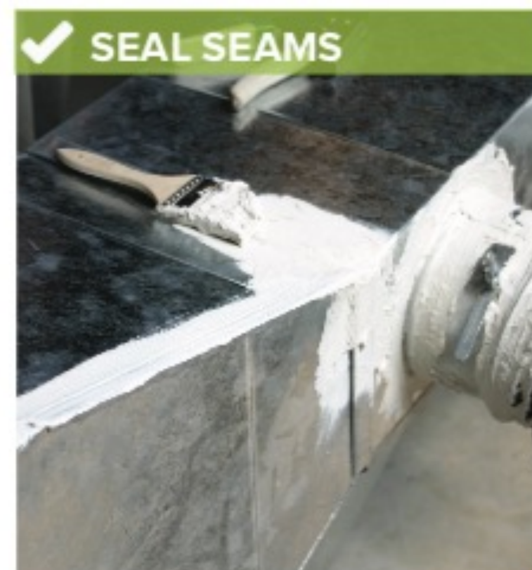
TECH TIPS:
HVAC Installation

Best practices for air-tight ductwork: Mastic

All duct leakage penalizes comfort, efficiency, durability, and moisture management.

Virginia code first established a numerical limit to duct leakage with the 2009 update and began requiring testing for ductwork outside of the building envelope with the 2015 update. The leakage limit is 4%.

Sealing ducts with bucket mastic and fabric mesh is widely considered the most reliable and durable method of minimizing duct leakage.



TECH TIPS:
HVAC Installation

Best practices for air-tight ductwork: Mastic

TECH TIPS:

HVAC Installation

Best practices for air-tight ductwork: Mastic

TECH TIPS:

HVAC Installation

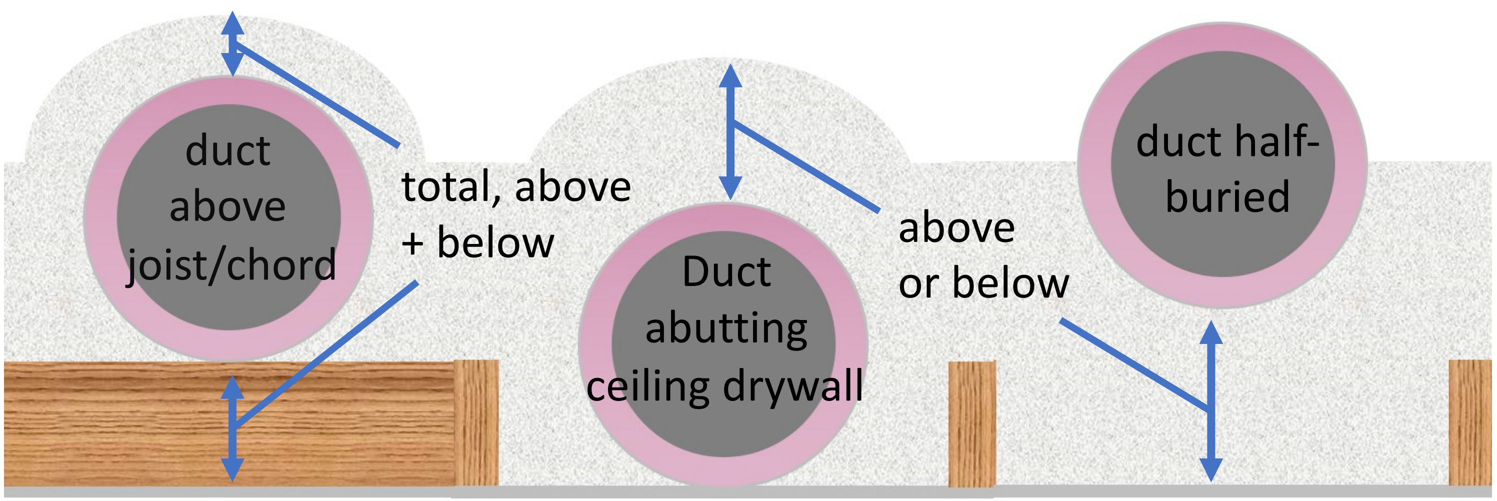
Best practices for air-tight ductwork: Mastic

TECH TIPS:
HVAC Installation

Buried Ducts: "At all points along each duct, the sum of the ceiling insulation R-value against and above the top of the duct, and against and below the bottom of the duct, shall be not less than R-19, excluding the R-value of the duct insulation." (R403.3.6 Ducts buried within ceiling insulation)

basc.pnnl.gov/code-compliance/buried-ducts-within-ceiling-insulation-vented-attics-all-climate-zones-code

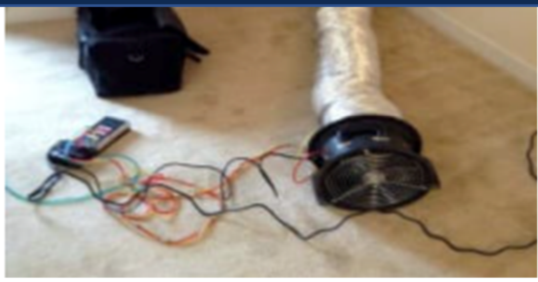
attic insulation: R-19 minimum, installed above, below, or as combined sum



code reference: R403.6 Ducts buried within ceiling insulation

Duct Sealing and Testing

2018 VRC/VECC Inspection Guide



Duct Testing and Sealing:

Summary: Virginia began requiring duct air-tightness to be measured with the 2015 code cycle, with a maximum leakage rate of 4%. This guide is intended to give both code and real world examples of what that change means for code enforcement in the Commonwealth.

Why: Consistent enforcement of the 2018 duct leakage provisions within the code will save the occupants of the more than 20,000 new homes built each year a combined $1.24 million on an annual basis. (Figure 1).[1] According to the Building America Solutions Center, "Duct leakage is a double hit on the utility bill: 1) duct leaks are an uncontrolled loss of conditioned air to the outdoors and 2) duct leakage drives building infiltration. For example, if a home had a 2.5-ton (30,000 BTU/H) cooling system moving 1,000 CFM (cubic feet per minute) of air and the ducts had 10% leakage (which is typical in code-built homes), the leakage rate would be 100 CFM. Each cubic foot of air carries with it 30 BTUs/H, so 3,000 BTUs of conditioned air would be lost to the outdoors each hour."[2] In addition to monetary and energy concerns, uncontrolled infiltration can have significant effects on health and durability.

Measure	Total Energy Savings (MMBtu)	Total Energy Cost Savings ($)	Total State Emissions Reduction (MT CO2e)
Duct Leakage	6,4168	1,244,243	31,520

Figure 1: Estimated Annual Statewide Savings Potential

If any component of an HVAC System is located outside of the building's thermal envelope, the system will be required to be pressure tested to determine air leakage. This test can take place at rough-in or after HVAC trim out has been completed. VECC R403.3.4 provides standards for leakage based on what components are installed during the time of the test:

- 3 Cubic Feet per Minute (CFM) / 100 Sq. Ft. of Floor Area Served (or 3% of CFA at rough-in without the air handler installed
- 4 Cubic Feet per Minute (CFM) / 100 Sq. Ft. of Floor Area Served (or 4% of CFA at rough-in with the air handler installed or at final)

$$\text{Duct Leakage} = \frac{\text{cfm}_{25}}{\text{square ft. of floor area served (CFA)}}$$

[1] https://www.energycodes.gov/sites/default/files/documents/Virginia_Residential_Field_Study.pdf

[2] https://basc.pnnl.gov/resource-guides/sealed-and-insulated-flex-ducts#edit-group-description

Virginia code (R403.3.3) allows anyone that has been trained on the duct testing equipment to provide duct leakage measurements.

Meeting N1103.3.3 (R403.3.3):

1. Determine location of HVAC systems within the home. If all ducts and associated air handlers are 100% within the building envelope, duct testing is not required. Spaces within the building envelope include conditioned crawl spaces, conditioned attics, and the space between conditioned floors. If there are multiple systems and some are completely within the building envelope and some are not, only the system(s) not fully within the building envelope are required to be tested.
2. If duct testing is required, determine the duct leakage target. The square feet served by each system must be determined in order to understand necessary duct leakage targets.
    a. *Example*: 1 system serving the entire home. Conditioned floor area of the home is 1,200 sq. ft.

        4% of conditioned floor area = **1,200 X 0.04 = 48**

        To pass final duct leakage at final inspection: **CFM_{25} must be ≤ 48 CFM**

        A written report of the results of the test shall be signed by the party conducting the test and provided to the code official. Check to ensure all systems are at or below required duct leakage based on floor area served.

Notes:

* *Duct boot to drywall and duct boot to subfloor connections are typically the largest offenders for total leakage, including returns boot connections to drywall*
* *Duct boots can be easily covered by drywall and lead to higher leakage in the field*
* *Ventilation systems connected to the central heating and cooling system can also increase leakage if not operating properly*
* *Based on the [Virginia Residential Energy Code Field Study](#) results, 94% of systems tested in the participating homes in 2017 and 2018 were over the 4 cfm/100 sq ft threshold, with that dropping to an 84% failure rate with the conditioned space exemption applied*
* *Duct leakage drives infiltration, or air leakage, through the envelope; it can negatively or positively pressurize the house depending on where the ducts are leaking, pulling outside air in through cracks in the building envelope or pushing conditioned air out. If the duct leakage is in the supply-side ducts, the house will be negatively pressurized compared to outdoors. If all the leakage is on the return side, the building will be positive with respect to outdoors[3]*

[3] https://basc.pnnl.gov/resource-guides/sealed-and-insulated-flex-ducts#edit-group-description

Duct Sealing Visuals:

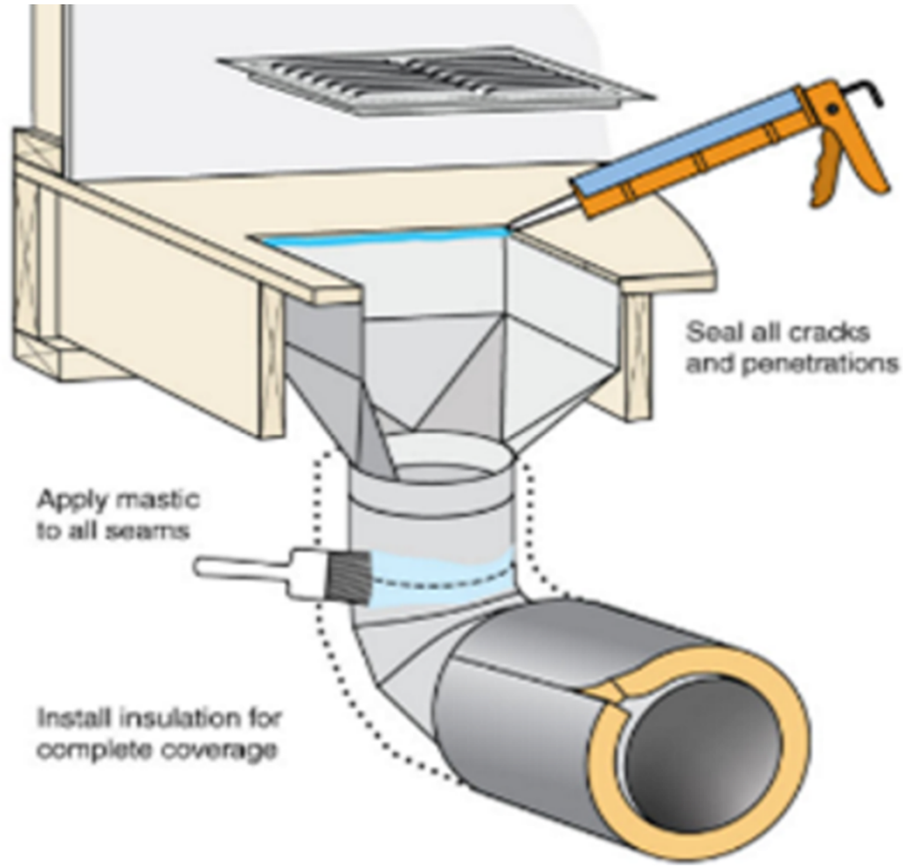


Figure 1: Joints and seams at duct boot sealed

Figure 2: Increased duct and envelope leakage if left unsealed

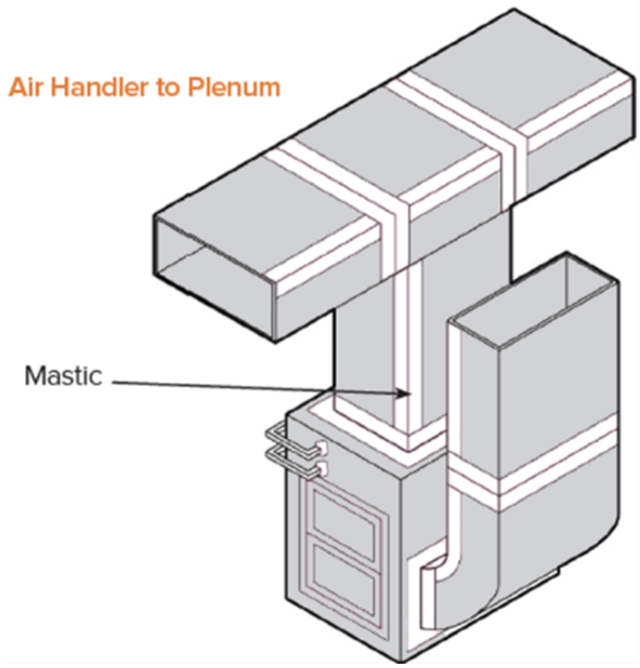


Figure 3: Well sealed plenum and trunk

Figure 4: Well sealed supply-to-trunk connection

Figure 5: Unsealed tabular duct takeoff

Figure 6: Unsealed and poorly supported duct takeoff

Figure 7: Mastic paste used as permanent seal – “thick as a nickel”

Duct Testing Code References:

Section R403.3.3/N1103.3.3 Duct testing (Mandatory). Ducts shall be pressure tested to determine air leakage by one of the following methods:

1. ***Rough-in test***. Total leakage shall be measured with a pressure differential of 0.1 inch water gage (25 Pa) across the system, including the manufacturer's air handler enclosure if installed at the time of the test. All registers shall be taped or otherwise sealed during the test.
2. ***Post-construction test***. Total leakage shall be measured with a pressure differential of 0.1 inch water gage (25 Pa) across the entire system, including the manufacturer's air handler enclosure. Registers shall be taped or otherwise sealed during the test.

Exception: A duct air leakage test shall not be required where the ducts and air handlers are located entirely within the *building thermal envelope*.

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 licensed mechanical contractor installing the mechanical system shall be permitted to perform the duct testing. The contractor shall have been trained on the equipment used to perform the test.

Section R403.3.4/N1103.3.4 Duct Leakage (Prescriptive). The total leakage of the ducts, measured in accordance with Section R403.3.3/N1103.3.3, shall be as follows:

1. ***Rough-in test.*** The total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m2) of conditioned floor area where the air handler is installed at the time of the test. Where the air handler is not installed at the time of the test, the total leakage shall be less than or equal to 3 cubic feet per minute (85 L/min) per 100 square feet (9.29 m2) of conditioned floor area.
2. ***Post-Construction test.*** Total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m2) of conditioned floor area.

Duct Sealing Code Reference:

Section R403.3.2/N1103.3.2 Sealing (Mandatory). Ducts, air handlers, and filter boxes shall be sealed. Joints and seams shall comply with Section M1601.4.1.

N1103.3.2.1 (R403.3.2.1) Sealed air handler. Air handlers shall have a manufacturer's designation for an air leakage of not greater than 2 percent of the design airflow rate when tested in accordance with ASHRAE 193.

Duct Location Code Reference:

Section R403.3.5/N1103.3.5 Building Cavities (mandatory). Building framing cavities should not be used as ducts or plenums.

Definitions:

Building Thermal Envelope: The basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space

Conditioned Space: An area, room, or space that is enclosed within the building thermal envelope and that is directly heated or cooled or indirectly heated or cooled

Above-Grade Wall: A wall more than 50% above grade and enclosing conditioned space. This includes between-floor spandrels, peripheral edges of floors, roof and basement knee-walls, dormer walls, gable end walls, walls enclosing mansard roof, and skylight shafts

Air Barrier: One or more materials joined together in a continuous manner to restrict or prevent the passage of air through the building thermal envelope and its assemblies

R-Value: The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area ($h \bullet ft^2 \bullet °F/Btu$) [($m^2 \bullet K)/W$]. **Note: In more general terms, resistance to heat flow of a single material, expressed as a whole number. Higher numbers denote higher resistance to heat flow*

U-Factor (U-Value): The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films ($Btu/h \bullet ft^2 \bullet °F$) [$W/(m^2 \bullet K)$]. **Note: In more general terms, resistance to heat flow of multiple materials expressed as a decimal point. Lower numbers denote higher resistance to heat flow*

Infiltration: The uncontrolled inward air leakage into a building caused by the pressure effects of wind, or the effect of differences in the indoor and outdoor air density or both

Duct Test Report

Testing Company	Name of Tester	Signature

Home Address	Permit Number	GPIN
Conditioned Square footage	**Source of Conditioned Square Footage**	**Number of HVAC Systems**

TEST RESULTS

System 1

☐ Duct tightness testing is not required. All ducts and the air handler are located entirely within the building thermal envelope.

Square Footage Served	Test Conditions	Maximum Allowed (CFM25)	*Attach supporting documentation (software generated report, photo of results, or similar*
		0.0	
Date	**Test results (cfm@25pa)**	**Compliance Status**	
		Pass	

System 2

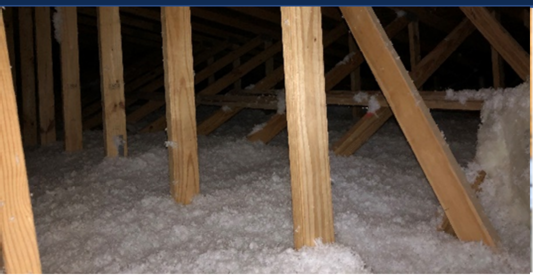
☐ Duct tightness testing is not required. All ducts and the air handler are located entirely within the building thermal envelope.

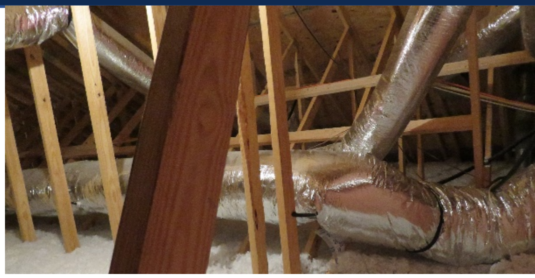
Square Footage Served	Test Conditions	Maximum Allowed (CFM25)	*Attach supporting documentation (software generated report, photo of results, or similar*
		0.0	
Date	**Test results (cfm@25pa)**	**Compliance Status**	
		Pass	

Notes

N1103.3.4 (R403.3.4) Duct Leakage (Prescriptive)

Test Conditions	Maximum Allowed Duct Leakage	Maximum Allowed (CFM25)
Rough-in with air handler installed	4 CFM per 100 sq ft of conditioned floor area	.04 x conditioned floor area served
Rough-in without air handler installed	3 CFM per 100 sq ft of conditioned floor area	.03 x conditioned floor area served
Post-construction	4 CFM per 100 sq ft of conditioned floor area	.04 x conditioned floor area served





Ducts Buried Within Insulation:

Summary: The residential portion of the Virginia Energy Conservation Code (VECC) now provides the option to bury ducts in insulation when they are in an attic. This provides better thermal insulation for the ducts and minimizes heat losses and gains while also ensuring that sufficient attic insulation is provided. This guide will cover the key installation details that must be followed in order to properly utilize this installation method.

Why: HVAC ductwork that is run outside of the building thermal envelope in a vented attic is only required to have R-8 insulation protecting it from extreme summer and winter temperatures in that space. While best practice dictates installing ductwork in conditioned space, many contractors prefer to locate this equipment in attics. In order to better protect ductwork from attic temperatures, the 2018 VECC allows for ducts to be buried within the attic insulation.

Items of Note:

- *The code is silent as to whether batts are allowed to be used for this installation method. However, only sprayed or blown insulation could be installed to avoid air gaps or compression without unusual effort by installers – particularly with round ducts. The batts would have to be carefully cut to fit against the sides of the duct to avoid an air gap. Any compression of the batts (e.g., from the duct resting on a batt) would have to be compensated for with additional insulation in order to achieve a fully code-compliant installation.*
- *Best practices for buried ducts include placing the ducts very close to or in contact with the ceiling drywall and encapsulating these ducts in closed cell foam. As always, duct systems should be well sealed and installed in as compact a layout as possible.*
- *The potential for condensation during the summer exists when burying ducts. Duct leakage and a lack of continuity of the vapor barrier on the duct insulation (e.g., rips in the duct jacket) are the two largest contributing factors to this risk. This is because it becomes more likely that the attic air will come in contact with a condensing plane that is at or below the attic air's dew point. It is recommended to encapsulate ducts in closed cell spray foam to minimize the potential for*

condensation. In the absence of encapsulating the duct in closed cell foam, extra attention should be paid to ensure the continuity of the vapor barrier on the duct insulation jacket.[1]

* *Well-sealed ducts properly buried in attic insulation have been shown to deliver 7 degrees cooler air in the summer – as compared to exposed ducts. This provides increased comfort for the occupants as well as energy savings.*[1]

Visual Reference:

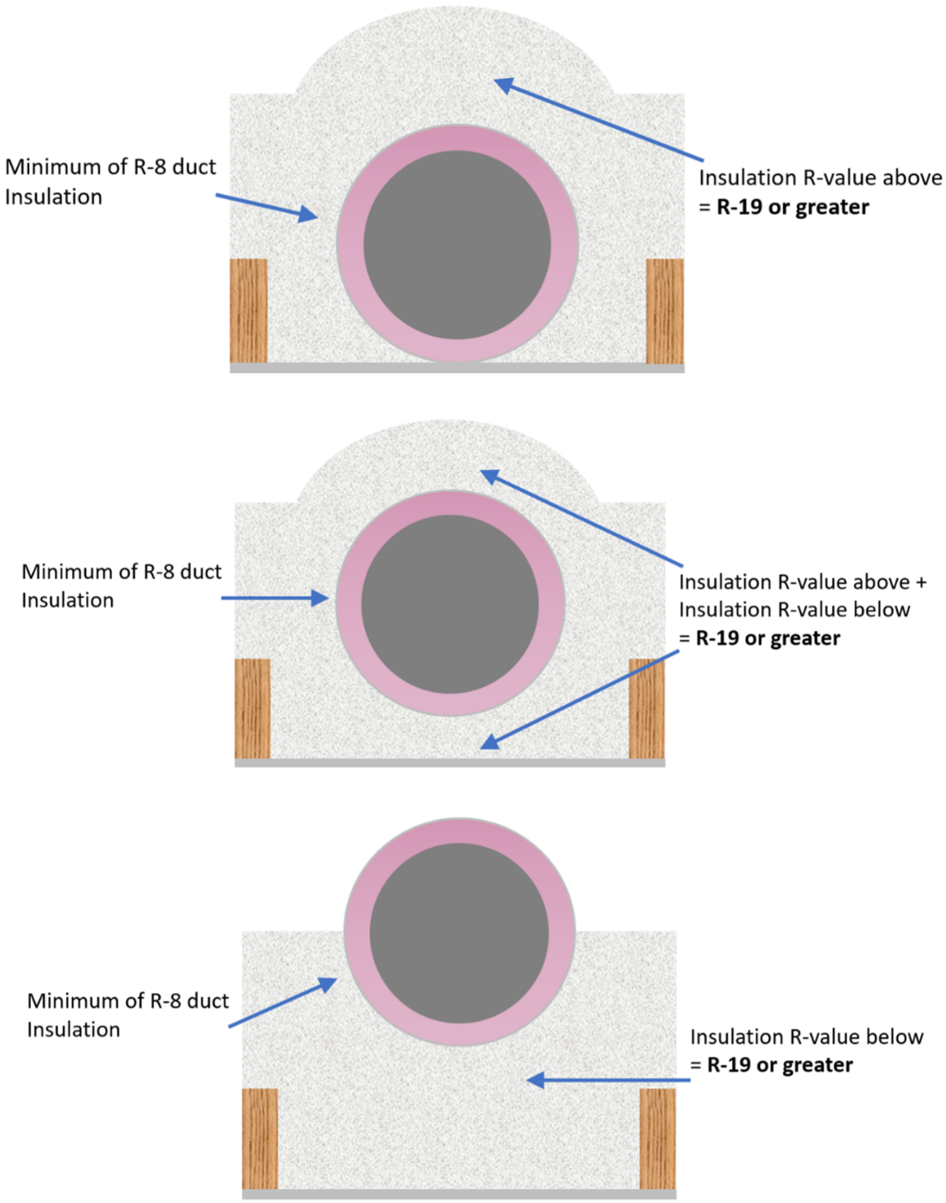


Figure 1: Different configuration options for burying ducts

[1] https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/compact-buried-ducts-hot-humid.pdf

2018 IECC/IRC Code Reference:

N1103.3.6 (R403.3.6)
Where supply and return air ducts are partially or completely buried in ceiling insulation, such ducts shall comply with all of the following:

1. 1.The supply and return duct shall have an insulation *R*-value not less than R-8.
2. 2.At all points along each duct, the sum of the ceiling insulation *R*-values against and above the top of the duct, and against and below the bottom of the duct shall be not less than R-19, excluding the *R*-value of the duct insulation.
3. 3.In *Climate Zones* 1A, 2A and 3A, the supply ducts shall be completely buried within ceiling insulation, insulated to an *R*-value of not less than R-13 and in compliance with the vapor retarder requirements of Section M1601.4.6.
   Exception: Sections of the supply duct that are less than 3 feet (914 mm) from the supply outlet shall not be required to comply with these requirements.

N1102.4.1.1 (R402.4.1.1) Installation (Mandatory)
The components of the building thermal envelope as listed in Table N1102.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table N1102.4.1.1, as applicable to the method of construction.

Table N1102.4.1.1 (R402.4.1.1) Air Barrier and Insulation Installation

Component	Air Barrier Criteria	Insulation Installation Criteria
General Requirements	A continuous air barrier shall be installed in the building envelope. The exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.	Air-permeable insulation shall not be used as a sealing material.
Ceiling/Attic	The air barrier in any dropped ceiling or soffit shall be aligned with the insulation and any gaps in the air barrier sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.

Definitions:

Air Barrier: One or more materials joined together in a continuous manner to restrict or prevent the passage of air through the building thermal envelope and its assemblies.

Attic: The unfinished space between the ceiling assembly and the roof assembly.

Building Thermal Envelope: The basement walls, exterior walls, floors, ceilings, roofs and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

Conditioned Space: An area, room or space that is enclosed within the building thermal envelope and that is directly heated or cooled or indirectly heated or cooled. Spaces are indirectly heated or cooled where they communicate through openings with conditioned spaces, where they are separated from conditioned spaces by uninsulated walls, floors or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling.

R-Value: Thermal resistance. The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area (h * ft2 * °F/Btu) [(m2 * K)/W]. **Note: In more general terms, resistance to heat flow of a single material, expressed as a whole number. Higher numbers denote higher resistance to heat flow*

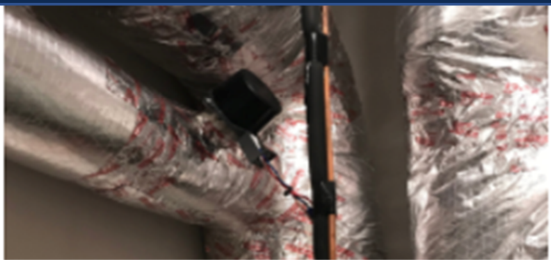
Vapor Barrier: *(Definition not from code)* A material or product that prevents the migration of moisture via vapor diffusion; a Class I vapor retarder with a perm rating of less than or equal to 0.1.

Vapor Retarder Class: A measure of the ability of a material or assembly to limit the amount of moisture that passes through that material or assembly. Vapor retarder class shall be defined using the desiccant method with Procedure A of ASTM E96 as follows:

- Class I: ≤0.1 perm rating
- Class II: > 0.1 to ≤ 1.0 perm rating
- Class III: > 1.0 to ≤ 10 perm rating

Whole-House Ventilation

2018 VRC/VECC Inspection Guide



2018 Whole-House Ventilation Code Requirements (section 403.6):

Summary: Virginia's Residential Energy Conservation Code has required mechanical ventilation in new homes since the 2012 version. Whole-house mechanical ventilation operates continuously or intermittently. Controls enable operation for not less than 25 percent (25%) of each four (4) hour segment. The intent of these systems is to provide ongoing delivery of controlled (ideally filtered) fresh air to the living space, expel stale air, dilute potential contaminants, and generally improve indoor environmental quality.

Why: Whole-house ventilation is fundamentally concerned with the health and well-being of the occupants. Estimates show that Americans spend up to 90% of their time indoors. To maintain healthy indoor environments, homes need a controlled means of bringing in fresh air and removing stale air on a regular schedule to ensure some dilution of contaminants and dissipation of odors.[1] There are three basic strategies used to bring in whole-house ventilation: supply, exhaust, and energy recovery ventilation. Depending on the strategy and equipment utilized, fresh air systems consist of air intake (**2018 VRC Sections: M1602.1, M1602.2**) and outlet vents, filters, ducts, controls, and fans (**2018 VECC Section: R403.6.1**). The strategy and equipment should take into account exterior temperature variations, desired indoor and prevalent outdoor humidity conditions, house configuration, and design objectives for the quantity and quality of air delivered.[2] Each system has its advantages and disadvantages, as listed in the table below.

Ventilation System	Pros	Cons
Exhaust	• Relatively inexpensive and simple to install • Works fine in cold climates	• Can draw pollutants into living space • Not appropriate for hot humid climates • Relies in part on random air leakage • Can increase heating and cooling costs • May require mixing of outdoor and indoor air to avoid drafts in cold weather • Can cause backdrafting in combustion appliances

[1] https://basc.pnnl.gov/building-science-measures/dilution-whole-house-ventilation
[2] https://basc.pnnl.gov/building-science-measures/properly-installed-whole-house-ventilation

Supply	• Relatively inexpensive and simple to install • Allows better control than exhaust systems • Minimize pollutants from outside living space • Prevent backdrafting of combustion gases from fireplaces and appliances • Allows filtering of pollen and dust in outdoor air • Allows dehumidification of outdoor air • Works well in hot or mixed climates	• Can cause moisture problems in cold climates • Will not always temper or remove moisture from incoming air • Can increase heating and cooling costs • May require mixing of outdoor and indoor air to avoid drafts in cold weather
Energy & Heat Recovery Ventilators	• Reduce heating and cooling costs • Available as both small wall- or window-mounted models or central ventilation systems • Allows filtering of outdoor air • Cost-effective in climates with extreme winters or summers and high fuel costs	• Can cost more to install than other ventilation systems • May not be cost-effective in mild climates • May be difficult to find contractors with experience and expertise to install these systems • Require freeze and frost protection in cold climates • Require more maintenance than other ventilation systems

Table 1: Pros and Cons of Various Mechanical Ventilation Systems[3]

Indoor air quality and ventilation needs vary greatly from home to home. Consider the following factors when choosing a specific design and equipment:

- **Occupancy:** A house or apartment with one occupant has very different ventilation needs compared to a household of five or more.
- **Occupant sensitivity:** Some people are more sensitive than others to contaminants. Pollutant levels that cause an asthma attack in one person may cause no problems for someone else.
- **Building characteristics:** The size, shape, design, and materials used in a building affect air leakage rates and pollutant sources.
- **Pollutant load:** Each house and apartment have different sources and levels of indoor pollutants
- **Weather:** Temperature, wind, and humidity vary throughout the year in any single location and in different climate zones. Each of these weather factors affects indoor air quality

Notes:

- *Providing fresh air by mechanical means uses energy – to operate fans and to heat/cool the incoming air. Optimize systems to avoid increasing relative humidity within the living space. Design for efficient operation and commission the fresh air system to ensure operation as designed.*
- *Best Practice: Select positive pressure or balanced ventilation systems in Virginia's mixed-humid climate. Avoid negative pressure/exhaust-only systems). See* ***www.buildingscience.com/documents/insights/bsi069-unintended-consequences-suck***

[3] https://www.energy.gov/energysaver/weatherize/ventilation/whole-house-ventilation

Whole-house Ventilation Equipment Examples:

Image 1 (above): Exhaust Ventilation Strategy – requires controls to ensure run times are met.

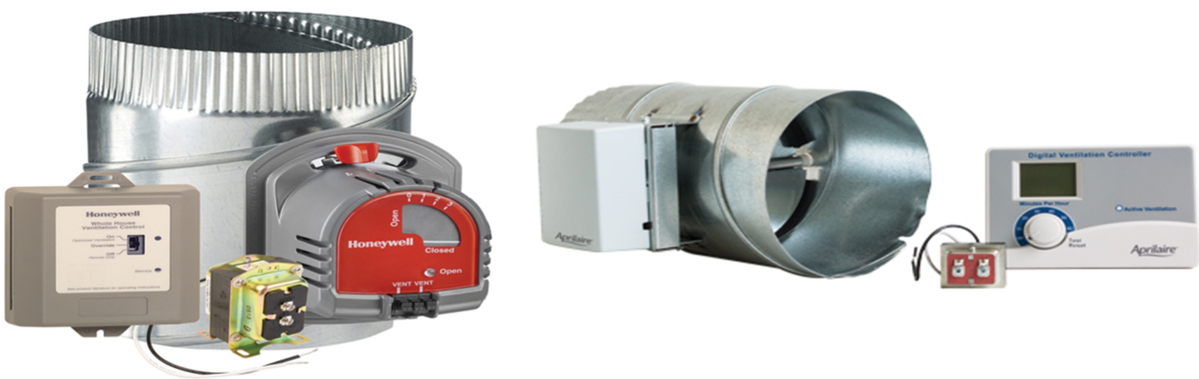


Image 2 (above): Common Supply Ventilation Systems – duct run from exterior to return plenum, automated damper, and controls

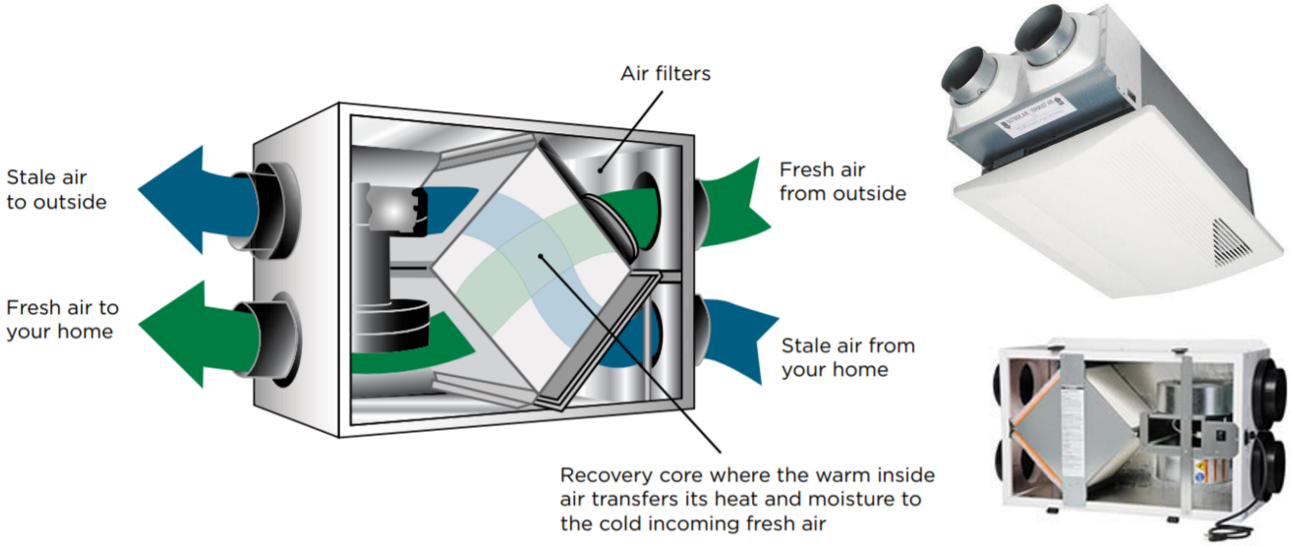


Image 1 (above): Balanced Ventilation Strategy utilizing heat or enthalpy recovery

Whole-House Ventilation Code Reference:

2018 VRC Section M1505.1 Mechanical Ventilation. General. Where local exhaust or whole-house mechanical ventilation is provided, the equipment shall be designed in accordance with this section.

2018 VRC Section M1505.4 Whole-house mechanical ventilation system. Whole-house mechanical ventilation systems shall be designed in accordance with Sections M1505.4.1 through M1505.4.4.

M1505.4.1 System Design. The whole-house ventilation system shall consist of one or more supply or exhaust fans, or a combination of such, and associated ducts and controls. Local exhaust or supply fans are permitted to serve as such a system. Outdoor air ducts connected to the return side of an air handler shall be considered as providing supply ventilation.

M1505.4.2 System Controls. The whole-house mechanical system shall be provided with controls that enable manual override.

***M1505.4.3 Mechanical ventilation rate*.** The whole-house mechanical ventilation system shall provide outdoor air at a continuous rate as determined in accordance with Table M1505.4.3(1) or Equation 15-1.

Equation 15-1: Ventilation rate in cubic feet per minute = (0.01 x total square foot area of house) + [7.5 x (number of bedrooms + 1)]

Exception: *The whole-house mechanical ventilation system is permitted to operate intermittently where the system has controls that enable operation for not less than 25 percent of each 4-hour segment and the ventilation rate prescribed in Table M1505.4.3(1) is multiplied by the factor determined in accordance with Table M1505.4.3(2).*

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

(above) Table 1505.4.3(1) Continuous whole-house ventilation system airflow rate requirements

RUN-TIME PERCENTAGE IN EACH 4-HOUR SEGMENT	25%	33%	50%	66%	75%	100%
Factor[a]	4	3	2	1.5	1.3	1.0

a. For ventilation system run time values between those given, the factors are permitted to be determined by interpolation.

b. Extrapolation beyond the table is prohibited.

(above) Table 1505.4.3(2) Intermittent whole-house mechanical ventilation rate factors.

2018 VECC Section R403.6.1 Whole-house mechanical ventilation system fan efficacy. Fans used to provide whole-house mechanical ventilation shall meet the efficacy requirements of Table R403.6.1.

> ***Exception:*** Where an air handler that is integral to tested and listed HVAC equipment is used to provide whole-house mechanical ventilation, the air handler shall be powered by an electronically commutated motor.

FAN LOCATION	AIR FLOW RATE MINIMUM (CFM)	MINIMUM EFFICACY (CFM/WATT)	AIR FLOW RATE MAXIMUM (CFM)
HRV or ERV	Any	1.2 cfm/watt	Any
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

(above) Table R403.6.1 Whole-house mechanical ventilation system fan efficacy

Fresh Air Inlet Location Requirements Code Reference:

2018 VRC Section R303.5 Opening location. Outdoor intake and exhaust openings shall be located in accordance with sections R303.5.1 and R303.5.2.

> ***R303.5.1 Intake openings.*** Mechanical and gravity outdoor air intake openings shall be located not less than 10 feet (3048 mm) from any hazardous or noxious contaminant, such as vents, chimneys, plumbing vents, streets, alleys, parking lots and loading docks.
>
> For the purpose of this section, the exhaust from dwelling unit toilet rooms, bathrooms and kitchens shall not be considered as hazardous or noxious.
>
> ***Exceptions:***
> 1. The 10-foot separation is not required where the intake opening is located 3 feet or greater below the contaminant source.
> 2. Vents and chimneys serving fuel-burning appliances shall be terminated in accordance with the applicable provisions of Chapters 18 and 24.
> 3. Clothes dryer exhaust ducts shall be terminated in accordance with Section M1502.3
>
> ***Section R303.5.2 Exhaust openings.*** Exhaust air shall not be directed onto walkways.

***R303.6 Outside opening protections*.** Air exhaust and intake openings that terminate outdoors shall be protected with corrosion-resistant screens, louvers or grilles having an opening size of not less than ¼ inch (6 mm) and a maximum opening size of ½ inch (13 mm), in any dimension. Openings shall be protected against local weather conditions. Outdoor air exhaust and intake openings shall meet the provision for *exterior wall* opening protectives in accordance with this code.

Definitions:

Above-Grade Wall: A wall more than 50% above grade and enclosing conditioned space; this includes between-floor spandrels, peripheral edges of floors, roof and basement knee-walls, dormer walls, gable end walls, walls enclosing mansard roof, and skylight shafts

Air Barrier: One or more materials joined together in a continuous manner to restrict or prevent the passage of air through the building thermal envelope and its assemblies

Building Thermal Envelope: The basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space

Conditioned Space: An area, room or space that is enclosed within the building thermal envelope and that is directly heated or cooled or indirectly heated or cooled. Spaces are indirectly heated or cooled where they communicate through openings with conditioned spaces, where they are separated from conditioned spaces by uninsulated walls, floors or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling.

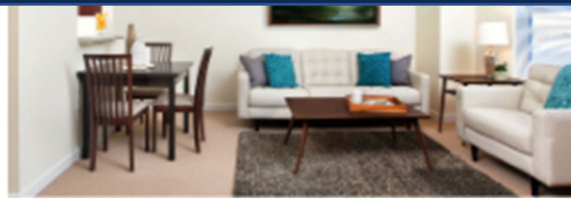
Infiltration: The uncontrolled inward air leakage into a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both

R-Value: Thermal resistance. The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area ($h \bullet ft^2 \bullet °F/Btu$) [($m^2 \bullet K)/W$]. **Note: In more general terms, resistance to heat flow of a single material, expressed as a whole number. Higher numbers denote higher resistance to heat flow*

U-Factor (U-Value): Thermal transmittance. The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films ($Btu/h \bullet ft^2 \bullet °F$) [$W/(m^2 \bullet K)$]. **Note: In more general terms, resistance to heat flow of multiple materials expressed as a decimal point. Lower numbers denote higher resistance to heat flow*

Indoor Air Quality, Code, and COVID

Improving Indoor Air Quality in Compliance with the 2018 VRC/VECC


Although improvements to ventilation and air cleaning cannot on their own eliminate the risk of airborne transmission of the SARS-CoV-2 virus, the **Environmental Protection Agency (EPA) recommends both increasing ventilation with outdoor air <u>and</u> improving air filtration** to make buildings safer for occupants. VRC Chapter 15 Exhaust Systems provides details for the safe installation and operation of all ventilation and exhaust options.

VENTILATION

- Bring in fresh air via one of the options listed below:
    - Install operable windows
    - Provide mechanical ventilation using a supply (positive pressure) strategy
    - Provide balanced mechanical ventilation using an energy recovery ventilator (ERV)
- Exhaust stale and/or polluted air
    - Remove air from the house with bathroom exhaust fans. Adding timer controls allows flexibility with the run times.
    - Install vented range hoods to reduce pollution from cooking activities and provide better overall indoor air quality. When atmospherically vented appliances exist within the building envelope, care should be taken to not create a situation where backdrafting is likely.

FILTRATION

- Properly sized HVAC systems have longer run times which increases total filtration.
- EPA recommends a MERV 13 filter, which traps very small particles, including viruses. The entire HVAC system should be designed and installed to accommodate this level of filtration.
- Ensure air filters fit properly. Air that can move past a filter (instead of through it) will retain pollutants.
- Provide instructions to the occupants on how often the filter should be changed, what size to get, and what MERV rating.
- Locating the air filter at the air handler avoids any return-side leakage that can occur between the return grille(s) and the air handler.

HVAC Filter Effectiveness							
MERV	Dust/Lint	Dust Mites	Pollen	Mold	Pet Dander	Bacteria	Attached Viruses
1-4	✓	✓	✓				
5-7	✓	✓	✓	✓			
8-12	✓	✓	✓	✓	✓	✓	
13-16+	✓	✓	✓	✓	✓	✓	✓

CODE

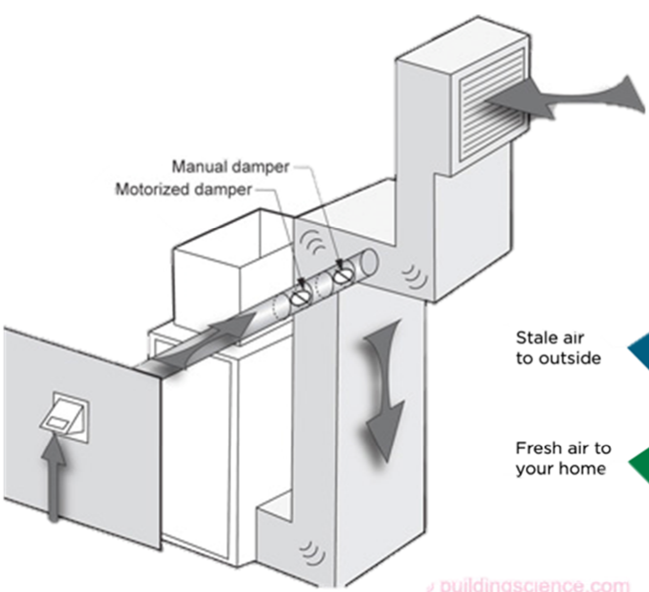
Mechanical ventilation is required in the 2018 USBC and is achievable through three strategies.

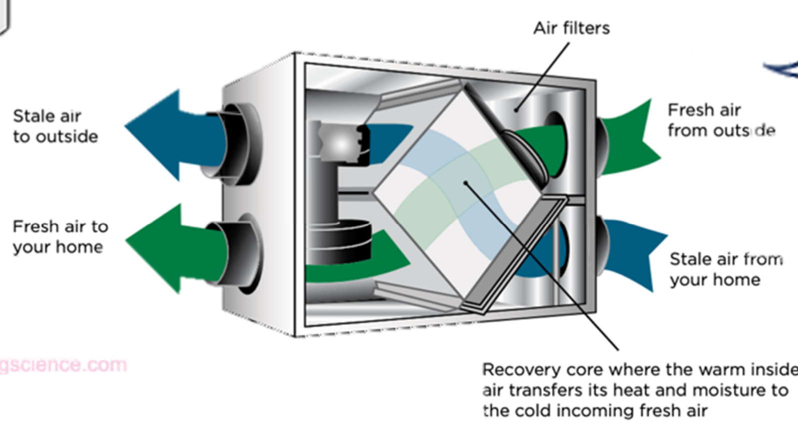
> ***Section N1103.6 (R403.6) Mechanical Ventilation (mandatory)***
> The *building* shall be provided with ventilation that complies with the requirements of Section M1505 or with other *approved* means of ventilation. Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating.

Ventilation Strategies

Various ventilation strategies may be used to meet mechanical ventilation including:

- **Exhaust** or negative pressure exhaust, often via bathroom exhaust ventilation utilizing timed settings to control exhaust ventilation
- **Supply** or positive pressure of fresh air introduced; most commonly circulated through air handler using an electronically-controlled motor
- **Balanced** ventilation where amount of air brought in or supplied is approximately equal to the amount of air exhausted, most commonly via an energy recovery ventilator in Virginia's climate





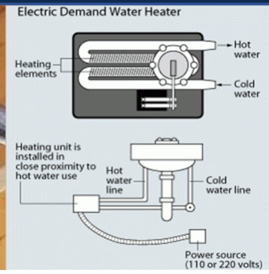
How much air is required?

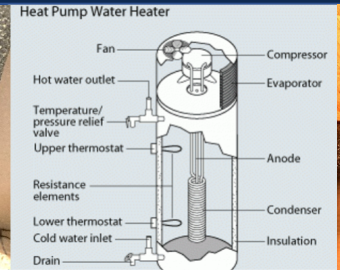
The rate of ventilation is measured in cubic feet per minute (CFM) and the amount of designed continuous ventilation is determined by home size (square feet) and number of bedrooms (equals assumed regular number of occupants). If using an intermittent or non-continuous ventilation strategy, the design ventilation is increased by an adjustment factor. (Source: Virginia Residential Code Table M1505.4.3(1))

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

Hot Water Pipe Insulation

2018 VRC/VECC Code Guide

Hot Water Pipe Insulation:

Summary: While the plumbing code (P2603.5) has long required freeze protection of water pipes as needed, the 2012 edition of Virginia's residential energy code began requiring specific insulation performance on some domestic hot water pipes for homes following the prescriptive path. That language changed slightly from the 2012 to 2015 editions but did not between the 2015 and 2018 editions. Per N1103.5. 3 (R403.5.3), pipe insulation of not less than R-3 should be installed on:

1. piping $^{3}/_{4}$ inch and larger in nominal diameter (Virginia's 2012 edition of the building code only required piping larger than ¾ inch to be insulated)
2. piping serving more than one dwelling unit
3. piping located outside conditioned space
4. piping from the water heater to a distribution manifold
5. piping located under a floor slab
6. buried piping
7. supply and return piping in recirculation systems other than demand recirculation systems

Why: Uninsulated piping increases risk of pipe failure, increases water and water heating costs, and can contribute to resident dissatisfaction with wait times for hot water. Risk of pipes freezing is reduced when they are insulated. PEX, a commonly used material, can suffer from long-term performance problems when degraded by UV exposure. Insulation helps to minimize UV exposure. Insulated hot water piping maintains the temperature in the pipes for longer, reducing wait time at fixtures and minimizing water waste.

Best practices for effective installation:

- Insulating pipes is quick and easy with typical hand tools after leakage tests and inspections but prior to cover-up by cavity insulation, drywall, and/or other coverings.
- Cut insulation to fit tightly around corners and nearby building components.
- Secure insulation as needed with tape, wire, clips, etc.

- For storage water heaters, also insulate the first foot of incoming cold water pipe adjacent to the water heater. Heat migrates up that pipe during times of no draw.
- Foam sleeves – from R-3 to R-5 – designed for insulating pipes are widely available for less than $.30 per linear foot (September 2022 pricing).
- Safety tip from the US Dept. of Energy: "On [atmospherically-vented] gas water heaters, insulation should be kept at least 6 inches from the flue. If pipes are within 8 inches of the flue, your safest choice is to use fiberglass pipe-wrap (at least 1-inch thick) without a facing. You can use either wire or aluminum foil tape to secure it to the pipe."[i]

How much energy does it save?

As of September 2022, conservation programs managed by electric utilities in Virginia calculate[ii] that pipe insulation reduces energy use by 17 kWh/year on ½" pipes and 26 kWh/year on ¾" pipe, per foot of pipe. In September 2022, much of Virginia is paying $.14 per kWh (prices will vary by utility jurisdiction and for other fuel sources). The table below calculates the potential savings over 30 years as achieved by insulating pipes in a typical home – based on unchanging electricity rates.

Pipe diameter (inches)	Annual kWh savings per foot	kWh cost	Savings per foot per year	Sample # feet of pipe in home	Savings per year for home	Mortgage term in years	Total savings over mortgage term
0.5	17	$ 0.14	$ 2.38	30	$ 71.40	30	$ 2,142.00
0.75	26	$ 0.14	$ 3.64	20	$ 72.80	30	$ 2,184.00
				Annual savings	$ 144.20	Lifetime savings	$ 4,326.00

2018 VECC and VRC Pipe Insulation Code References:

Section R403.5.3/N1103.5.3 Hot Water Pipe Insulation (Prescriptive). Insulation for hot water piping with a thermal resistance, R-value, of not less than R-3 shall be applied to the following:

1. Piping $^{3}/_{4}$ inch (19 mm) and larger in nominal diameter.
2. Piping serving more than one dwelling unit.
3. Piping located outside the conditioned space.
4. Piping from the water heater to a distribution manifold.
5. Piping located under a floor slab.
6. Buried piping.
7. Supply and return piping in recirculation systems other than demand recirculation systems.

[i] https://www.energy.gov/energysaver/do-it-yourself-savings-project-insulate-hot-water-pipes.
Banner graphics from https://www.energy.gov/energysaver/water-heating; photos from Viridiant.

[ii] Energy savings calculations are presented in the Mid-Atlantic Technical Reference Manual (TRM) V9 at https://neep.org/mid-atlantic-technical-reference-manual-trm-v9

LIGHTING

Tips for Meeting the 2018 Virginia Residential Energy Code

As of 2022, there's an affordable LED for every residential application. While the 2015 code required 75% utilization of compact fluorescent lamp (CFL) or light-emitting diode (LED) rather than incandescent bulbs, the 2018 Virginia Residential Code (at N1104.1, R404.1 in the VECC) requires that at least 90% of the permanently installed lighting fixtures contain only high-efficacy lamps or that 90% of the lamps in permanently installed fixtures be high-efficacy. LEDs use 10-15% of the energy of incandescent bulbs to make the same amount of light and last up to 50,000 hours.

LED

CFL

Incandescent

≥ 90%

Combination of both

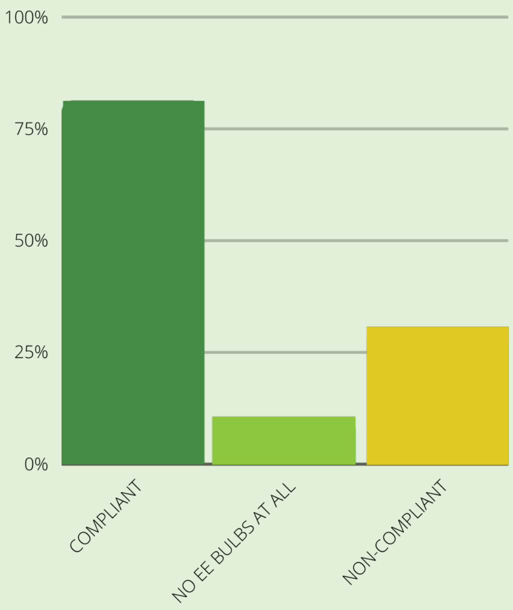
≤ 10%

Incandescents

High-Efficacy Lighting

2017-2018 Virginia Residential "Field Study" of energy code enforcement results

www.energycodes.gov/residential-energy-code-field-studies



Tips for Verifying High-Efficacy Bulbs are Installed

- LEDs are designed to make light, not heat. They won't be hot to the touch upon activation like incandescent bulbs.
- LEDs often have plastic bulbs – because they don't get so hot!
- Look for the ENERGY STAR label.
- Use a lighting ballast discriminator, an electronic sensor that indicates if lighting is CFL or LED.

A lighting ballast discriminator can detect the frequency of a bulb's ballast with the simple push of a button, telling you what type of bulb is present. A green light indicates a CFL or an LED, while a red light indicates an incandescent.

Contact Viridiant with any questions or comments via: admin@viridiant.org or (804) 225-9843