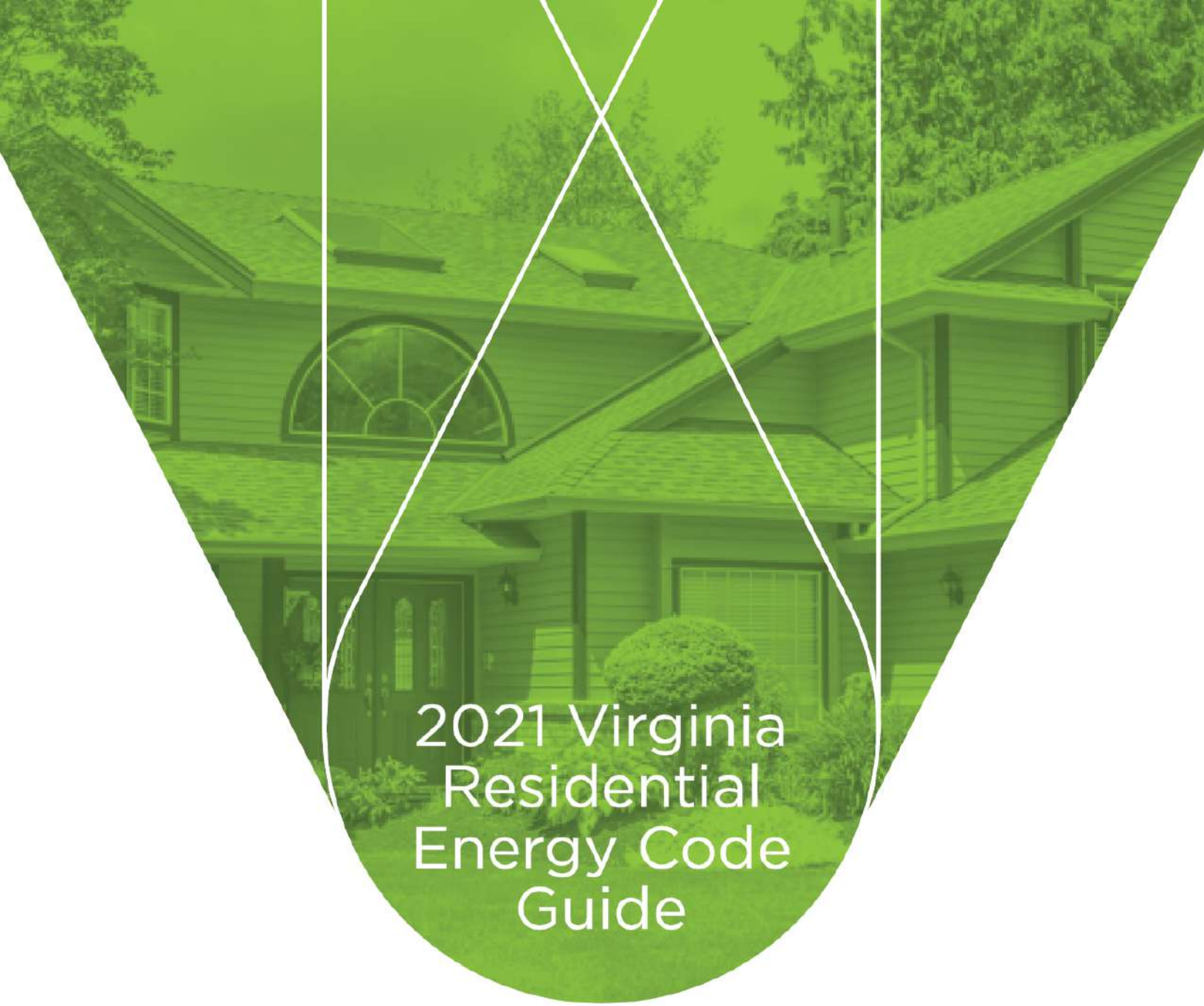

2021 Virginia Residential Energy Code Guide

VIRGINIA DHCD

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SOUTHEAST ENERGY EFFICIENCY ALLIANCE

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2021 VRC/VECC Update Guide

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Resources denoted with an * can be accessed digitally at www.viridiant.org/research-resources/.

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Your Resource Guide to the 2021 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 advance beneficial and uniform implementation of the residential portions of the 2021 Virginia Energy Conservation Code (VECC, the "Energy Code").

Notable energy-related changes in the 2021 update include:

• New climate zones for colder (5A) and warmer (3A) cities and counties; most jurisdictions remain the same (4A) • R60 attic insulation in zones 4A and 5A, R30 floor & R19 basement/crawl wall insulation in Zone 5A • Slab insulation must now extend 4 ft • Greater specificity regarding maintaining performance of floor insulation • Additional air sealing details required • Duct systems entirely within the building thermal envelope must be tested to demonstrate leakage not exceeding 8%	• Mechanical ventilation systems (required in all homes since 2015 code) must be tested to confirm required airflow is occurring. • Dimmers or occupant sensors included with most interior lighting • Daylight sensors providing automatic shut off for exterior lighting • Additional Efficiency Package Option requirement: For prescriptive path, include either enhanced envelope performance, more efficient HVAC equipment, reduced energy use in service water heating, more efficient duct thermal distribution, or improved air sealing and efficient ventilation system

Digital resources (denoted with an *) can be found by visiting https://viridiant.org/research-resources/ or scanning this QR code.

These resources are intended to support and provide deeper context and understanding of the implementation of 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, 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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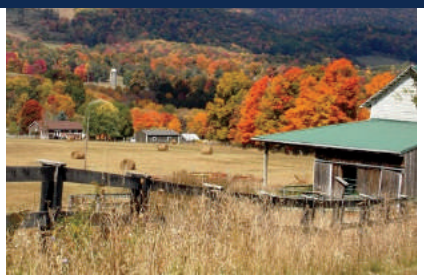
New Climate Zones for 24 Jurisdictions

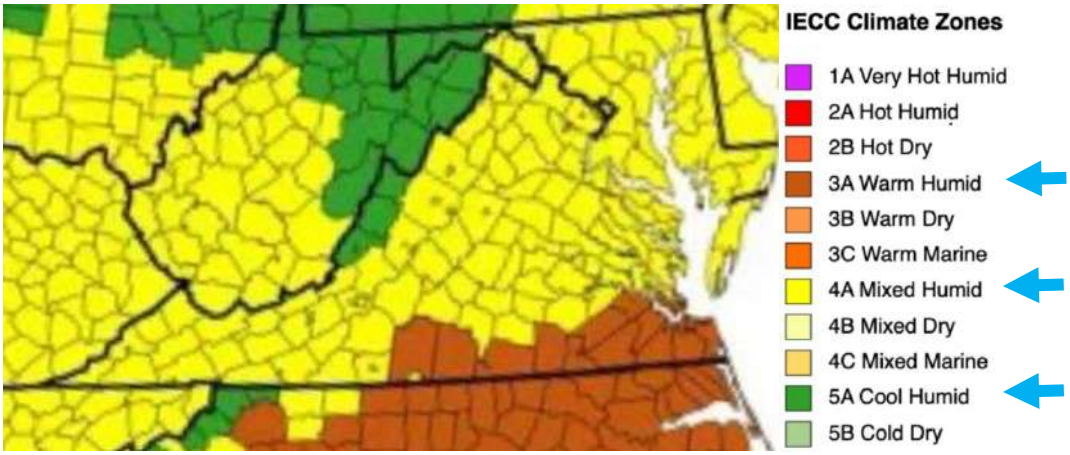
2021 VRC/VECC Update Guide

Changes to IECC Climate Zone Designations for Virginia Localities:

Summary: Virginia is no longer entirely within the 4A Mixed Humid zone. Nineteen Cities and Counties along the southern and eastern edge of the Commonwealth are now 3A Warm Humid, and five Cities and Counties on the northwest edge of the Commonwealth are now 5A Cool Humid.

This designation drives thermal performance requirements for different building elements in the code's U-Factor and R-Value tables. While window and skylight U-Factors and wood frame wall R-Values are consistent across all 3 Virginia climate zones, the values for other components will vary climate zone to climate zone. Code compliance reviewers should also be sure to take note of changing heating degree days (HDDs) and cooling degree days (CDD) listed for their locations – which are used in the load calculations for heating and cooling equipment.



Source: https://basc.pnnl.gov/images/climate-zone-map-iecc-2021

Why: The climate zones used by the IECC are developed and published by the American Society of Heating, Refrigeration, and Air-Conditioning Engineer (ASHRAE) in response to historical average temperature and humidity.

Additional Resources:

- www.ashrae.org

2021 VRC/VECC Code References:

TABLE N1101.7 (R301.1) CLIMATE ZONES, MOISTURE REGIMES, AND WARM HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

Virginia cities and counties now 5A (Cool Humid):

Alleghany Bath	Clifton Forge Covington	Highland

Virginia cities and counties now 3A (Warm Humid):

Brunswick Chesapeake Emporia Franklin Greensville Halifax Hampton	Isle of Wight Mecklenburg Newport News Norfolk Pittsylvania Portsmouth	South Boston Southampton Suffolk Surry Sussex Virginia Beach

All other Jurisdictions remain 4A (Mixed Humid)

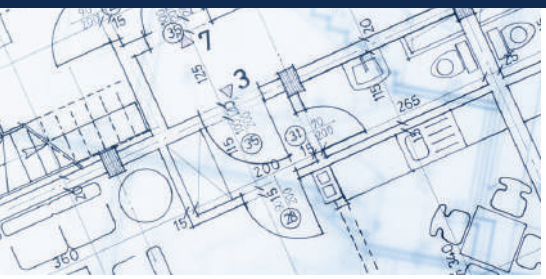
For the purposes of climate zone designations, towns are considered part of the counties in which they lie.

Definitions:

CLIMATE ZONE. A geographical region based on climatic criteria as specified in this code.

Expanded Compliance Path Options

2021 VRC/VECC Update Guide



Pathways to Energy Code Compliance:

Summary: The International Energy Conservation Code (IECC) has included both prescriptive and performance pathways for energy compliance since its conception, beginning with the 1998 IECC. The 2021 Virginia Residential Code updates the allowable compliance pathways to include three options – Prescriptive, Total Building Performance, and Energy Rating Index. Each option also requires meeting a new requirement, "additional energy efficiency" (N1101.13.5 (R401.2.5)), described below:

- Prescriptive pathway compliance can be achieved by utilizing a checklist of minimum performance thresholds for various building components. This is the easy-to-follow compliance option that guides builders with minimum R-Values, window values, air changes per hour, etc. Collectively, these prescribed thresholds provide for a home that meets the code's energy utilization goal.
- Performance pathway compliance options utilize software during the design phase to simulate – or "model" – the as-designed home's overall energy utilization. A home design complies with the code so long as the energy utilization of the modeled home does not exceed that of the "reference" home. Performance pathways allow a builder to, for example, use less insulation in one portion of the building envelope if more is provided elsewhere or to install a less efficient HVAC system if overall insulation levels are increased. A designer can create the basic structure of the home in the software and then pick and choose among efficiency measures as desired, periodically "running the model" to see if that combination of efficiency elements meets or exceeds the performance of the reference design.

Virginia's 2021 Energy Code provides two performance pathway options:

- The Total Building Performance Path (N1105 (R405)), previously called the Simulated Performance Path, models energy utilization based on that home's needs for heating and cooling, mechanical ventilation, and service hot water.
- The Energy Rating Index or ERI, (N1106 (R406)) is comparable to the Home Energy Rating Score (HERS) Index offered by the Residential Energy Services Network (RESNET). The ERI's energy model incorporates nearly every element of the home that affects energy use, including building geometry, insulation and window values, shading and orientation of glazing, mechanical equipment, mechanical ventilation, air tightness, duct tightness, appliances, etc. The ERI software then calculates a numerical score, with a lower number indicating a more efficient home. For instance, an ERI of 100 indicates performance equivalent to that of the 2006 IECC and an ERI of 0 indicates a "net zero" home. The as-designed home should score not greater than the reference design thresholds listed in Table N1106.5 (R406.5): 51 for Climate Zone 3, 54 for Climate Zone 4, and 55 for Climate Zone 5. However, the new Additional Energy Efficiency

requirement states that homes using the ERI pathway must have a score that is at least 5% less than the maximum scores listed in that table. That reduces the maximum scores to 48 for CZ 3, 51 for CZ 4, and 52 for CZ 5.

Even as they allow a designer flexibility to customize particular building elements, both performance pathways also stipulate minimum thresholds for key elements. For example, the Total Building Performance Path will not allow R-Values less than those in the 2009 IECC, and both pathways require testing of whole-home air leakage and duct leakage.

Additional Resources:

- https://www.iccsafe.org/building-safety-journal/bsj-technical/residential-compliance-options-of-the-international-energy-conservation-code/

2021 VRC/VECC Code References:

N1101.13 (R401.2) Application. Residential buildings shall comply with Section N1101.13.5 and Section N1101.13.1, N1101.13.2, N1101.13.3 or N1101.13.4.

Exception: Additions, alterations, repairs and changes of occupancy to existing buildings complying with Section N1109.

N1101.13.1 (R401.2.1) Prescriptive Compliance Option. The Prescriptive Compliance Option requires compliance with Sections N1101 through N1104.

N1101.13.2 (R401.2.2) Total Building Performance Option. The Total Building Performance Compliance Path requires compliance with Section N1105. [Available at https://codes.iccsafe.org/content/VARC2021P1/chapter-11-re-energy-efficiency#VARC2021P1_Ch11_SecN1105.]

N1101.13.3 (R401.2.3) Energy Rating Index Option. The Energy Rating Index (ERI) option requires compliance with Section N1106. [Available at https://codes.iccsafe.org/content/VARC2021P1/chapter-11-re-energy-efficiency#VARC2021P1_Ch11_SecN1106.]

N1101.13.5 (R401.2.5) Additional energy efficiency. This section establishes additional requirements applicable to all compliance approaches to achieve additional energy efficiency.

1. For buildings complying with Section N1101.13.1, one of the additional efficiency package options shall be installed according to Section N1108.2.
2. For buildings complying with Section N1101.13.2, the building shall meet one of the following:
   2.1. One of the additional efficiency package options in Section N1108.2 shall be installed without including such measures in the proposed design under Section N1105.
   2.2. The proposed design of the building under Section N1105.2 shall have an annual energy cost that is less than or equal to 95 percent of the annual energy cost of the standard reference design.
3. For buildings complying with the Energy Rating Index alternative Section N1101.13.3, the Energy Rating Index value shall be at least 5 percent less than the Energy Rating Index target specified.

The option selected for compliance shall be identified on the certificate required by Section N1101.14.

Definitions:

ENERGY ANALYSIS. A method for estimating the annual energy use of the proposed design and standard reference design based on estimates of energy use.

ENERGY COST. The total estimated annual cost for purchased energy for the building functions regulated by this code, including applicable demand charges.

ENERGY SIMULATION TOOL. An approved software program or calculation-based methodology that projects the annual energy use of a building.

ERI REFERENCE DESIGN. A version of the rated design that meets the minimum requirements of the 2006 International Energy Conservation Code.

PROPOSED DESIGN. A description of the proposed building used to estimate annual energy use for determining compliance based on total building performance.

RATED DESIGN. A description of the proposed building used to determine the energy rating index.

Additional Efficiency Packages

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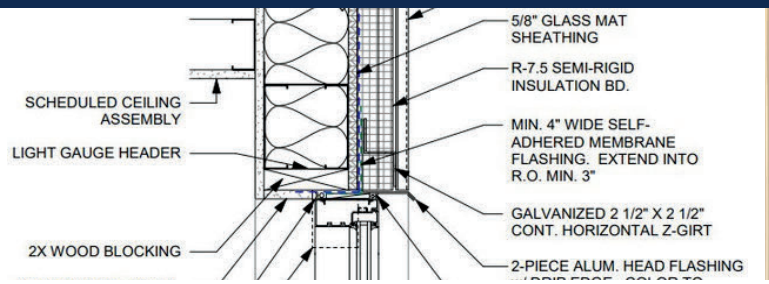

Options for Required Additional Energy Efficiency Measures:

Summary: The additional efficiency options package requirement is new in the 2021 Virginia Residential Code. For each of the three energy compliance pathways (Prescriptive, Total Building Performance, ERI), builders must include an additional measure to reduce energy demand. The available options vary depending on the compliance pathway being followed.

Why: The new Additional Energy Efficiency section is intended to increase energy savings and reduce utility costs to occupants over the life cycle of the building. Designers may select the option that works best for the project, both in terms of implementation and budget.

Meeting 1101.13.5 (R401.2.5) Additional Efficiency Option

Prescriptive Compliance Pathway

In addition to meeting all of the requirements of N1101 – N1104, the home must include *one* of the following:

- *A better thermal envelope* – at least 5% higher performing building envelope (as calculated by the total average R-Value) achieved via some combination of increased insulation and/or better insulating doors/windows. The area-weighted average SHGC for glazed windows and doors must be at least 5% better than what is listed in Table 1102.1.2.
- *Better HVAC equipment* – install equipment that is better than federal minimums.
    - Furnace/AC combos must be at least 95 AFUE and 16 SEER*
    - Heat pumps must be at least 10 HSPF* and 16 SEER*
    - Ground source/geothermal heat pumps must have a 3.5 COP or higher
- *Reduced water heating energy usage* – install better than standard water heating equipment.
    - Gas, propane, or other fossil fuel fired water heaters must have a .82 EF** or higher
    - Electric water heaters must be 2.0 EF** or higher. Only heat pump water heaters currently obtain that efficiency.
    - Solar water heating with a .4 solar fraction or better.
- *More efficient duct system* – reduce heating and cooling losses from installing ducts outside of conditioned space. All heating/cooling ducts must be installed in conditioned space (see N1103.3.2 (R403.3.2) for the definition of “conditioned space”). Hydronic distribution system equipment also must be located within conditioned space.
- *Improved air sealing and ventilation* – improve air sealing to achieve 3ACH50 or less, plus obtain more efficient mechanical ventilation by installing a heat recovery ventilator (HRV) or energy recovery ventilator (ERV).

*HVAC equipment ratings changed to SEER2 and HSPF2 in 2023 – after the publication of the 2021 model energy codes. The Residential Energy Services Network (RESNET), which provides energy ratings for homes, has provided the following conversion factors. The SEER2 or HSPF2 is divided by the conversion factor to obtain the equivalent SEER or HSPF.

Equipment Type	**SEER2/SEER**	**HSPF2/HSPF**
Ductless Systems	1.00	0.90
Ducted Split System	0.95	0.85
Ducted Packaged System	0.95	0.84
Small Duct High Velocity System	1.00	0.85
Ducted Space-Constrained Air Conditioner	0.97	Not Applicable
Ducted Space-Constrained Heat Pump	0.99	0.85

RESNET Addendum 71f: https://www.resnet.us/wp-content/uploads/FS_Adndm71fSEER2_webpost.pdf

Example: A 14.5 SEER2 ducted split heat pump is 15.26 SEER (14.5/.95 = 15.26)

**Water heaters are now rated in UEF. The equivalent UEF for 2.0 EF is 2.15 UEF.

Total Building Performance Compliance Pathway

Homes using this pathway must include one of the following:

- the proposed home design obtains an annual energy cost at least 5 percent less than the standard reference design or
- the home is equipped with at least one of the additional efficiency package options listed above for the prescriptive path – and – that additional element must not be included in the calculations for annual energy costs demonstrating savings relative to the reference design.

Energy Rating Index Option

For the Energy Rating Index (ERI) energy compliance path, the requirement is simply that the home must achieve a score 5 percent better than the code's target for that climate zone.

Climate Zone	Base ERI Target	5 Percent Improvement
3	51	48
4	54	51
5	55	52

Plan Review Focus: The home's construction documents are to note the home's planned energy compliance pathway. For TBP and ERI pathways, builders applying for permits must submit a compliance report (see N1105.3.2.1 (R405.3.2.1) and N1106.7.2.1 (R406.7.2.1)) showing the modeled home's energy costs/ERI as complying with program requirements. A second compliance report documenting how the as-built home meets program requirements is required when applying for a certificate of occupancy.

Additional Resources:

- https://www.iccsafe.org/building-safety-journal/bsj-technical/residential-compliance-options-of-the-international-energy-conservation-code/

2021 VRC/VECC Code References:

N1101.5 (R103.2) Information on construction documents. Construction documents shall be drawn to scale on suitable material. Electronic media documents are permitted to be submitted when approved by the code official. 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 as herein governed. Details shall include the following as applicable:

1. Energy compliance path.
2. Insulation materials and their R-values.
3. Fenestration U-factors and solar heat gain coefficients (SHGC).
4. Area-weighted U-factor and solar heat gain coefficient (SHGC) calculations.
5. Mechanical system design criteria.
6. Mechanical and service water heating systems and equipment types, sizes and efficiencies.
7. Equipment and system controls.
8. Duct sealing, duct and pipe insulation and location.
9. Air sealing details.

N1101.13 (R401.2) Application. Residential buildings shall comply with Section N1101.13.5 and Section N1101.13.1, N1101.13.2, N1101.13.3 or N1101.13.4.
Exception: Additions, alterations, repairs and changes of occupancy to existing buildings complying with Section N1109.

N1101.13.1 (R401.2.1) Prescriptive Compliance Option. The Prescriptive Compliance Option requires compliance with Sections N1101 through N1104.

N1101.13.2 (R401.2.2) Total Building Performance Option. The Total Building Performance Compliance Path requires compliance with Section N1105.

N1101.13.3 (R401.2.3) Energy Rating Index Option. The Energy Rating Index (ERI) option requires compliance with Section N1106.

N1101.13.5 (R401.2.5) Additional energy efficiency. This section establishes additional requirements applicable to all compliance approaches to achieve additional energy efficiency.

1. For buildings complying with Section N1101.13.1, one of the additional efficiency package options shall be installed according to Section N1108.2.
2. For buildings complying with Section N1101.13.2, the building shall meet one of the following:
    2.1. One of the additional efficiency package options in Section N1108.2 shall be installed without including such measures in the proposed design under Section N1105.
    2.2. The proposed design of the building under Section N1105.2 shall have an annual energy cost that is less than or equal to 95 percent of the annual energy cost of the standard reference design.
3. For buildings complying with the Energy Rating Index alternative Section N1101.13.3, the Energy Rating Index value shall be at least 5 percent less than the Energy Rating Index target specified.

The option selected for compliance shall be identified on the certificate required by Section N1101.14.

N1108.2 (R408.2) Additional efficiency package options. Additional efficiency package options for compliance with Section N1101.13.5 are set forth in Sections N1108.2.1 through N1108.2.5.

N1108.2.1 (R408.2.1) Enhanced envelope performance option. The total building thermal envelope UA, the sum of U-factor times assembly area, shall be less than or equal to 95 percent of the total UA resulting from multiplying the U-factors in Table N1102.1.2 by the same assembly area as in the proposed building. The UA calculation shall be performed in accordance with Section N1102.1.5. The area-weighted average SHGC of all glazed fenestration shall be less than or equal to 95 percent of the maximum glazed fenestration SHGC in Table N1102.1.2.

N1108.2.2 (R408.2.2) More efficient HVAC equipment performance option. Heating and cooling equipment shall meet one of the following efficiencies:

1. Greater than or equal to 95 AFUE natural gas furnace and 16 SEER air conditioner.
2. Greater than or equal to 10 HSPF/16 SEER air source heat pump.
3. Greater than or equal to 3.5 COP ground source heat pump. For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

N1108.2.3 (R408.2.3) Reduced energy use in service water-heating option. The hot water system shall meet one of the following efficiencies:

1. Greater than or equal to 0.82 EF fossil fuel service water-heating system.
2. Greater than or equal to 2.0 EF electric service water-heating system.
3. Greater than or equal to 0.4 solar fraction solar water-heating system.

N1108.2.4 (R408.2.4) More efficient duct thermal distribution system option. The thermal distribution system shall meet one of the following efficiencies:

1. 100 percent of ducts and air handlers located entirely within the building thermal envelope.
2. 100 percent of ductless thermal distribution system or hydronic thermal distribution system located completely inside the building thermal envelope.
3. 100 percent of duct thermal distribution system located in conditioned space as defined by Section N1103.3.2.

N1108.2.5 (R408.2.5) Improved air sealing and efficient ventilation system option. The measured air leakage rate shall be less than or equal to 3.0 ACH50, with either an Energy Recovery Ventilator (ERV) or Heat Recovery Ventilator (HRV) installed. Minimum HRV and ERV requirements, measured at the lowest tested net supply airflow, shall be greater than or equal to 75 percent Sensible Recovery Efficiency (SRE), less than or equal to 1.1 W/CFM Fan Energy and shall not use recirculation as a defrost strategy. In addition, the ERV shall be greater than or equal to 50 percent Latent Recovery/Moisture Transfer (LRMT).

Definitions:

BUILDING THERMAL ENVELOPE. The basement walls, exterior walls, floors, ceiling, roofs and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

ENERGY ANALYSIS. A method for estimating the annual energy use of the proposed design and standard reference design based on estimates of energy use.

ENERGY COST. The total estimated annual cost for purchased energy for the building functions regulated by this code, including applicable demand charges.

ENERGY SIMULATION TOOL. An approved software program or calculation-based methodology that projects the annual energy use of a building.

ERI REFERENCE DESIGN. A version of the rated design that meets the minimum requirements of the 2006 International Energy Conservation Code.

PROPOSED DESIGN. A description of the proposed building used to estimate annual energy use for determining compliance based on total building performance.

RATED DESIGN. A description of the proposed building used to determine the energy rating index.

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].

SERVICE WATER HEATING. Supply of hot water for purposes other than comfort heating.

U-FACTOR (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 × ft2× °F) [W/(m2× K)].

Certificate

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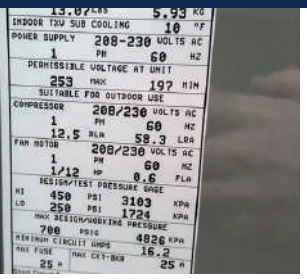

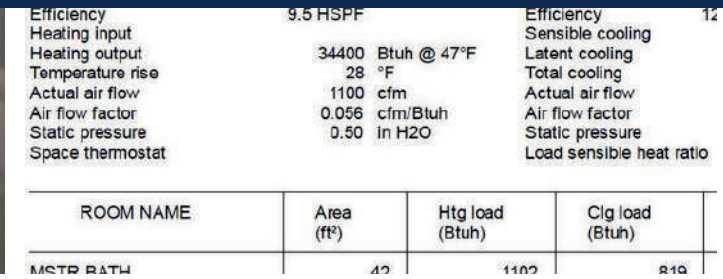

Efficiency	9.5 HSPF	Efficiency	12
Heating Input		Sensible cooling	
Heating output	34400 Btuh @ 47°F	Latent cooling	
Temperature rise	28 °F	Total cooling	
Actual air flow	1100 cfm	Actual air flow	
Air flow factor	0.056 cfm/Btuh	Air flow factor	
Static pressure	0.50 in H2O	Static pressure	
Space thermostat		Load sensible heat ratio	

ROOM NAME	Area (ft²)	Htg load (Btuh)	Clg load (Btuh)
MSTR BATH	42	1102	819

Mandatory Certificate of Energy Features:

Summary: Model codes began requiring posting of a certificate listing key energy details with the 2006 edition. The 2018 Virginia Residential Code began requiring this for the Commonwealth. The builder or other approved party must ensure a compliant document is created and posted in a convenient location.

2021 VRC/VECC Code References:

N1101.14 (R401.3) Certificate.
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. The certificate shall indicate the following:

1. 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.
2. U-factors of fenestration and the solar heat gain coefficient (SHGC) of fenestration. Where there is more than one value for any component of the building envelope, the certificate shall indicate both the value covering the largest area and the area weighted average value if available.
3. The results from any required duct system and building envelope air leakage testing performed on the building.
4. The types, sizes 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 is not required to be indicated for gas-fired unvented room heaters, electric furnaces and electric baseboard heaters.
5. Where on-site photovoltaic panel systems have been installed, the array capacity, inverter efficiency, panel tilt and orientation shall be noted on the certificate.
6. For buildings where an Energy Rating Index score is determined in accordance with Section N1106, the Energy Rating Index score, both with and without any on-site generation, shall be listed on the certificate.
7. The code edition under which the structure was permitted and the compliance path used.

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Building Energy Elements Certificate

Street Address: City: State: VA

Building Envelope					
Insulation R-Values					
Ceiling:		Above Grade Walls:			
Foundation Walls:		Floor Over Unconditioned Space:			
Slab:		Crawlspace Walls:			
Infiltration (blower door test):	ACH50:		CFM50:		
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 R-Value:		Total Duct Leakage %:			CFM25:		
HVAC System 2 (as applicable)								
Heating:	Type:			Efficiency:		Fuel:		
Cooling:	Type:			Efficiency:				
Ducts:	Insulation R-Value:		Total Duct Leakage %:			CFM25:		
Water Heater	Type:			Efficiency:		Fuel:		

Photovoltaic Power Systems (as applicable)			
Nameplate Output in KW		Inverter Efficiency:	
Panel Tilt(s):		Panel orientation(s):	

Energy Rating Index (as applicable)			
With on-site generation:		Without on-site generation:	

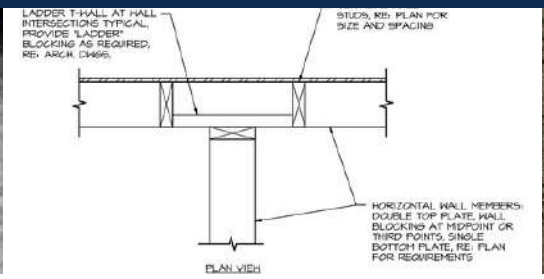
Building Code Edition Utilized for Permit			
Year:		Energy Compliance Pathway:	

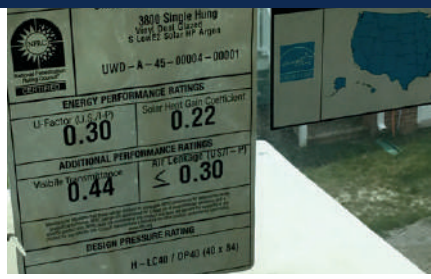
Builder or Design Professional			
Name:		Date:	
Signature:			

2021 Virginia Residential Code (Energy Conservation Code) N1101.14 (R401.3) Certificate:
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.

Updates to U-Factor & R-Value Tables

2021 VRC/VECC Update Guide





Changes to Thermal Performance Requirements:

Summary: Maximum U-Factors and minimum R-Values stipulated by the energy code change regularly in response to updated cost-benefit analysis comparing the cost of implementing greater thermal resistance strategies versus that of heating and cooling energy. U-Factors and R-Values also vary by climate zone, and with Virginia's new climate zones these requirements now vary by jurisdiction. The values required by the Prescriptive compliance option are presented in table N1102.1.3 (R402.1.3) INSULATION MINIMUM R-VALUES AND FENESTRATION REQUIREMENTS BY COMPONENT.

Glazing

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	GLAZED FENESTRATION SHGC
3	0.30	0.55	0.25
4 except Marine	0.30	0.55	0.40
5 and Marine 4	0.30	0.55	0.40

Building Envelope - Walls

CLIMATE ZONE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE	BASEMENT WALL *R*-VALUE	CRAWL SPACE WALL *R*-VALUE
3	15 cavity *or* 13 cavity+1ci	8/13	13 cavity *or* 5ci	13 cavity *or* 5ci
4 except Marine	15 cavity *or* 13 cavity+1ci	8/13	13 cavity *or* 10ci	13 cavity *or* 10ci
5 and Marine 4	15 cavity *or* 13 cavity+1ci	13/17	19 cavity *or* 15ci *or* 13 cavity+5ci	19 cavity *or* 15ci *or* 13 cavity+5ci

Building Envelope – Floors and Ceilings

CLIMATE ZONE	CEILING *R*-VALUE	FLOOR *R*-VALUE	SLAB *R*- VALUE & DEPTH
3	49	19	10ci, 2 ft
4 except Marine	60	19	10ci, 4 ft
5 and Marine 4	60	30	10cit, 4 ft

Notes:

- *"ci" refers to continuous – insulation material that is uninterrupted by framing components, such as insulated sheathing.*
- *Mass walls shall be in accordance with Section N1102.2.5 (R402.2.5). The second R-value applies where more than half of the insulation is on the interior of the mass wall.*
- *Crawlspace walls are not insulated only when the crawlspace is vented to the outside and the floor above is insulated.*

Changes of note affecting Virginia include:

- R-60 attic insulation for most of Virginia (climate zones 4 and 5).
- R-30 floor insulation for the five jurisdictions in climate zone 5
- 4 foot wide/deep slab insulation in climate zones 4 and 5
- R-19 cavity, R15 continuous, or 13+5 insulation for basement and crawlspace walls in climate zone 5

A home utilizing the Total Building Performance option is permitted to reduce the thermal performance of any building envelope component compared to the values listed in Table N1102.1.3 (R402.1.3) so long as the overall building package is calculated by approved software to obtain an annual energy cost not greater than that of the standard reference design home – and – so long as those building components perform at least as well as the prescriptive levels noted in Table R402.1.3 of the *2009* IECC. Additionally, the window U-Factors and SHGC values notes in Table N1102.1.2 (R402.1.2) must be met.

A home following the ERI compliance pathway is permitted to reduce the thermal performance of any building envelope as long as the proposed UA of the building is no more than 115% of the UA of the building using the values in Table N1102.1.2 (R402.1.2). The software used to generate an ERI score is also able to show UA compliance. Additionally, the ERI target in Table N1106.5 (R406.5) must be met, as well as the additional energy efficiency requirement of N1101.13.5 (R401.2.5). When on-site renewables are used for compliance these requirements are different and N1106.3.2. (R406.3.2) should be referenced.

Plan Review Focus: Construction documents should note which energy compliance path is being followed, insulation R-Values, and fenestration U-Factor and SHGC values.

Additional Resources:

- https://www.greenbuildingadvisor.com/article/getting-slab-edge-insulation-right
- https://basc.pnnl.gov/search?keywords=Insulation
- https://sws.nrel.gov/spec/4 Detailed installation guidelines

2021 VRC/VECC Code References:

N1102.1.4 (R402.1.4) R-value computation. Cavity insulation alone shall be used to determine compliance with the cavity insulation R-value requirements in Table N1102.1.3. Where cavity insulation is installed in multiple layers, the R-values of the cavity insulation layers shall be summed to determine compliance with the cavity insulation R-value requirements. The manufacturer's settled R-value shall be used for blown-in insulation. Continuous insulation (ci) alone shall be used to determine compliance with the continuous insulation R-value requirements in Table N1102.1.3. Where continuous insulation is installed in multiple layers, the R-values of the continuous insulation layers shall be summed to determine compliance with the continuous insulation R-value requirements. Cavity insulation R-values shall not be used to determine compliance with the continuous insulation R-value requirements in Table N1102.1.3. Computed R-values shall not include an R-value for other building materials or air films. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table N1102.1.3, the manufacturer's labeled R-value for insulated siding shall be reduced by R-0.6.

N1102.1.5 (R402.1.5) Total UA alternative. Where the total building thermal envelope UA, the sum of U-factor times assembly area, is less than or equal to the total UA resulting from multiplying the U-factors in Table N1102.1.2 by the same assembly area as in the proposed building, the building shall be considered to be incompliance with Table N1102.1.2. The UA calculation shall be performed using a method consistent with the ASHRAE Handbook of Fundamentals and shall include the thermal bridging effects of framing materials. In addition to UA compliance, the SHGC requirements of Table N1102.1.2 and the maximum fenestration U-factors of Section N1102.5 shall be met.

N1102.2.1 (R402.2.1) Ceilings with attics. Where Section N1102.1.3 requires R-49 insulation in the ceiling or attic, installing R-38 insulation over 100 percent of the ceiling or attic area requiring insulation shall satisfy the requirement for R-49 insulation wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. Where Section N1102.1.2 requires R-60 insulation in the ceiling or attic, installing R-49 over 100 percent of the ceiling or attic area requiring insulation shall satisfy the requirement for R-60 insulation wherever the full height of uncompressed R-49 insulation extends over the wall top plate at the eaves. This reduction shall not apply to the insulation and fenestration criteria in Section N1102.1.2 and the Total UA alternative in Section N1102.1.5.

R402.2.2 Ceilings without attics. Where Section R402.1.3 requires insulation R-values greater than R-30 in the interstitial space above a ceiling and below the structural roof deck, and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation R-value for such roof/ceiling assemblies shall be R-30. Insulation shall extend over the top of the wall plate to the outer edge of such plate and shall not be compressed. This reduction of insulation from the requirements of Section R402.1.3 shall be limited to 500 square feet (46 m2) or 20 percent of the total insulated ceiling area, whichever is less. This reduction shall not apply to the Total UA alternative in Section R402.1.5.

R402.2.3 Eave baffle. For air-permeable insulation in vented attics, a baffle shall be installed adjacent to soffit and eave vents. Baffles shall maintain a net free area opening equal to or greater than the size of the vent. The baffle shall extend over the top of the attic insulation. The baffle shall be permitted to be any solid material. The baffle shall be installed to the outer edge of the exterior wall top plate so as to provide maximum space for attic insulation coverage over the top plate. Where soffit venting is not continuous, baffles shall be installed continuously to prevent ventilation air in the eave soffit from bypassing the baffle.

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:

1. Hinged vertical doors shall have a minimum overall R-5 insulation value;
2. Hatches and scuttle hole covers shall be insulated to a level equivalent to the insulation on the surrounding surfaces; and
3. Pull down stairs shall have a minimum of 75percent of the panel area having R-5 rigid insulation.

Access shall be provided to all equipment that prevents damaging or compressing the insulation. A wood-framed or equivalent baffle or retainer is required to be provided when loose fill insulation is installed, the purpose of which is to prevent the loose fill insulation from spilling into the living space when the attic access is opened, and to provide a permanent means of maintaining the installed R-value of the loose fill insulation.

N1102.2.4.1 (R402.2.4.1) Access hatch and door insulation installation and retention. Vertical or horizontal access hatches and doors from conditioned spaces to unconditioned spaces such as attics and crawl spaces shall be weatherstripped. Access that prevents damaging or compressing the insulation shall be provided to all equipment. Where loose-fill insulation is installed, a wood-framed or equivalent baffle, retainer, or dam shall be installed to prevent loose-fill insulation from spilling into living space from higher to lower sections of the attic, and from attics covering conditioned spaces to unconditioned spaces. The baffle or retainer shall provide a permanent means of maintaining the installed R-value of the loose-fill insulation.

R402.2.7 Floors. Floor cavity insulation shall comply with one of the following:

1. Installation shall be installed to maintain permanent contact with the underside of the subfloor decking in accordance with manufacturer instructions to maintain required R-value or readily fill the available cavity space.
2. Floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing separating the cavity and the unconditioned space below. Insulation shall extend from the bottom to the top of all perimeter floor framing members and the framing members shall be air sealed.
3. A combination of cavity and continuous insulation shall be installed so that the cavity insulation is in contact with the top side of the continuous insulation that is installed on the underside of the floor framing separating the cavity and the unconditioned space below. The combined R-value of the cavity and continuous insulation shall equal the required R-value for floors. Insulation shall extend from the bottom to the top of all perimeter floor framing members and the framing members shall be air sealed.

N1102.2.8 (R402.2.8) Basement walls. Basement walls shall be insulated in accordance with Table N1102.1.3.
Exception: Basement walls associated with unconditioned basements where all of the following requirements are met:

1. The floor overhead, including the underside stairway stringer leading to the basement, is insulated in accordance with Section N1102.1.3 and applicable provisions of Sections N1102.2 and N1102.2.7.
2. There are no uninsulated duct, domestic hot water or hydronic heating surfaces exposed to the basement.
3. There are no HVAC supply or return diffusers serving the basement.
4. The walls surrounding the stairway and adjacent to conditioned space are insulated in accordance with Section N1102.1.3 and applicable provisions of Section N1102.2.
5. The door(s) leading to the basement from conditioned spaces are insulated in accordance with Section N1102.1.3 and applicable provisions of Section N1102.2, and weatherstripped in accordance with Section N1102.4.
6. The building thermal envelope separating the basement from adjacent conditioned spaces complies with Section N1102.4.

N1102.2.8.1 (R402.2.8.1) Basement wall insulation installation. Where basement walls are insulated, the insulation shall be installed from the top of the basement wall down to 10 feet (3048 mm) below grade or to the basement floor, whichever is less.

N1102.2.9 (R402.2.9) 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 N1102.1.3.
Exception: Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation.

R402.2.9.1 Slab-on-grade floor insulation installation. Where installed, 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 R402.1.3 or the distance of the proposed design, as applicable, 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.

N1102.2.10 (R402.2.10) Crawl space walls. Crawl space walls shall be insulated in accordance with Table N1102.1.3.

> **Exception:** Crawl space walls associated with a crawl space that is vented to the outdoors and the floor overhead is insulated in accordance with Table N1102.1.3 and Section N1102.2.7.

N1102.2.10.1 (R402.2.10.1) Crawl space wall insulation installation. Where crawl space wall insulation is installed, it 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.

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.

APPROVED. Acceptable to the code official.

APPROVED AGENCY. An established and recognized agency that is regularly engaged in conducting tests furnishing inspection services, or furnishing product certification, where such agency has been approved by the code official.

BASEMENT WALL. A wall 50 percent or more below grade and enclosing conditioned space.

BUILDING. Any structure used or intended for supporting or sheltering any use or occupancy, including any mechanical systems, service water-heating systems and electric power and lighting systems located on the building site and supporting the building.

BUILDING THERMAL ENVELOPE. The basement walls, exterior walls, floors, ceiling, roofs and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

CAVITY INSULATION. Insulating material located between framing members.

CLIMATE ZONE. A geographical region based on climatic criteria as specified in this code.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly 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.

CONTINUOUS AIR BARRIER. A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (ci). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

CRAWL SPACE WALL. The opaque portion of a wall that encloses a crawl space and is partially or totally below grade.

CURTAIN WALL. Fenestration products used to create an external nonload-bearing wall that is designed to separate the exterior and interior environments.

DWELLING UNIT ENCLOSURE AREA. The sum of the area of ceiling, floors, and walls separating a dwelling unit's conditioned space from the exterior or from adjacent conditioned or unconditioned spaces. Wall height shall be measured from the finished floor of the dwelling unit to the underside of the floor above.

ENERGY ANALYSIS. A method for estimating the annual energy use of the proposed design and standard reference design based on estimates of energy use.

ENERGY SIMULATION TOOL. An approved software program or calculation-based methodology that projects the annual energy use of a building.

ERI REFERENCE DESIGN. A version of the rated design that meets the minimum requirements of the 2006 International Energy Conservation Code.

EXTERIOR WALL. Walls including both above-grade walls and basement walls.

FENESTRATION. Products classified as either vertical fenestration or skylights.

- Skylights. Glass or other transparent or translucent glazing material installed at a slope of less than 60 degrees (1.05 rad) from horizontal including unit skylights, tubular daylighting devices, and glazing materials in solariums, sunrooms, roofs and sloped walls.
- Vertical fenestration. Windows that are fixed or operable, opaque doors, glazed doors, glazed block and combination opaque/glazed doors composed of glass or other transparent or translucent glazing materials and installed at a slope of not less than 60 degrees (1.05 rad) from horizontal.

FENESTRATION PRODUCT, SITE-BUILT. A fenestration designed to be made up of field-glazed or field-assembled units using specific factory cut or otherwise factory-formed framing and glazing units. Examples of site-built fenestration include storefront systems, curtain walls and atrium roof systems.

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.

INSULATED SIDING. A type of continuous insulation with manufacturer-installed insulating material as an integral part of the cladding product having an R-value of not less than R-2.

LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, approved agency or other organization concerned with product evaluation that maintains periodic inspection of the production of such labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

LISTED. Equipment, materials, products or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

OPAQUE DOOR. A door that is not less than 50-percent opaque in surface area.

PROPOSED DESIGN. A description of the proposed building used to estimate annual energy use for determining compliance based on total building performance.

RATED DESIGN. A description of the proposed building used to determine the energy rating index.

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].
SERVICE WATER HEATING. Supply of hot water for purposes other than comfort heating.

SOLAR HEAT GAIN COEFFICIENT (SHGC). The ratio of the solar heat gain entering the space through the fenestration assembly to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation that is then reradiated, conducted or convected into the space.

STANDARD REFERENCE DESIGN. A version of the proposed design that meets the minimum requirements of this code and is used to determine the maximum annual energy use requirement for compliance based on total building performance.

THERMAL ISOLATION. Physical and space conditioning separation from conditioned spaces. The conditioned spaces shall be controlled as separate zones for heating and cooling or conditioned by separate equipment.

U-FACTOR (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 × ft2× °F) [W/(m2× K)].

Overhead Insulation Details

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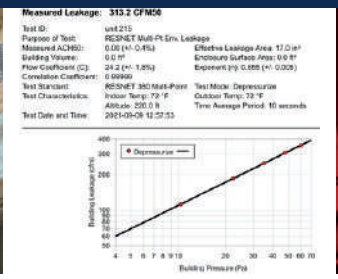
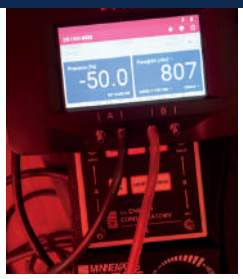




Updated Details for Attic Insulation:

As in previous editions of the Virginia Residential Code, the nameplate attic insulation R-Value on the attic floor (R-60 in climate zones 4 and 5; R-49 in climate zone 3) applies only when the roof framing prevents the full height of insulation from being installed at the building perimeter – as in the image below.

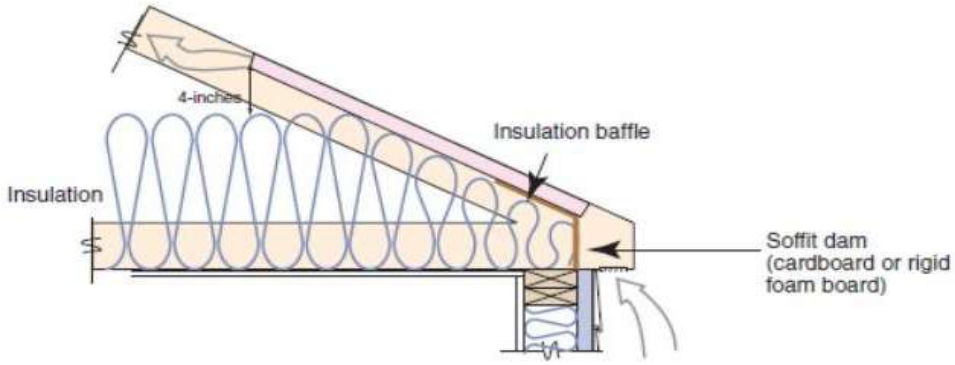
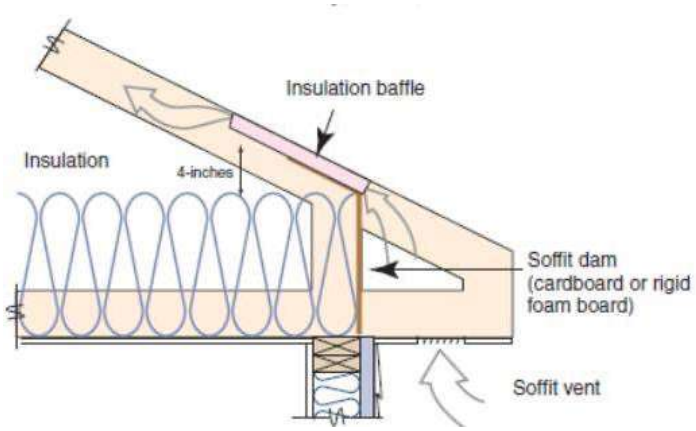


Image from https://basc.pnnl.gov/resource-guides/attic-eave-minimum-insulation

In climate zones 4 and 5, R-49 overhead insulation is sufficient if that amount can be obtained over the entire top plate of the exterior wall beneath. For a vented attic with insulation on the attic floor, this typically is achieved using raised heel trusses (as shown below). That reduced minimum R-Value also applies to cathedral ceilings or unvented attics. In climate zone 3, R-38 serves as this alternative minimum when those conditions hold.



Images from https://basc.pnnl.gov/resource-guides/attic-eave-minimum-insulation

Note also that section N1102.2.3 (R402.2.3) Eave baffle now requires soffit dam assemblies to be made airtight. Builders should caulk or otherwise seal around soffit dam material to prevent air movement through the side of the insulation layer. The only pathway to the attic from vented soffits should be via the insulation baffle installed against the bottom of the roof decking.

Image: daylight shows gaps to be caulked around cardboard baffles to eliminate air intrusion; photo: Viridiant

Wall/ceiling abutting vented attic space:

New code language specifies construction strategies to maintain full thickness of loose attic floor insulation over the entire footprint of rooms with walls that abut unconditioned attic space. This was added to the section that requires dams around attic hatches when loose fill insulation is used. As around hatches, these wood, cardboard or other dam or retainer can be used to allow the full height of the loose-fill insulation to extend over the full width of the top plate of the wall abutting the attic. It keeps insulation from falling off the insulated ceiling. If rigid sheathing is used to cover the attic side of the wall below, it can be extended up the necessary height to serve as a dam as in the image below.

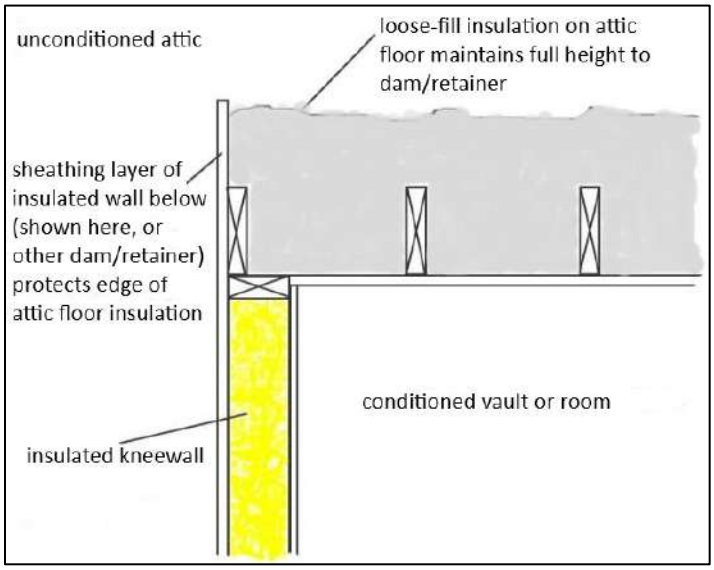


Image: Viridiant

2021 VRC/VECC Code References:

N1102.1.4 (R402.1.4) R-value computation. Cavity insulation alone shall be used to determine compliance with the cavity insulation R-value requirements in Table N1102.1.3. Where cavity insulation is installed in multiple layers, the R-values of the cavity insulation layers shall be summed to determine compliance with the cavity insulation R-value requirements. The manufacturer's settled R-value shall be used for blown-in insulation. Continuous insulation (ci) alone shall be used to determine compliance with the continuous insulation R-value requirements in Table N1102.1.3. Where continuous insulation is installed in multiple layers, the R-values of the continuous insulation layers shall be summed to determine compliance with the continuous insulation R-value requirements. Cavity insulation R-values shall not be used to determine compliance with the continuous insulation R-value requirements in Table N1102.1.3. Computed R-values shall not include an R-value for other building materials or air films. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table N1102.1.3, the manufacturer's labeled R-value for insulated siding shall be reduced by R-0.6.

N1102.1.5 (R402.1.5) Total UA alternative. Where the total building thermal envelope UA, the sum of U-factor times assembly area, is less than or equal to the total UA resulting from multiplying the U-factors in Table N1102.1.2 by the same assembly area as in the proposed building, the building shall be considered to be in compliance with Table N1102.1.2. The UA calculation shall be performed using a method consistent with the ASHRAE Handbook of Fundamentals and shall include the thermal bridging effects of framing materials. In addition to UA compliance, the SHGC requirements of Table N1102.1.2 and the maximum fenestration U-factors of Section N1102.5 shall be met.

N1102.2.1 (R402.2.1) Ceilings with attics. Where Section N1102.1.3 requires R-49 insulation in the ceiling or attic, installing R-38 insulation over 100 percent of the ceiling or attic area requiring insulation shall satisfy the requirement for R-49 insulation wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. Where Section N1102.1.2 requires R-60 insulation in the ceiling or attic, installing R-49 over 100 percent of the ceiling or attic area requiring insulation shall satisfy the requirement for R-60 insulation wherever the full height of uncompressed R-49 insulation extends over the wall top plate at the eaves. This reduction shall not apply to the insulation and fenestration criteria in Section N1102.1.2 and the Total UA alternative in Section N1102.1.5.

N1102.2.2 (R402.2.2) Ceilings without attics. Where Section N1102.1.3 requires insulation R-values greater than R-30 in the interstitial space above a ceiling and below the structural roof deck, and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation R-value for such roof/ceiling assemblies shall be R-30. Insulation shall extend over the top of the wall plate to the outer edge of such plate and shall not be compressed. This reduction of insulation from the requirements of Section N1102.1.3 shall be limited to 500 square feet (46 m2) or 20 percent of the total insulated ceiling area, whichever is less. This reduction shall not apply to the Total UA alternative in Section N1102.1.5.

N1102.2.3 (R402.2.3) Eave baffle. For air-permeable insulation in vented attics, a baffle shall be installed adjacent to soffit and eave vents. Baffles shall maintain a net free area opening equal to or greater than the size of the vent. The baffle shall extend over the top of the attic insulation. The baffle shall be permitted to be any solid material. The baffle shall be installed to the outer edge of the exterior wall top plate so as to provide maximum space for attic insulation coverage over the top plate. Where soffit venting is not continuous, baffles shall be installed continuously to prevent ventilation air in the eave soffit from bypassing the baffle.

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:

1. Hinged vertical doors shall have a minimum overall R-5 insulation value;
2. Hatches and scuttle hole covers shall be insulated to a level equivalent to the insulation on the surrounding surfaces; and
3. Pull down stairs shall have a minimum of 75 percent of the panel area having R-5 rigid insulation.

Access shall be provided to all equipment that prevents damaging or compressing the insulation. A wood-framed or equivalent baffle or retainer is required to be provided when loose fill insulation is installed, the purpose of which is to prevent the loose fill insulation from spilling into the living space when the attic access is opened, and to provide a permanent means of maintaining the installed R-value of the loose fill insulation.

N1102.2.4.1 (R402.2.4.1) Access hatch and door insulation installation and retention. Vertical or horizontal access hatches and doors from conditioned spaces to unconditioned spaces such as attics and crawl spaces shall be weatherstripped. Access that prevents damaging or compressing the insulation shall be provided to all equipment. Where loose-fill insulation is installed, a wood-framed or equivalent baffle, retainer, or dam shall be installed to prevent loose-fill insulation from spilling into living space from higher to lower sections of the attic, and from attics covering conditioned spaces to unconditioned spaces. The baffle or retainer shall provide a permanent means of maintaining the installed R-value of the loose-fill insulation.

Definitions:

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CAVITY INSULATION. Insulating material located between framing members.

CLIMATE ZONE. A geographical region based on climatic criteria as specified in this code.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly 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.

CONTINUOUS AIR BARRIER. A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (ci). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

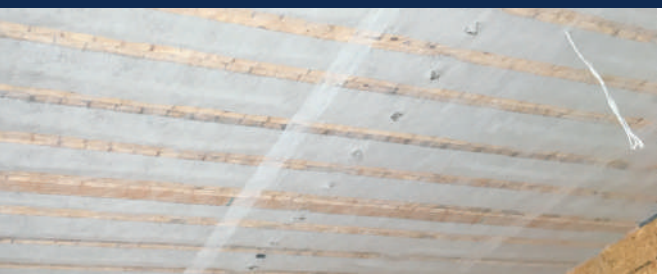
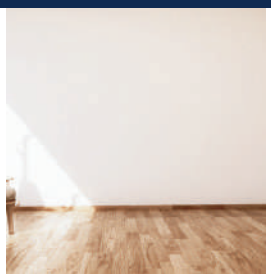
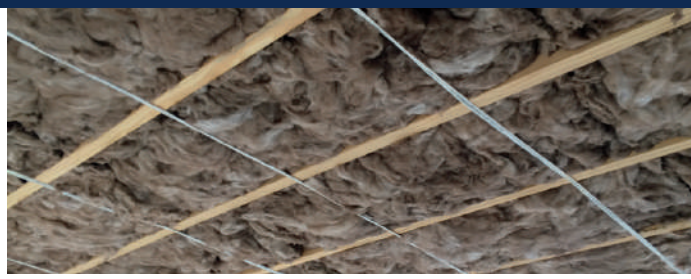
EXTERIOR WALL. Walls including both above-grade walls and basement walls.

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].

SERVICE WATER HEATING. Supply of hot water for purposes other than comfort heating.

Floor Insulation Strategies

2021 VRC/VECC Update Guide

Three Options for Insulating Framed Floors

With the 2021 code update, R-19 floor insulation remains the minimum required across most of Virginia (climate zones 3 and 4), but R-30 is now the minimum for climate zone 5 jurisdictions. Section N1102.2.7 (R402.2.7) adds specificity for three options when insulating floors over unconditioned spaces such as vented crawlspaces, garages, and cantilevers.

Option 1: Insulation must be installed to "maintain permanent contact" with the floor above and to "maintain required R-value or readily fill the available cavity space."

- Spray foam insulation applied to the underside of the subfloor thick enough to achieve the required R-Value would work well for this option. With trusses or I-joists that present openings and irregularities in cavity shape, a loose-fill or liquid-applied insulation is necessary for providing even, continuous thermal coverage.
- While commonly used to hold up batt insulation, wire stays wedged between framing members compress batts (reducing R-Value), do not provide even suspension of insulation, and routinely fall out within a few years.

Figure 1: https://basc.pnnl.gov/resource-guides/floor-above-garage#edit-group-description

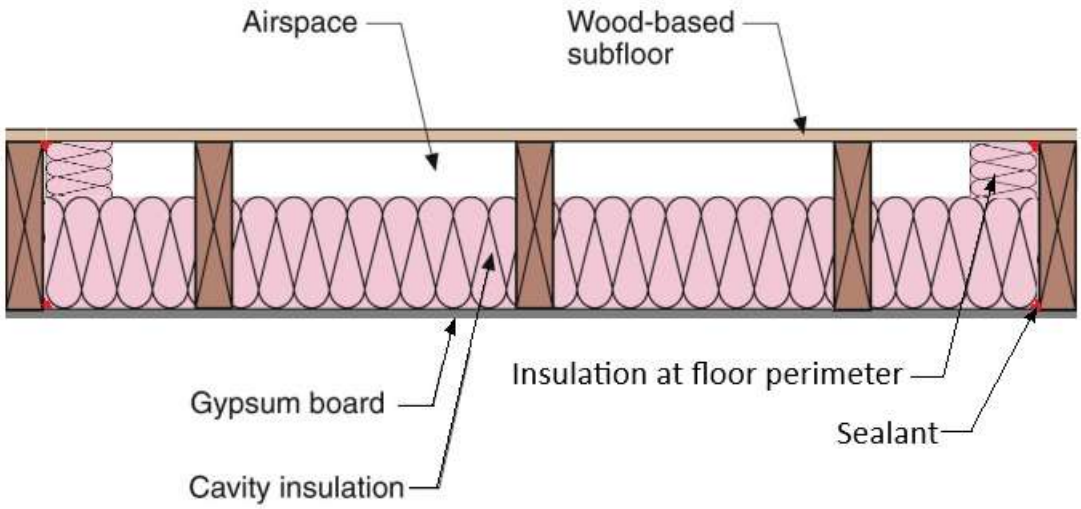
Figure 2: Traditional wire stays compress batts, support irregularly, and fall out - Insulated floor over vented crawl in 8-month-old Virginia home. Photo: Viridiant

Option 2: Airtight framing cavity plus perimeter insulation

- This option allows leaving an airspace between the insulation and the subfloor above – perhaps for installing ductwork. Below that, cavity insulation is installed to achieve the minimum R-

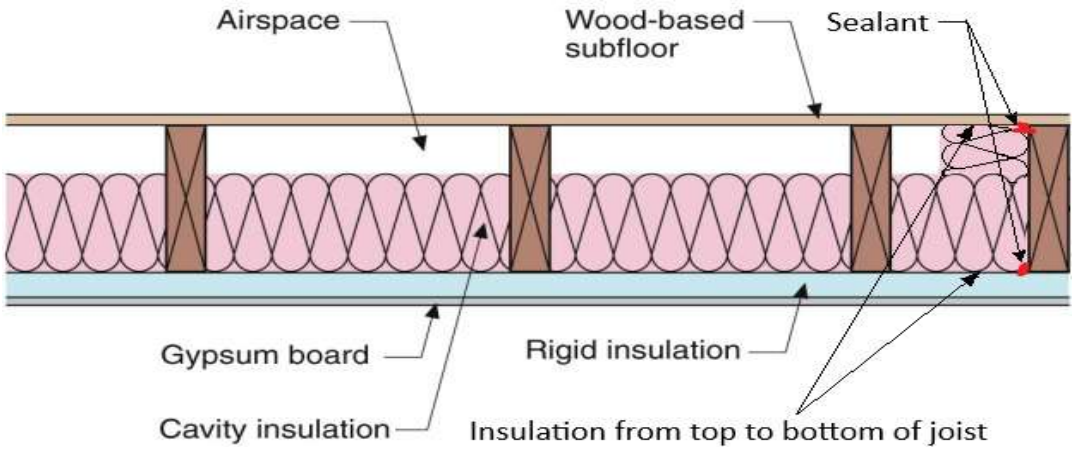
Value. The cavity insulation should be in direct contact with air-tight sheathing attached to the underside of the floor framing.

- To prevent that airspace from continuing to the building perimeter, the code requires that "insulation shall extend from the bottom to the top of all perimeter floor framing members and the framing members shall be air sealed."



Option 3: Airtight framing cavity with continuous insulation

- This option allows leaving an airspace between the insulation and the subfloor above – perhaps for installing ductwork. Below that, some combination of cavity and continuous insulation (insulated sheathing) is installed to collectively achieve the minimum R-Value. The cavity insulation should contact the continuous insulation.
- As in Option 2 above, to prevent that airspace from continuing to the building perimeter, the code requires that "insulation shall extend from the bottom to the top of all perimeter floor framing members and the framing members shall be air sealed."



Images adapted from: https://basc.pnnl.gov/code-compliance/sealing-and-insulating-existing-floors-above-unconditioned-spaces-code-compliance

2021 VRC/VECC Code References:

N1102.1.4 (R402.1.4) R-value computation. Cavity insulation alone shall be used to determine compliance with the cavity insulation R-value requirements in Table N1102.1.3. Where cavity insulation is installed in multiple layers, the R-values of the cavity insulation layers shall be summed to determine compliance with the cavity insulation R-value requirements. The manufacturer's settled R-value shall be used for blown-in insulation. Continuous insulation (ci) alone shall be used to determine compliance with the continuous insulation R-value requirements in Table N1102.1.3. Where continuous insulation is installed in multiple layers, the R-values of the continuous insulation layers shall be summed to determine compliance with the continuous insulation R-value requirements. Cavity insulation R-values shall not be used to determine compliance with the continuous insulation R-value requirements in Table N1102.1.3. Computed R-values shall not include an R-value for other building materials or air films. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table N1102.1.3, the manufacturer's labeled R-value for insulated siding shall be reduced by R-0.6.

N1102.2.7 (R402.2.7) Floors. Floor cavity insulation shall comply with one of the following:

1. Installation shall be installed to maintain permanent contact with the underside of the subfloor decking in accordance with manufacturer instructions to maintain required R-value or readily fill the available cavity space.
2. Floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing separating the cavity and the unconditioned space below. Insulation shall extend from the bottom to the top of all perimeter floor framing members and the framing members shall be air sealed.
3. A combination of cavity and continuous insulation shall be installed so that the cavity insulation is in contact with the top side of the continuous insulation that is installed on the underside of the floor framing separating the cavity and the unconditioned space below. The combined R-value of the cavity and continuous insulation shall equal the required R-value for floors. Insulation shall extend from the bottom to the top of all perimeter floor framing members and the framing members shall be air sealed.

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.

BUILDING THERMAL ENVELOPE. The basement walls, exterior walls, floors, ceiling, roofs and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

CAVITY INSULATION. Insulating material located between framing members.

CLIMATE ZONE. A geographical region based on climatic criteria as specified in this code.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly 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.

CONTINUOUS AIR BARRIER. A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (ci). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

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].

Slab Edge Insulation

2021 VRC/VECC Update Guide



Slab Edge Insulation:

Slab insulation requirements changed for much of Virginia with the modifications to the Prescriptive Pathway R-Value requirements and climate zones contained in the 2021 Virginia Residential Code. Concrete is an excellent conductor of heat, making effective insulation critical. Key details include placement of insulation, depth of insulation, thermal breaks between conditioned and unconditioned spaces, and how additions or retrofits to existing homes should be handled.

CLIMATE ZONE	SLAB R-VALUE AND DEPTH
3	**10 continuous, 2 feet**
4	**10 continuous, 4 feet**
5	**10 continuous, 4 feet**

For heated slabs, insulation not less than R-5 must be installed under the balance of the slab not addressed by the applicable slab edge insulation requirement.

Slabs drive energy consumption primarily as a result of heat conducted outward and through the perimeter of the slab. Proper installation of insulation around the perimeter of the slab edge greatly reduces heat loss and gain through the exposed concrete. *Insulation is included in slab-on-grade construction for two purposes:*

- *Insulation prevents heat loss in winter and heat gain in summer. This effect is most pronounced at the slab perimeter, where an above-grade slab edge comes into closer contact with outdoor air/ambient conditions.*
- *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:

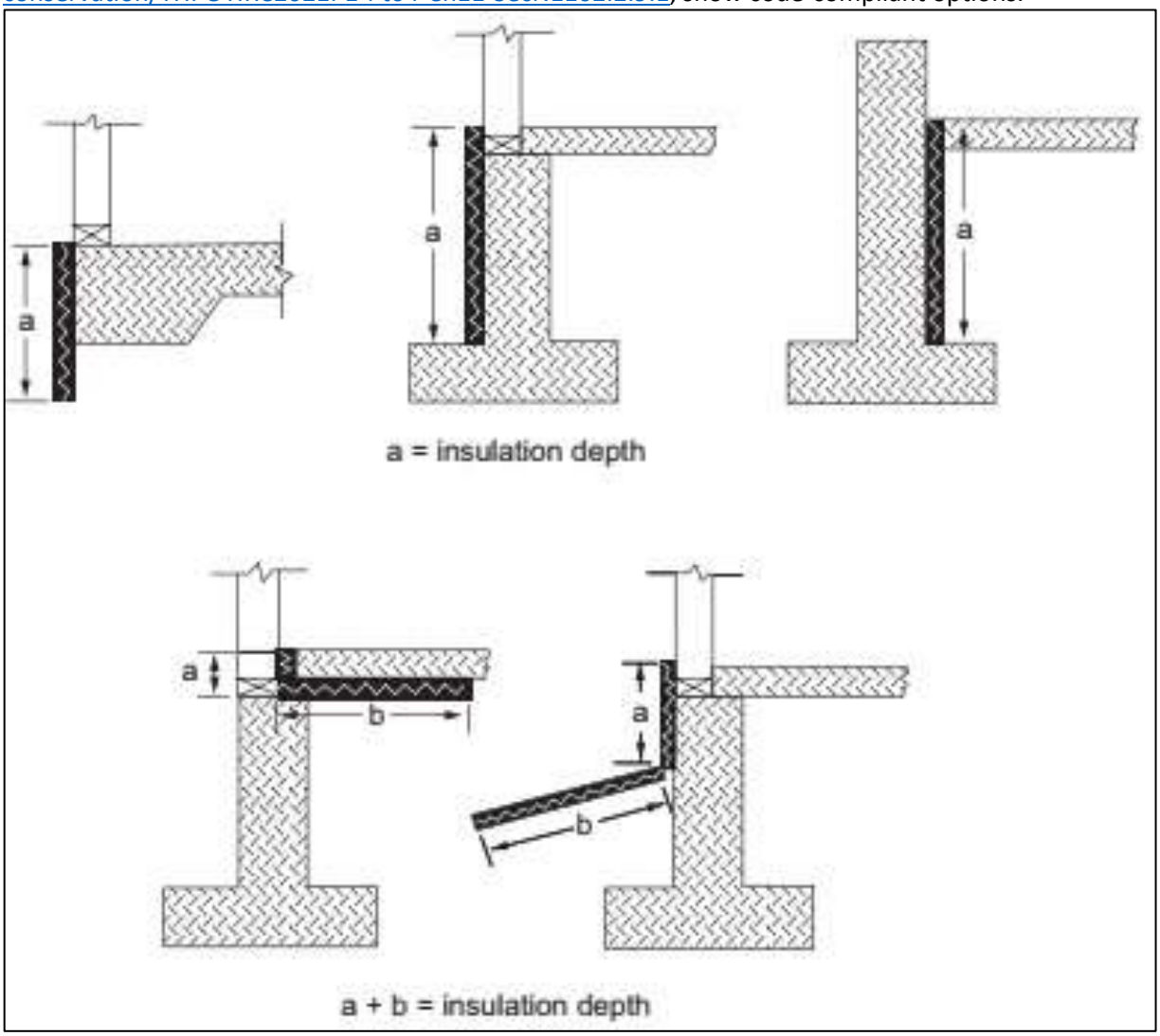
- Typical insulation products used below grade include extruded polystyrene, expanded polystyrene, and rigid mineral fiber panels (Baechler et al. 2005). Extruded polystyrene (XPS) is nominally R-5 per inch. Expanded polystyrene (EPS) is nominally R-4 per inch and can be less expensive. Below-grade foams can be at risk for moisture accumulation under certain

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

conditions.[2]

- 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 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 the insulating value of slab insulations. Proper compressive strength and ground contact rated insulations should be specified.

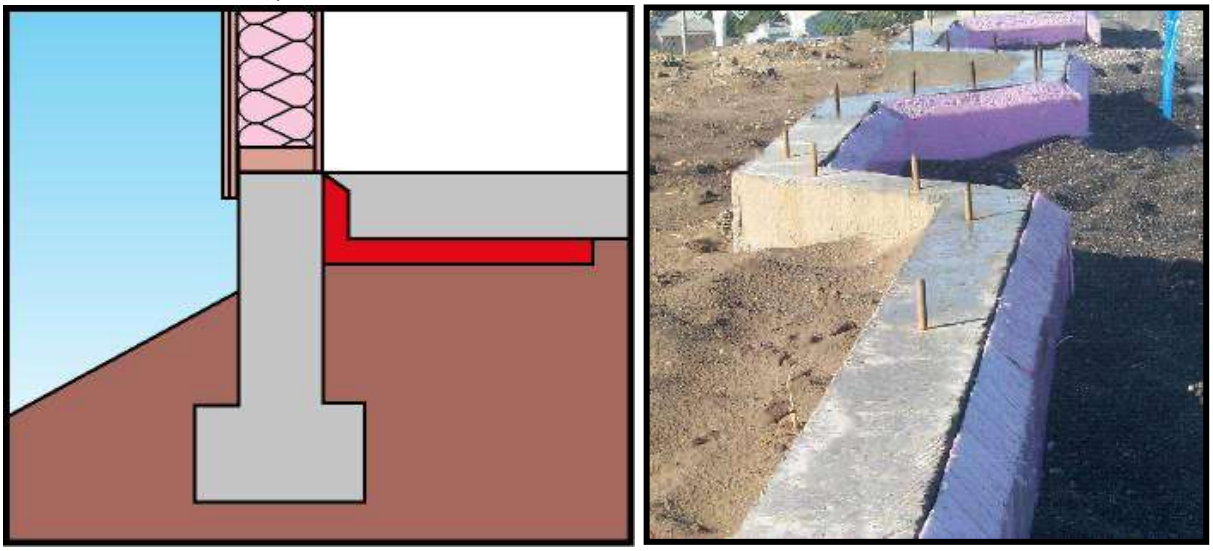
The slab insulation drawings below, available at codes.iccsafe.org/s/THPOTIRC2021P1/part-iv-energy-conservation/THPOTIRC2021P1-Pt04-Ch11-SecN1102.2.9.1, show code-compliant options.



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

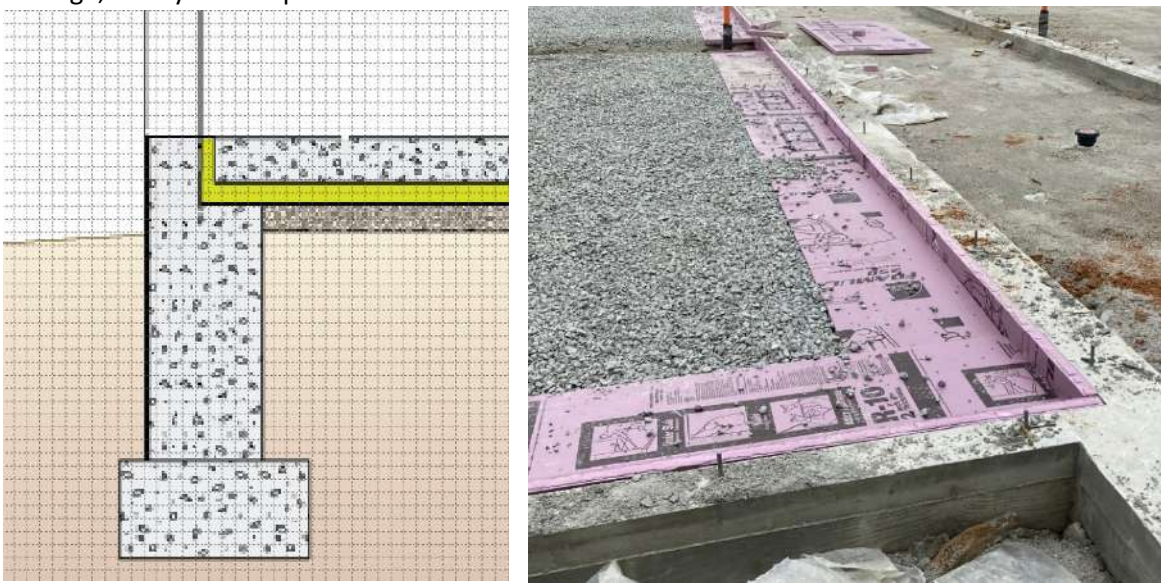
The Total Building Performance or Energy Rating Index pathways offer an option to include sufficient total thermal protection for the whole home using other external slab insulation designs. The research described at https://www.greenbuildingadvisor.com/article/getting-slab-edge-insulation-right shows how to avoid any performance penalty from reduced depth of slab insulation.

Another option not shown above is to cut a 45 degree bevel at the top of the interior slab to allow for concrete to extend some or all of the way to the bottom inside corner of the plate. The images below show versions of this option.



A beveled edge cut into the slab insulation. Drawing and photo from https://www.energycodes.gov/technical-assistance/training/courses/residential-provisions-2021-iecc

Where interior sheathing (drywall or similar) plus base molding and shoe molding will cover the top edge of the interior slab insulation such that the narrow strip of insulation left exposed is not at risk of damage, it may be acceptable to leave off the bevel cut – as shown below.



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 and extending not less 2' Climate Zone 3 and 4' for Climate Zones 4 and 5. 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.

Resources:

- https://basc.pnnl.gov/resource-guides/slab-edge-insulation#edit-group-description
- https://foundationhandbook.ornl.gov/handbook/chapter4.shtml
- https://www.greenbuildingadvisor.com/article/getting-slab-edge-insulation-right
- https://www.energy.wsu.edu/documents/FAQ%20Slabs%20prescriptive%20requirements~2023-12-20.pdf

2021 VRC/VECC Code References:

R703.4 Flashing. Approved corrosion-resistant flashing shall be applied shingle-fashion in a manner to prevent entry of water into the wall cavity or penetration of water to the building structural framing components. Self-adhered membranes used as flashing shall comply with AAMA 711. Fluid-applied membranes used as flashing in exterior walls shall comply with AAMA 714. The flashing shall extend to the surface of the exterior wall finish. Approved corrosion-resistant flashings shall be installed at the following locations:

1. Exterior window and door openings. Flashing at exterior window and door openings shall be installed in accordance with Section R703.4.1.
2. At the intersection of chimneys or other masonry construction with frame or stucco walls, with projecting lips on both sides under stucco copings.
3. Under and at the ends of masonry, wood or metal copings and sills.
4. Continuously above all projecting wood trim.
5. Where exterior porches, decks or stairs attach to a wall or floor assembly of wood-frame construction.
6. At wall and roof intersections.
7. At built-in gutters.

R703.8.5 Flashing. Flashing shall be located beneath the first course of masonry above finished ground level above the foundation wall or slab and at other points of support, including structural floors, shelf angles and lintels where masonry veneers are designed in accordance with Section R703.8. See Section R703.4 for additional requirements.

N1101.5 (R103.2) Information on construction documents. Construction documents shall be drawn to scale on suitable material. Electronic media documents are permitted to be submitted when approved by the code official. 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 as herein governed. Details shall include the following as applicable:

1. Energy compliance path.
2. Insulation materials and their R-values.
3. Fenestration U-factors and solar heat gain coefficients (SHGC).
4. Area-weighted U-factor and solar heat gain coefficient (SHGC) calculations.
5. Mechanical system design criteria.
6. Mechanical and service water heating systems and equipment types, sizes and efficiencies.
7. Equipment and system controls.
8. Duct sealing, duct and pipe insulation and location.
9. Air sealing details.

N1101.11.1 (R303.2.1) 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.

TABLE N1102.1.3 (R402.1.3) INSULATION MINIMUM R-VALUES AND FENESTRATION REQUIREMENTS BY COMPONENT

CLIMATE ZONE	SLAB R-VALUE AND DEPTH*
3	**10 continuous, 2 feet**
4	**10 continuous, 4 feet**
5	**10 continuous, 4 feet**

*R-5 insulation shall be provided under the full slab area of a heated slab in addition to the required slab edge insulation R-value for slabs. as indicated in the table. The slab-edge insulation for heated slabs shall not be required to extend below the slab.

N1102.2.9 (R402.2.9) 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 N1102.1.3.

Exception: Slab-edge insulation is not required in jurisdictions designated by the code official as having a very heavy termite infestation.

N1102.2.9.1 (R402.2.9.1) Slab-on-grade floor insulation installation. Where installed, 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 extend the distance provided in Table N1102.1.3 or the distance of the proposed design, as applicable, 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.

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.

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.

CAVITY INSULATION. Insulating material located between framing members.

CLIMATE ZONE. A geographical region based on climatic criteria as specified in this code.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly 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.

CONTINUOUS AIR BARRIER. A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (ci). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

EXTERIOR WALL. Walls including both above-grade walls and basement walls.

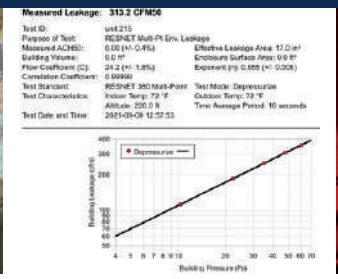
HEATED SLAB. Slab-on-grade construction in which the heating elements, hydronic tubing, or hot air distribution system is in contact with, or placed within or under, the slab.

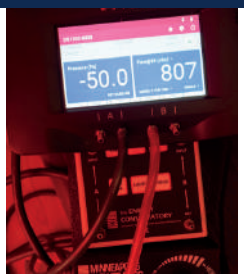
R-VALUE (THERMAL RESISTANCE). The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area (h × ft2 × °F/Btu) [(m2 × K)/W].

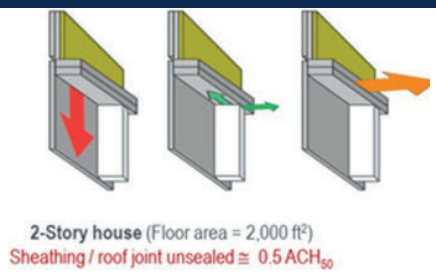
THERMAL ISOLATION. Physical and space conditioning separation from conditioned spaces. The conditioned spaces shall be controlled as separate zones for heating and cooling or conditioned by separate equipment.

Air Sealing Requirements

2021 VRC/VECC Update Guide







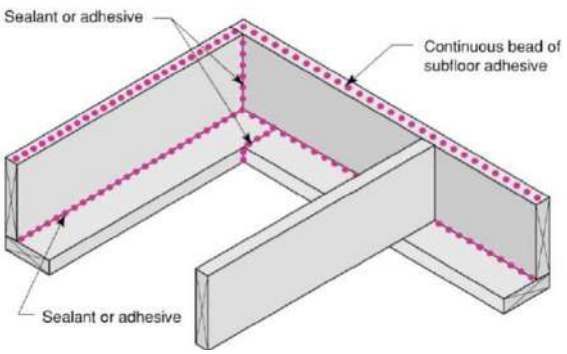
Added Language in Table of Required Air Sealing:

Summary: Conscientious, detail-oriented air sealing is among the most cost-effective tools available to builders seeking to meet code and construct a durable, energy efficient home. The residential energy code has included a list of required air sealing details since the first edition of the International Energy Conservation Code (IECC) in 1998. Each new version has provided more specificity to help ensure key locations of potential drafts are not missed.

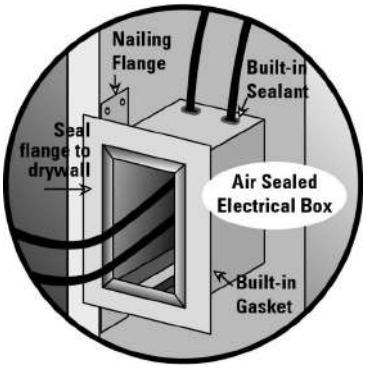
TABLE N1102.4.1.1 (R402.4.1.1) AIR BARRIER, AIR SEALING AND INSULATION INSTALLATION lists locations specifically requiring air sealing. That said, smart construction prioritizes close attention to any and all areas where building materials meet or holes are cut in order to make the home's air barrier complete and continuous – and thereby better manage moisture, pests, air quality, comfort, and heating/cooling costs. Of course, the ultimate test of effective air sealing is the blower door test. Confirming that the locations listed in Table N1102.4.1.1 (R402.4.1.1) are sealed helps ensure the home will pass the blower door test on the first attempt.

Noteworthy new air sealing requirements:
For unvented crawlspaces and conditioned basements, the entire sill plate and rim joist assembly should be made airtight by sealing (with caulk or adhesive) butt joints, corners, and linear joints between boards.

Ideally, a home's primary air barrier occurs at the exterior sheathing layer. Generally, it is much easier to keep it continuous and complete there. The 2021 code stipulates that, if there is not a continuous air barrier installed *behind* the electrical and communication boxes, then those boxes should be made airtight.



Source: https://bsesc.energy.gov/energy-basics/sill-plates-are-installed-sealing-rim-joists



Source: https://basc.pnnl.gov/images/air-tight-electrical-boxes-have-built-gaskets-and-self-sealing-wire-holes

Plan Review Focus: Ideally, plans would note where the continuous air barrier is intended, so that inspectors know whether to look for items such as sealed electrical boxes.

Notes: Air movement through the building envelope can bring moisture-laden air from the exterior during the summertime and lead to potential moisture issues. Air movement through air-permeable insulation such as fiberglass will reduce the R-Value of those materials. Table N1102.4.1.1 (R402.4.1.1) covers major areas of potential air leakage, but there will be other areas of leakage. Being present at a home during the blower door test can be a valuable way to identify additional leakage areas. The house is depressurized during the test and air movement can be felt at leakage spots while the blower fan is running.

Additional Resources:

- https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Thermal_Enclosure_System_Rater_Checklist_Guidebook_Rev04_v5_FINAL_508.pdf
- https://buildingscience.com/documents/digests/bsd-104-understanding-air-barriers (and related documents)
- https://sws.nrel.gov/spec/3 Detailed guide to air-sealing work

2021 VRC/VECC Code References:

N1102.4.1 (R402.4.1) Building thermal envelope. The building thermal envelope shall comply with Sections N1102.4.1.1 through N1102.4.1.3. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

N1102.4.1.1 (R402.4.1.1) Installation. The components of the building thermal envelope shall be installed in accordance with the manufacturer's instructions and the criteria indicated in Table N1102.4.1.1, as applicable to the method of construction. Where required by the code official, an

TABLE N1102.4.1.1 (R402.4.1.1) AIR BARRIER, AIR SEALING AND INSULATION INSTALLATION[a]

COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA[d]
General requirements	A continuous air barrier shall be installed in the building envelope.	Air-permeable insulation shall not be used as a sealing material.
	Breaks or joints in the air barrier shall be sealed.	
Ceiling/attic	The air barrier in any dropped ceiling or soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.
	Access openings, drop down stairs or knee wall doors to unconditioned attic spaces shall be sealed.	
	Knee walls shall be sealed.	

Walls	The junction of the foundation and sill plate shall be sealed.	Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance, R-value, of not less than R-3 per inch. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.
	The junction of the top plate and the top of exterior walls shall be sealed.	
	Knee walls shall be sealed.	
Windows, skylights and doors	The space between framing and skylights, and the jambs of windows and doors, shall be sealed.	—
Rim joists	Rim joists shall include an exterior air barrier.[b]	Rim joists shall be insulated so that the insulation maintains permanent contact with the exterior rim board.[b]
	The junctions of the rim board to the sill plate and the rim board and the subfloor shall be air sealed.	
Floors, including cantilevered floors and floors above garages	The air barrier shall be installed at any exposed edge of insulation.	Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking. Alternatively, floor framing cavity insulation shall be in contact with the top side of sheathing, or continuous insulation installed on the underside of floor framing and extending from the bottom to the top of all perimeter floor framing members.
Basement crawl space and slab foundations	Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder/air barrier in accordance with Section N1102.2.10. (R402.2.10).	Crawl space insulation, where provided instead of floor insulation, shall be installed in accordance with Section N1102.2.10 (R402.2.10).
	Penetrations through concrete foundation walls and slabs shall be air sealed.	Conditioned basement foundation wall insulation shall be installed in accordance with Section N1102.2.8.1 (R402.2.8.1).
	Class 1 vapor retarders shall not be used as an air barrier on below-grade walls and shall be installed in accordance with Section R702.7.	Slab-on-grade floor insulation shall be installed in accordance with Section N1102.2.10 (R402.2.9.1).

HVAC register boots	HVAC supply and return register boots that penetrate building thermal envelope shall be sealed to the subfloor, wall covering or ceiling penetrated by the boot.	—
Concealed sprinklers	Where 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.	—

a. Inspection of log walls shall be in accordance with the provisions of ICC 400.
b. Air barrier and insulation full enclosure is not required in unconditioned/ventilated attic spaces and at rim joists.
c. Air barriers used behind showers and tubs on exterior walls shall be of a permeable material that does not cause the entrapment of moisture in the stud cavity.
d. Structural integrity of headers shall be in accordance with the applicable building code.

N1102.4.1.2 (R402.4.1.2) Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding 5 air changes per hour. Testing shall be conducted in accordance with RESNET/ICC 380, ASTM E779, or ASTM E1827 and reported at a pressure of 0.2 inches w.g. (50 Pa). 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.

Note: Should additional sealing be required as a result of the test, consideration may be given to the issuance of a temporary certificate of occupancy in accordance with Section 116.1.1.

During testing:

1. Exterior windows and doors and fireplace and stove doors shall be closed, but not sealed beyond the intended weather stripping 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.

Exception: When testing individual dwelling units, an air leakage rate not exceeding 0.30 cubic feet per minute per square foot [0.008 m3/(s × m2)] of the dwelling unit enclosure area, tested in accordance with ANSI/RESNET/ICC 380, ASTM E779 or ASTM E1827 and reported at a pressure of 0.2 inch water gauge (50 Pa), shall be permitted in all climate zones for:

1. Attached single- and multiple-family building dwelling units.
2. Buildings or dwelling units that are 1,500 square feet (139.4 m2) or smaller.

Mechanical ventilation shall be provided in accordance with Section M1505 of this code or Section 403.3.2 of the International Mechanical Code, as applicable, or with other approved means of ventilation.

N1102.4.1.3 (R402.4.1.3) Leakage rate. When complying with Section N1101.2.1 (R401.2.1), the building or dwelling unit shall have an air leakage rate not exceeding 5 air changes per hour in Climate Zones 3 through 5, when tested in accordance with Section N1102.4.1.2 (R402.4.1.2).

N1102.4.2 (R402.4.2) Fireplaces. New wood-burning fireplaces shall have tight-fitting flue dampers or doors, and outdoor combustion air Where using tight-fitting doors on factory-built fireplaces listed and labeled in accordance with UL 127, the doors shall be tested and listed for the fireplace.

N1102.4.3 (R402.4.3) Fenestration air leakage. Windows, skylights and sliding glass doors shall have an air infiltration rate of not greater than 0.3 cfm per square foot (1.5 L/s/m2), and for swinging doors not greater than 0.5 cfm per square foot (2.6 L/s/m2), when tested in accordance with NFRC 400 or AAMA/WDMA/CSA 101/I.S.2/A440 by an accredited, independent laboratory and listed and labeled by the manufacturer.

Exception: Site-built windows, skylights and doors.

N1102.4.4 (R402.4.4) Rooms containing fuel-burning appliances. In Climate Zones 3 through 8, where open-combustion airducts provide combustion air to open combustion fuel-burning appliances, the appliances and combustion air opening shall be located outside the building thermal envelope or enclosed in a room that is isolated from inside the thermal envelope. Such rooms shall be sealed and insulated in accordance with the envelope requirements of Table N1102.1.3, where the walls, floors and ceilings shall meet a minimum of the basement wall R-value requirement. The door into the room shall be fully gasketed and any water lines and ducts in the room insulated in accordance with Section N1103. The combustion air duct shall be insulated where it passes through conditioned space to an R-value of not less than R-8.

Exceptions:

1. Direct vent appliances with both intake and exhaust pipes installed continuous to the outside.
2. Fireplaces and stoves complying with Sections N1102.4.2 and R1006.

N1102.4.5 (R402.4.5) Recessed lighting. Recessed luminaires installed in the building thermal envelope shall be sealed to limit air leakage between conditioned and unconditioned spaces. Recessed luminaires shall be IC-rated and labeled as having an air leakage rate of not greater than 2.0 cfm (0.944 L/s) when tested in accordance with ASTM E283 at a pressure differential of 1.57 psf (75 Pa). Recessed luminaires shall be sealed with a gasket or caulked between the housing and the interior wall or ceiling covering.

N1102.4.6 (R402.4.6) Electrical and communication outlet boxes (air-sealed boxes). Electrical and communication outlet boxes installed in the building thermal envelope shall be sealed to limit air leakage between conditioned and unconditioned spaces. Electrical and communication outlet boxes shall be tested in accordance with NEMA OS 4, Requirements for Air-Sealed Boxes for Electrical and Communication Applications, and shall have an air leakage rate of not greater than 2.0 cubic feet per minute (0.944 L/s) at a pressure differential of 1.57 psf (75 Pa). Electrical and communication outlet boxes shall be marked "NEMA OS 4" or "OS 4" in accordance with NEMA OS 4. Electrical and communication outlet boxes shall be installed per the manufacturer's instructions and with any supplied components required to achieve compliance with NEMA OS 4.

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.

ADDITION. An extension or increase in the conditioned space floor area, number of stories or height of a building or structure.

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.

ALTERATION. Any construction, retrofit or renovation to an existing structure other than repair or addition. Also, a change in a building, electrical, gas, mechanical or plumbing system that involves an extension, addition or change to the arrangement, type or purpose of the original installation.

BASEMENT WALL. A wall 50 percent or more below grade and enclosing conditioned space.

BUILDING THERMAL ENVELOPE. The basement walls, exterior walls, floors, ceiling, roofs and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

CAVITY INSULATION. Insulating material located between framing members.

CONDITIONED FLOOR AREA. The horizontal projection of the floors associated with the conditioned space.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly 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.

CONTINUOUS AIR BARRIER. A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (ci). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

CRAWL SPACE WALL. The opaque portion of a wall that encloses a crawl space and is partially or totally below grade.

DWELLING UNIT. A single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking and sanitation.

DWELLING UNIT ENCLOSURE AREA. The sum of the area of ceiling, floors, and walls separating a dwelling unit's conditioned space from the exterior or from adjacent conditioned or unconditioned spaces. Wall height shall be measured from the finished floor of the dwelling unit to the underside of the floor above.

ENERGY ANALYSIS. A method for estimating the annual energy use of the proposed design and standard reference design based on estimates of energy use.

ENERGY COST. The total estimated annual cost for purchased energy for the building functions regulated by this code, including applicable demand charges.

EXTERIOR WALL. Walls including both above-grade walls and basement walls.

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.

INSULATED SIDING. A type of continuous insulation with manufacturer-installed insulating material as an integral part of the cladding product having an R-value of not less than R-2.

LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, approved agency or other organization concerned with product evaluation that maintains periodic inspection of the production of such labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

LISTED. Equipment, materials, products or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

ROOF ASSEMBLY. A system designed to provide weather protection and resistance to design loads. The system consists of a roof covering and roof deck or a single component serving as both the roof covering and the roof deck. A roof assembly includes the roof covering, underlayment and roof deck and can also include a thermal barrier, an ignition barrier, insulation or a vapor retarder.

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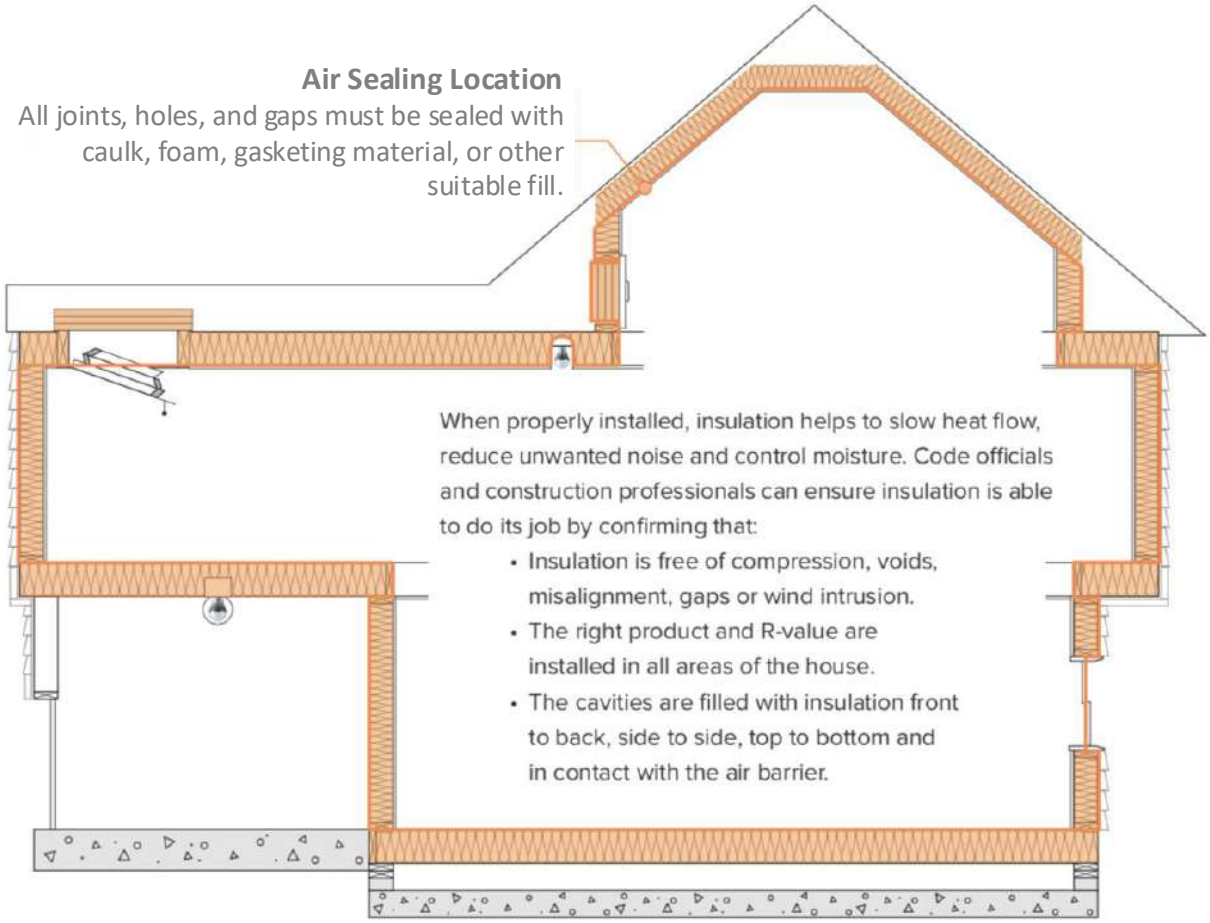
INSULATION INSTALLATION

Tips for Meeting the 2021 VRC/VECC

To obtain the R-values in the 2021 VRC/VECC Table N1102.1.3 (R402.1.1), insulation shall be installed in accordance with the manufacturer's instructions and the criteria indicated in Table N1102.4.1.1 (R402.4.1.1), as applicable to the method of construction.



Insulation

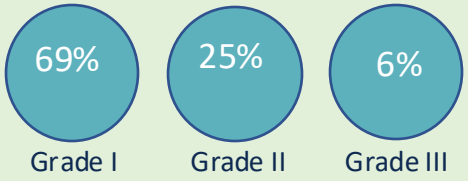
The 2017-2018 Virginia Residential "Field Study" gauged energy code enforcement. www.energycodes.gov/residential-energy-code-field-studies

Ceiling Insulation *R-Value*

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

Ceiling Insulation *Quality*

- Study results : 69% COMPLIANT



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

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

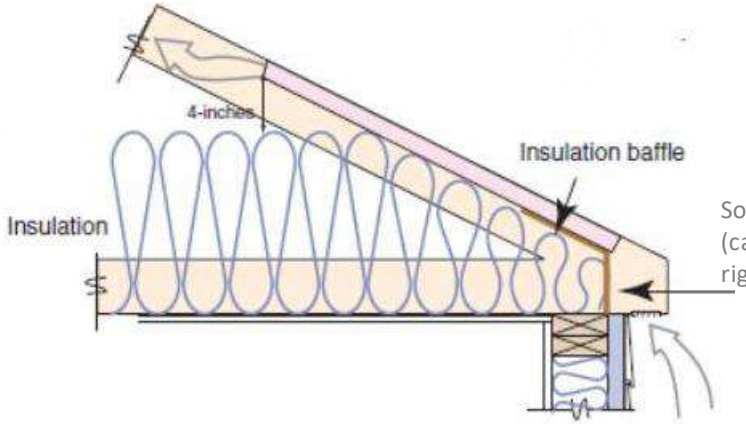
See the Insulation, Air Barrier, and Air Sealing Inspection Checklist to make sure code-compliance is achieved.

Example Details

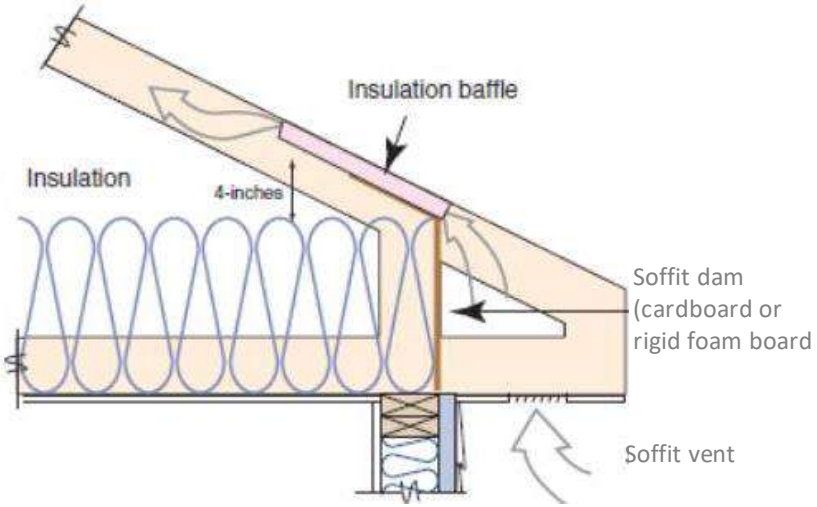
Images: basc.pnnl.gov/resource-guides

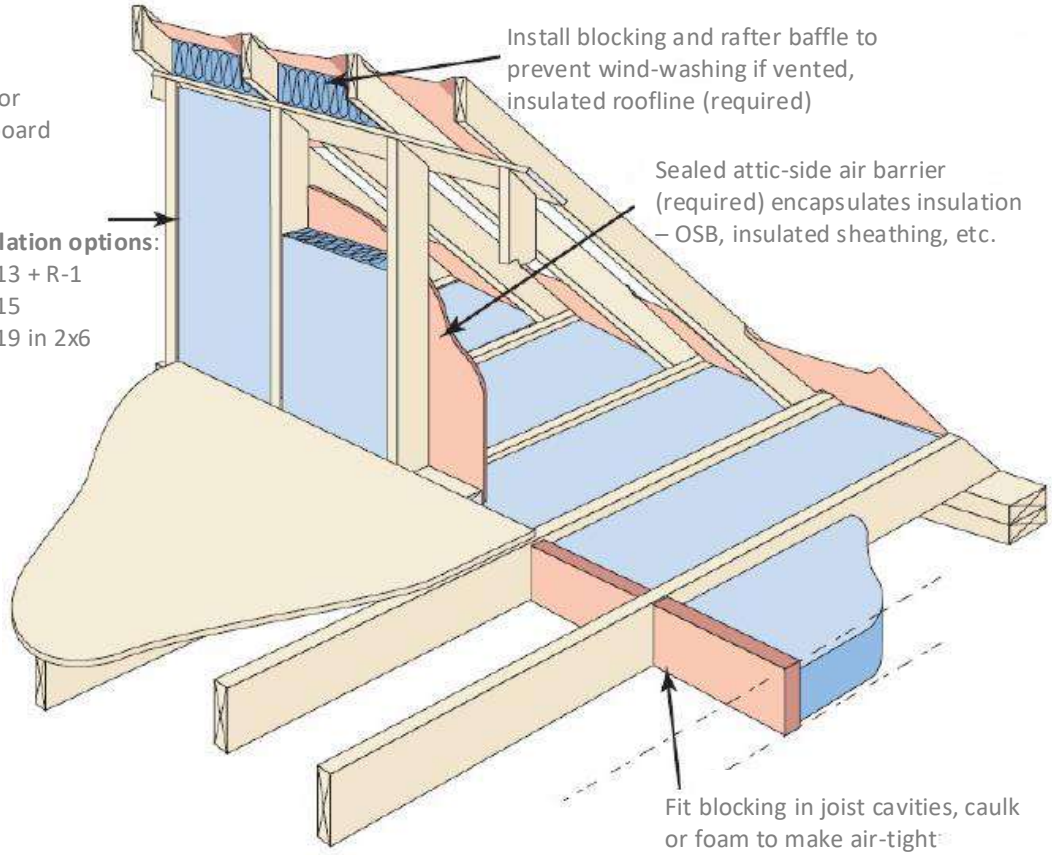
Inspecting Insulation
- Air sealing
- Baffling
- Obstructions
- Odd-sized cavities

Standard Truss with tapered insulation depth



Energy Truss with full height insulation (recommended)





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

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

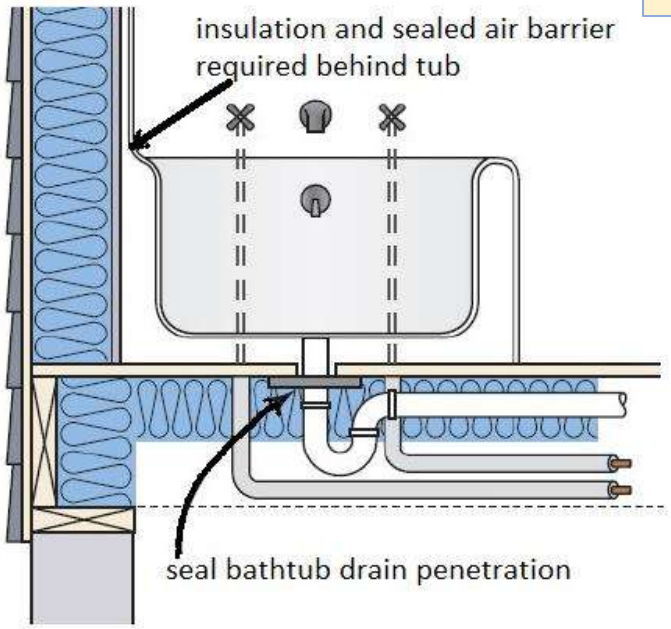
Example Details

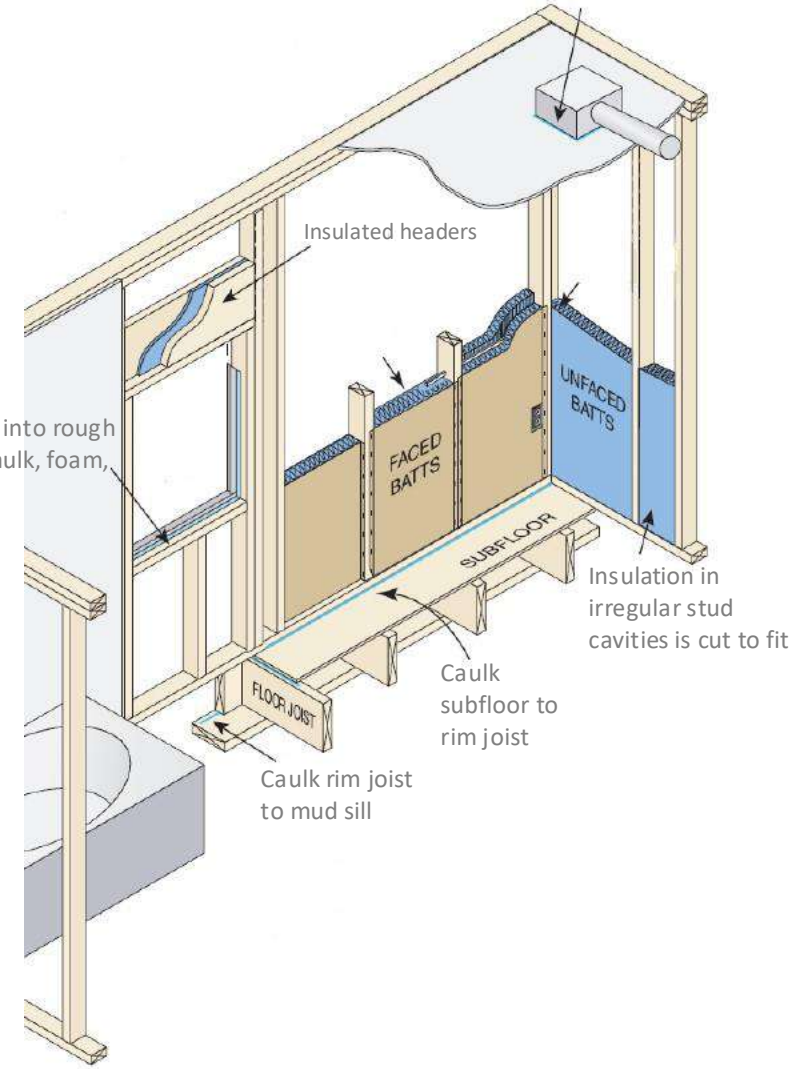
Images: basc.pnnl.gov/resource-guides

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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Success with the 2021 Virginia Energy Conservation Code:
Tech Tips for Builders

INSULATION

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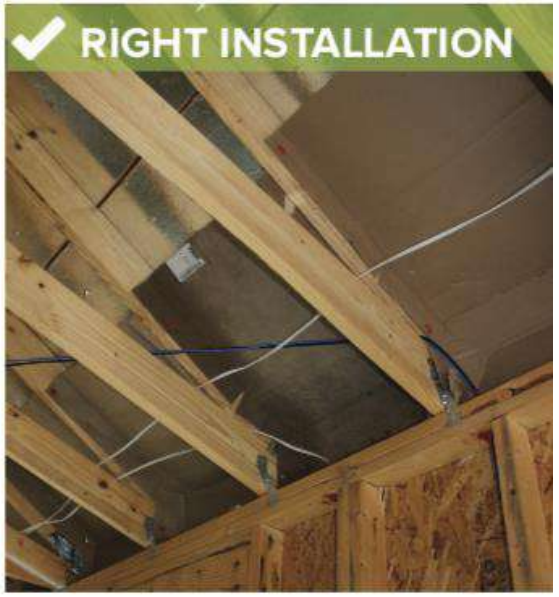
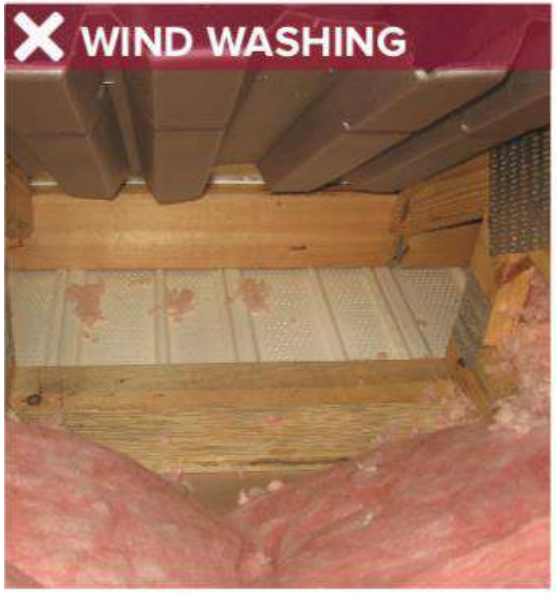
TECH TIPS:
INSULATION

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 2021 R-Value requirements[a]. Insulation shall be installed in accordance with the manufacturer's instructions.

Climate Zone	Ceiling[b]	Wood Frame Wall[g]	Mass Wall[h]	Floor	Basement/ Crawl Wall[c,g]	Slab[d] R-Value & Depth
Zone 3	R-49	R-15 or 13+1	R-8/13	R-19	R-5ci or 13	R-10, 2 ft
Zone 4	R-60	R-15 or 13+1	R-8/13	R-19	R-10ci or 13	R-10, 4 ft
Zone 5	R-60	R-15 or 13+1	R-13/17	R-30	R-15ci or 19 or 13+5	R-10, 4 ft

ci = continuous insulation.

a. R-values are minimums. U-factors and SHGC are maximums. Where insulation is installed in a cavity that is less than the label or design thickness of the insulation, the installed R-value of the insulation shall be not less than the R-value specified in the table.

b. 5ci or 13" means R-5 continuous insulation (ci) on the interior or exterior surface of the wall or R-13 cavity insulation on the interior side of the wall. "10cior 13" means R-10 continuous insulation (ci) on the interior or exterior surface of the wall or R-13 cavity insulation on the interior side of the wall. "15ci or19 or 13&5ci" means R-15 continuous insulation (ci) on the interior or exterior surface of the wall; or R-19 cavity insulation on the interior side of the wall; or R-13 cavity insulation on the interior of the wall in addition to R-5 continuous insulation on the interior or exterior surface of the wall.

c. R-5 insulation shall be provided under the full slab area of a heated slab in addition to the required slab edge insulation R-value for slabs. as indicated in the table. The slab-edge insulation for heated slabs shall not be required to extend below the slab.

d. Basement wall insulation is not required in Warm Humid locations as defined by Figure R301.1 and Table R301.1.

e. The first value is cavity insulation; the second value is continuous insulation. Therefore, as an example, "13&5" means R-13 cavity insulation plus R-5continuous insulation.

f. Mass walls shall be in accordance with Section R402.2.5. The second R-value applies where more than half of the insulation is on the interior of the mass wall.

g. A maximum U-factor of 0.32 shall apply in Climate Zones 3 through 8 to vertical fenestration products installed in buildings located either:
   1. Above 4,000 feet in elevation, or
   2. In windborne debris regions where protection of openings is required by Section R301.2.1.2 of the International Residential Code.

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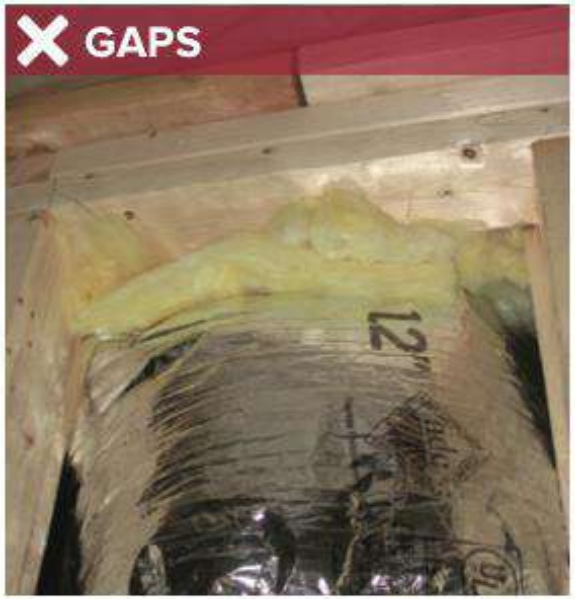
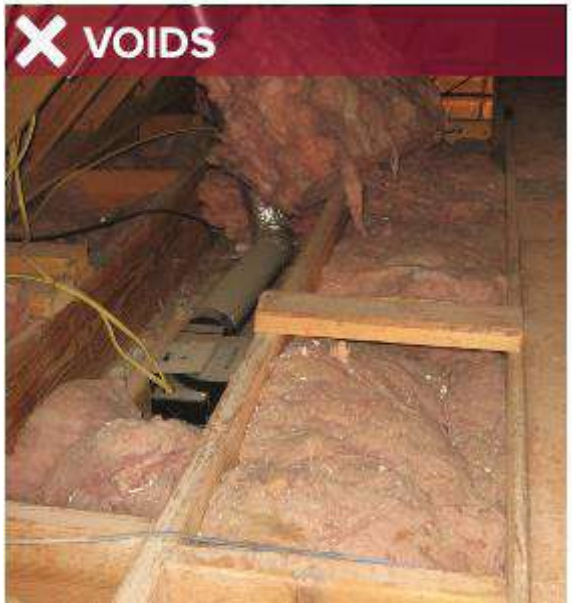
TECH TIPS:
INSULATION

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





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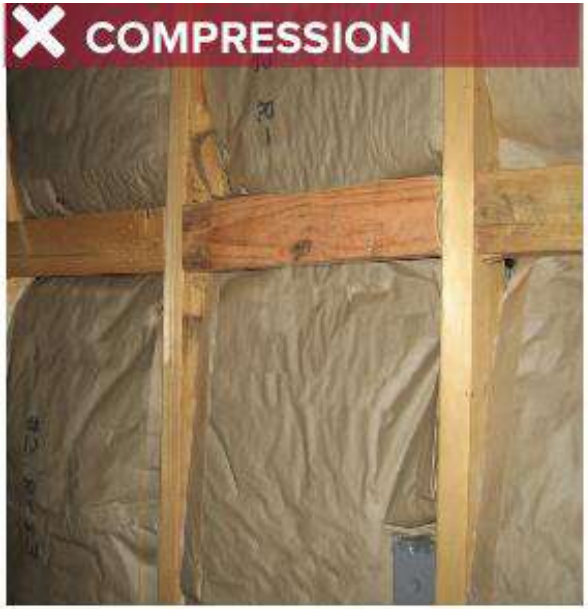
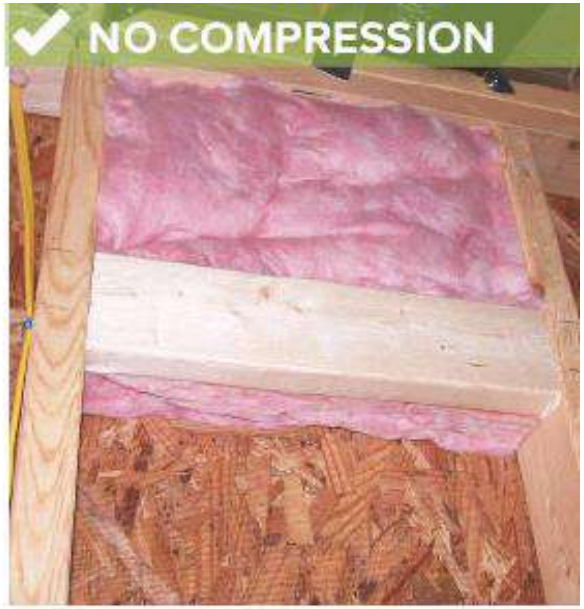
INSULATION

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





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TECH TIPS:
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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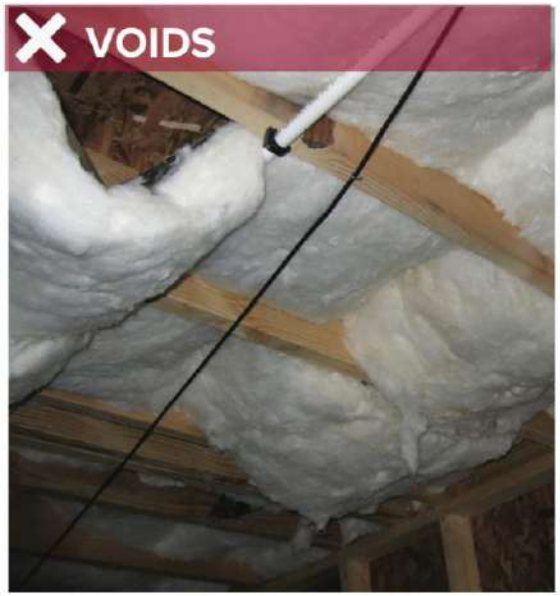
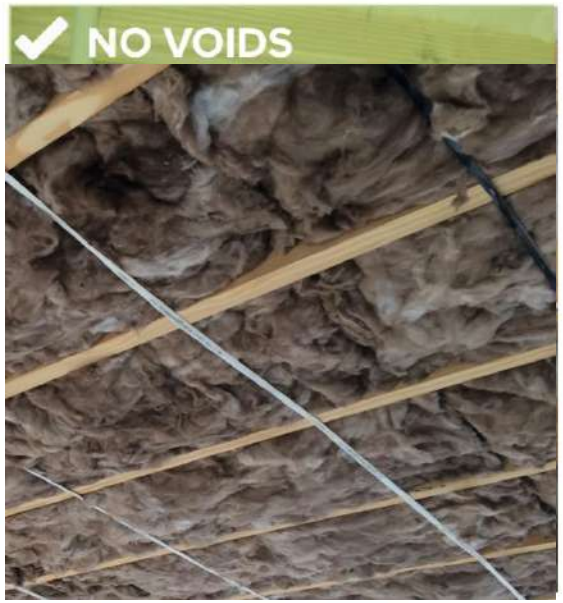
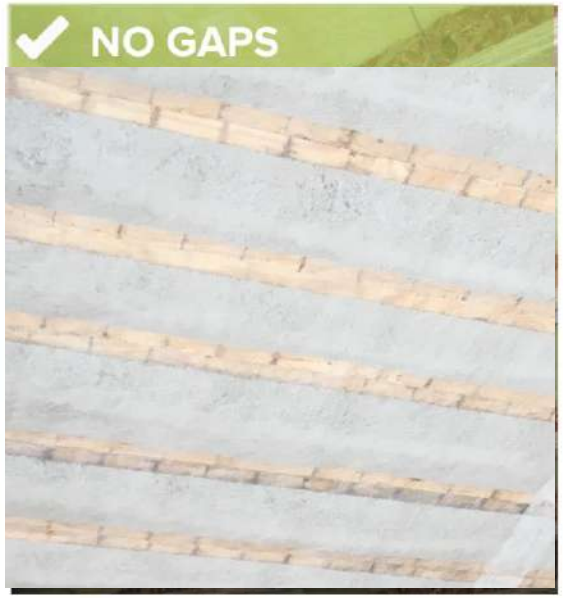
TECH TIPS:
INSULATION

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/R-30 depending on local minimums and encapsulate with an exterior rigid air barrier and air sealing.

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

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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 insula
install baffles/dam around th
attic access opening to hold
insulation in place.

Blower Door Test Report

Home

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		

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.*

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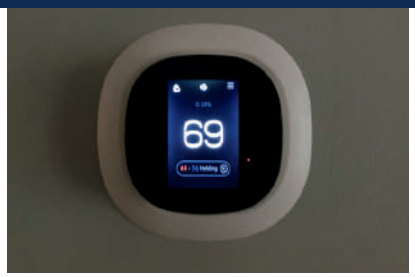
Programmable Thermostat Requirements

2021 VRC/VECC Review Guide



Primary Thermostats Require Multi-Day Programmability:

Summary: The Virginia Residential Code has long required the installation of a programmable thermostat for the "primary" heating and cooling system serving the home. With the 2021 edition, this device must include the ability to schedule different setpoints "at different times of the day and different days of the week." Compliant equipment could offer weekday/weekend programming only or unique schedules for all 7 days.

2021 VRC/VECC Code References:

N1103.1 (R403.1) Controls. Not less than one thermostat shall be provided for each separate heating and cooling system.

N1103.1.1 (R403.1.1) Programmable thermostat. The thermostat controlling the primary heating or cooling system of the dwelling unit shall be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points at different times of the day and different days of the week. This thermostat shall include the capability to set back or temporarily operate the system to maintain zone temperatures of not less than 55°F (13°C) to not greater than 85°F (29°C). The thermostat shall be programmed initially by the manufacturer with a heating temperature setpoint of not greater than 70°F (21°C) and a cooling temperature setpoint of not less than 78°F (26°C).

Definitions:

DWELLING UNIT. A single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking and sanitation.

MANUAL. Capable of being operated by personal intervention (see "Automatic").

OCCUPANT SENSOR CONTROL. An automatic control device that detects the presence or absence of people within an area and causes lighting, equipment or appliances to be regulated accordingly.

THERMOSTAT. An automatic control device used to maintain temperature at a fixed or adjustable set point.

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Ducts Buried Within Insulation

2021 VRC/VECC Update Guide



Ducts Buried Within Insulation:

Summary: The 2018 Virginia Residential Code was the first edition to include prescriptive requirements to be complied with when ducts are buried within ceiling insulation. 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 installed 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 entirely in conditioned space, many designers prefer to locate this equipment in vented attics. To better protect ductwork from attic temperatures, the Virginia Residential Code allows 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]

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

Visual Reference:

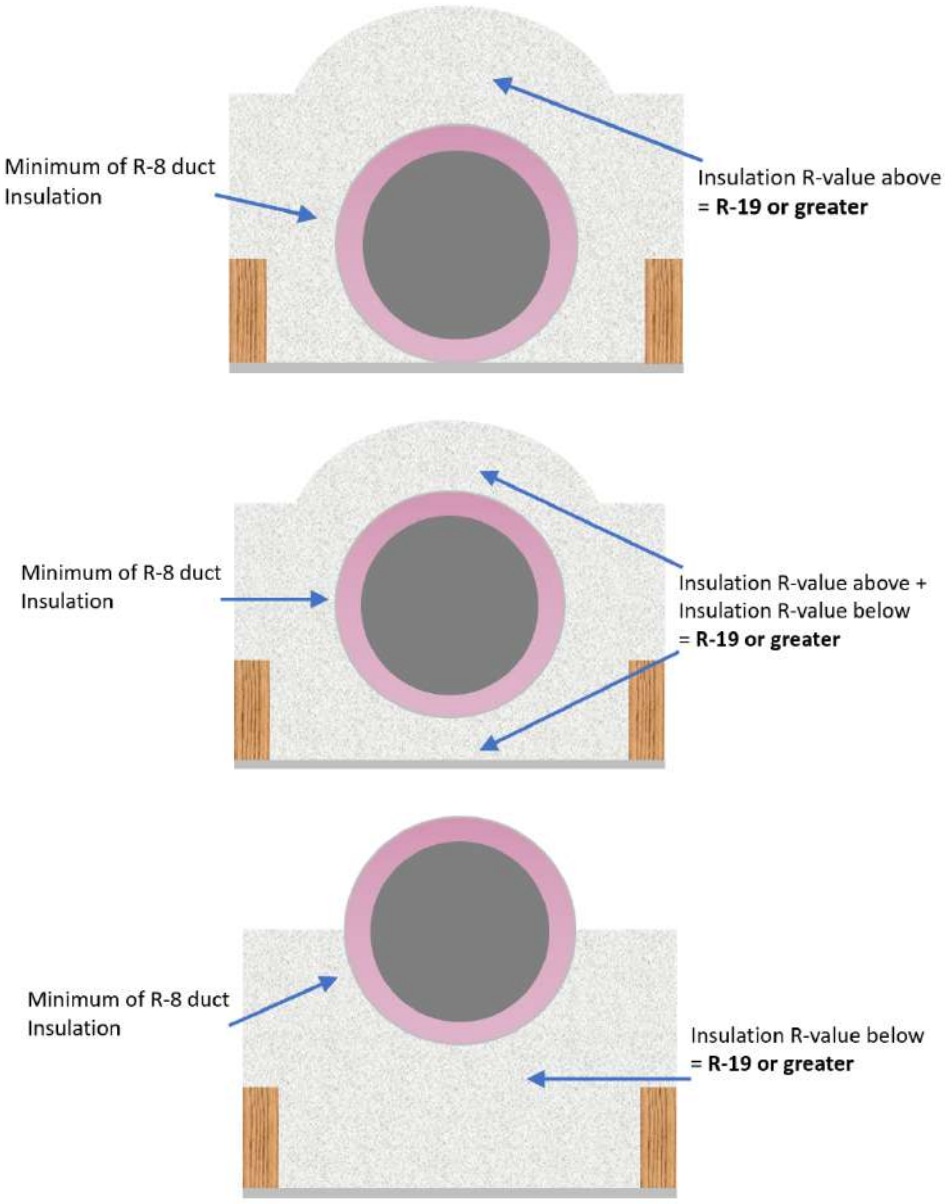


Figure 1: Different configuration options for burying ducts

2021 VRC/VECC Code References:

N1103.3.1 (R403.3.1) Ducts located outside conditioned space. Supply and return ducts located outside conditioned space shall be insulated to an R-value of not less than R-8 for ducts 3 inches (76 mm) in diameter and larger and not less than R-6 for ducts smaller than 3 inches (76 mm) in diameter. Ducts buried beneath a building shall be insulated as required by this section or have an equivalent thermal distribution efficiency. Underground ducts utilizing the thermal distribution efficiency method shall be listed and labeled to indicate the R-value equivalency.

N1103.3.2 (R403.3.2) Ducts located in conditioned space. For ductwork to be considered inside a conditioned space, it shall comply with one of the following:

1. The duct system is located completely within the continuous air barrier and within the building thermal envelope.
2. Ductwork in ventilated attic spaces is buried within ceiling insulation in accordance with Section N1103.3.3 and all of the following conditions exist:
    2.1. The air handler is located completely within the continuous air barrier and within the building thermal envelope.
    2.2. The duct leakage, as measured either by a rough-in test of the ducts or a postconstruction total system leakage test to outside the building thermal envelope in accordance with Section N1103.3.6, is less than or equal to 1.5 cubic feet per minute (42.5 L/min) per 100 square feet (9.29 m2) of conditioned floor area served by the duct system.
    2.3. The ceiling insulation R-value installed against and above the insulated duct is greater than or equal to the proposed ceiling insulation R-value, less the R-value of the insulation on the duct.
3. Ductwork in floor cavities located over unconditioned space shall have the following:
    3.1. A continuous air barrier installed between unconditioned space and the duct.
    3.2. Insulation installed in accordance with Section N1102.2.7.
    3.3. A minimum R-19 insulation installed in the cavity width separating the duct from unconditioned space.
4. Ductwork located within exterior walls of the building thermal envelope shall have the following:
    4.1. A continuous air barrier installed between unconditioned space and the duct.
    4.2. Minimum R-10 insulation installed in the cavity width separating the duct from the outside sheathing.
    4.3. The remainder of the cavity insulation fully insulated to the drywall side.

N1103.3.3 (R403.3.3) Ducts buried within ceiling insulation. Where supply and return air ducts are partially or completely buried in ceiling insulation, such ducts shall comply with all of the following:

1. The supply and return duct shall have an insulation R-value not less than R-8.
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. In Climate Zones 0A, 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.

N1103.3.3.1 (R403.3.3.1) Effective R-value of deeply buried ducts. Where using the Total Building Performance Compliance Option in accordance with Section N1101.13.2, sections of ducts that are installed in accordance with Section N1103.3.3, located directly on or within 5.5 inches (140 mm) of the ceiling, surrounded with blown-in attic insulation having an R-value of

R-30 or greater and located such that the top of the duct is not less than 3.5 inches (89 mm) below the top of the insulation, shall be considered as having an effective duct insulation R-value of R-25.

N1102.4.1.1 (R402.4.1.1) Installation. The components of the building thermal envelope as indicated in Table N1102.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria indicated in Table 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.

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.

ATTIC, HABITABLE. A finished or unfinished habitable space within an attic.

BUILDING THERMAL ENVELOPE. The basement walls, exterior walls, floors, ceiling, roofs and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

CAVITY INSULATION. Insulating material located between framing members.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly 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.

CONTINUOUS AIR BARRIER. A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (ci). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

DUCT. A tube or conduit utilized for conveying air. The air passages of self-contained systems are not to be construed as air ducts.

DUCT SYSTEM. A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans and accessory air-handling equipment and appliances.

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].

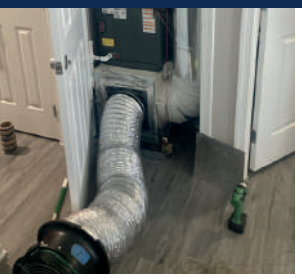
VAPOR PERMEABLE. The property of having a moisture vapor permeance rating of 5 perms (2.9 × 10-10 kg/Pa × s × m2) or greater, where tested in accordance with Procedure A or Procedure B of ASTM E96. A vapor permeable material permits the passage of moisture vapor.

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

Duct Leakage Testing

2021 VRC/VECC Update Guide




Heating/Cooling Ductwork Must Meet Air-Tightness Standard:

Summary: Virginia began requiring duct airtightness to be measured with the 2015 Virginia Residential Code, with a maximum allowed leakage rate of 4%. If the air handler and ductwork of the HVAC system were within conditioned space, the system was exempt from testing. With the 2021 update, this exemption is removed, and all ducts serving or integrated with heating and cooling systems must be tested. Air handlers plus their associated ductwork located fully within conditioned space are allowed a maximum leakage rate of 8%. This guide is intended to give both code and real-world examples of what that change means for code enforcement in the Commonwealth.

Why: Testing to ensure heating/cooling ductwork does not exceed the leakage threshold is a simple, cost-effective way of improving comfort, air quality, and energy efficiency over the lifetime of that ductwork. Virginia's residential energy code began requiring heating/cooling ducts to be tested for leakage with the 2015 edition – but only for ductwork installed outside of the home's air barrier/thermal envelope. The maximum allowable leakage for those ducts is 4 percent. With the 2021 update, ductwork inside conditioned space also must be tested. Here, leakage must not exceed 8 percent. Duct leakage inside the building envelope compromises comfort, air quality, and moisture management – as well as energy efficiency. On the supply side, leaked air means some or all rooms do not receive the amount of conditioned air those rooms were intended to receive based on load calculations, equipment capacity, and the duct layout design. On the return side, leakage can mean return air is bypassing the filter.

Meeting N1103.3.6 (R403.3.6):

This test can take place at rough-in or after HVAC trim out has been completed. N1103.3.6 (R403.3.6) provides standards for leakage based on what components are installed during the time of the test and the stage of construction:

Air Handler and Ductwork not entirely within Conditioned Space

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

Air Handler and Ductwork entirely within Conditioned Space

Test Conditions	Maximum Allowed Duct Leakage	Maximum Allowed (CFM25)
Rough-in with air handler installed	8 CFM per 100 sq ft of conditioned floor area	.08 x conditioned floor area served
Rough-in without air handler installed	8 CFM per 100 sq ft of conditioned floor area	.08 x conditioned floor area served
Post-construction	8 CFM per 100 sq ft of conditioned floor area	.08 x conditioned floor area served

Example
1 system serving the entire home. The system is in a vented attic. Conditioned floor area of the home is 1,200 sq. ft. Testing is done at the end of construction.

- 4% of conditioned floor area = 1,200 X 0.04 = 48
- To pass final duct leakage at final inspection: CFM25 must be ≤ 48 CFM

Per Section N1103.3.5 (R403.3.5), anyone that has been trained on the duct testing equipment to provide duct leakage measurements. Duct leakage is sometimes categorized as either "total" or "leakage to outside." The energy code only references total duct leakage.

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

Duct Sealing Visuals:

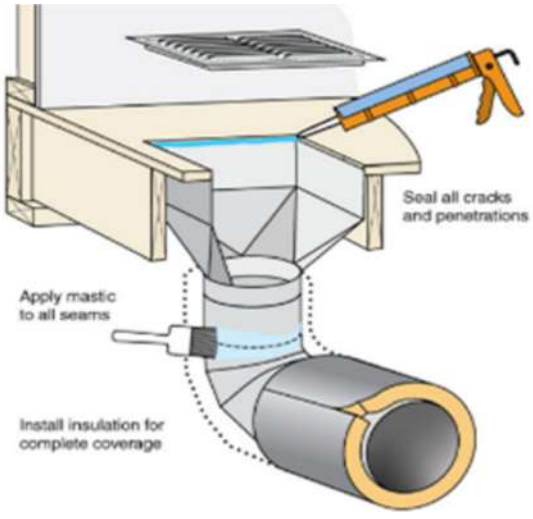


Figure 1: Joints and seams at duct boot sealed

Figure 2: Increased duct and envelope leakage if left unsealed

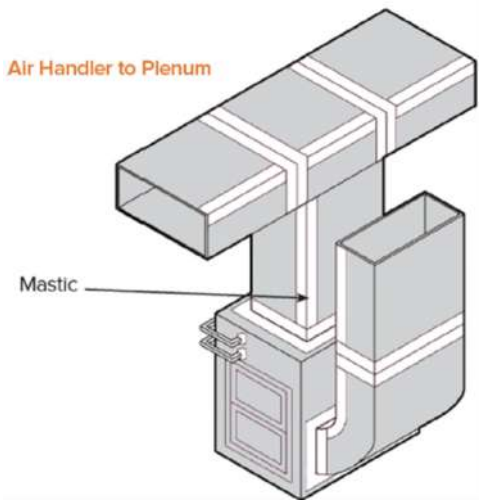


Figure 3: Well sealed plenum and trunk

Figure 4: Well sealed supply-to-trunk connection

Figure 5: Unsealed tabular duct takeoff

Figure 6: Unsealed and poorly supported duct takeoff. The immediate 90 degree turn should use hard duct.

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

Additional Resources:

- https://basc.pnnl.gov/resource-guides/total-duct-leakage-tests
- https://www.resnet.us/wp-content/uploads/ANSIRESNETICC_380-2019_vf1.24.19_cover%5E0TOC-2.pdf
  ANSI/RESNET/ICC 380-2019 Standard for Testing Airtightness of Building, Dwelling Unit, and Sleeping Unit Enclosures; Airtightness of Heating and Cooling Air Distribution Systems; and Airflow of Mechanical Ventilation Systems

2021 VRC/VECC Code References:

N1103.3 (R403.3) Ducts. Ducts and air handlers shall be installed in accordance with Sections N1103.3.1 through N1103.3.7.

N1103.3.1 (R403.3.1) Ducts located outside conditioned space. Supply and return ducts located outside conditioned space shall be insulated to an R-value of not less than R-8 for ducts 3 inches (76 mm) in diameter and larger and not less than R-6 for ducts smaller than 3 inches (76 mm) in diameter. Ducts buried beneath a building shall be insulated as required by this section or have an equivalent thermal distribution efficiency. Underground ducts utilizing the thermal distribution efficiency method shall be listed and labeled to indicate the R-value equivalency.

N1103.3.2 (R403.3.2) Ducts located in conditioned space. For ductwork to be considered inside a conditioned space, it shall comply with one of the following:

1. The duct system is located completely within the continuous air barrier and within the building thermal envelope.
2. Ductwork in ventilated attic spaces is buried within ceiling insulation in accordance with Section N1103.3.3 and all of the following conditions exist:
    2.1. The air handler is located completely within the continuous air barrier and within the building thermal envelope.
    2.2. The duct leakage, as measured either by a rough-in test of the ducts or a postconstruction total system leakage test to outside the building thermal envelope in accordance with Section N1103.3.6, is less than or equal to 1.5 cubic feet per minute (42.5 L/min) per 100 square feet (9.29 m2) of conditioned floor area served by the duct system.
    2.3. The ceiling insulation R-value installed against and above the insulated duct is greater than or equal to the proposed ceiling insulation R-value, less the R-value of the insulation on the duct.
3. Ductwork in floor cavities located over unconditioned space shall have the following:
    3.1. A continuous air barrier installed between unconditioned space and the duct.
    3.2. Insulation installed in accordance with Section N1102.2.7.
    3.3. A minimum R-19 insulation installed in the cavity width separating the duct from unconditioned space.
4. 4.Ductwork located within exterior walls of the building thermal envelope shall have the following:
    4.1. A continuous air barrier installed between unconditioned space and the duct.
    4.2. Minimum R-10 insulation installed in the cavity width separating the duct from the outside sheathing.
    4.3. The remainder of the cavity insulation fully insulated to the drywall side.

N1103.3.3 (R403.3.3) Ducts buried within ceiling insulation. Where supply and return air ducts are partially or completely buried in ceiling insulation, such ducts shall comply with all of the following:

1. The supply and return duct shall have an insulation R-value not less than R-8.
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. In Climate Zones 0A, 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.

N1103.3.3.1 (R403.3.3.1) Effective R-value of deeply buried ducts. Where using the Total Building Performance Compliance Option in accordance with Section N1101.13.2, sections of ducts that are installed in accordance with Section N1103.3.3, located directly on or within 5.5 inches (140 mm) of the ceiling, surrounded with blown-in attic insulation having an R-value of R-30 or greater and located such that the top of the duct is not less than 3.5 inches (89 mm) below the top of the insulation, shall be considered as having an effective duct insulation R-value of R-25.

N1103.3.4 (R403.3.4) Sealing. Ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply with Section M1601.4.1.

N1103.3.4.1 (R403.3.4.1) 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.

N1103.3.5 (R403.3.5) Duct testing. Ducts shall be pressure tested in accordance with ANSI/RESNET/ICC 380 or ASTM E1554 to determine air leakage by one of the following methods:

1. 1.Rough-in test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the system, including the manufacturer's air handler enclosure if installed at the time of the test. Registers shall be taped or otherwise sealed during the test.
2. 2.Postconstruction test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (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 for ducts serving heating, cooling or ventilation systems that are not integrated with ducts serving heating or cooling systems.

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.

N1103.3.6 (R403.3.6) Duct leakage. The total leakage of the ducts, where measured in accordance with Section N1103.3.5, shall be as follows:

1. Rough-in test: The total leakage shall be less than or equal to 4.0 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 3.0 cubic feet per minute (85 L/min) per 100 square feet (9.29 m2) of conditioned floor area.
2. Postconstruction test: Total leakage shall be less than or equal to 4.0 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m2) of conditioned floor area.

3. Test for ducts within thermal envelope: Where all ducts and air handlers are located entirely within the building thermal envelope, total leakage shall be less than or equal to 8.0 cubic feet per minute (226.6 L/min) per 100 square feet (9.29 m2) of conditioned floor area.

Exceptions:
1. Direct vent appliances with both intake and exhaust pipes installed continuous to the outside.
2. Fireplaces and stoves complying with Sections N1102.4.2 and R1006.

M1601.4.1 Joints, seams and connections. Longitudinal and transverse joints, seams and connections in metallic and nonmetallic ducts shall be constructed as specified in SMACNA HVAC Duct Construction Standards—Metal and Flexible and NAIMA Fibrous Glass Duct Construction Standards. Joints, longitudinal and transverse seams, and connections in ductwork shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems, liquid sealants or tapes. Tapes and mastics used to seal fibrous glass ductwork shall be listed and labeled in accordance with UL 181A and shall be marked “181A-P” for pressure-sensitive tape, “181 A-M” for mastic or “181 A-H” for heat-sensitive tape.

Tapes and mastics used to seal metallic and flexible air ducts and flexible air connectors shall comply with UL 181B and shall be marked “181 B-FX” for pressure-sensitive tape or “181 BM” for mastic. Duct connections to flanges of air distribution system equipment shall be sealed and mechanically fastened. Mechanical fasteners for use with flexible nonmetallic air ducts shall comply with UL 181B and shall be marked 181B-C. Crimp joints for round metallic ducts shall have a contact lap of not less than 1 inch (25 mm) and shall be mechanically fastened by means of not less than three sheet-metal screws or rivets equally spaced around the joint.

Closure systems used to seal all ductwork shall be installed in accordance with the manufacturers’ instructions.
Exceptions:
1. Spray polyurethane foam shall be permitted to be applied without additional joint seals.
2. Where a duct connection is made that is partially without access, three screws or rivets shall be equally spaced on the exposed portion of the joint so as to prevent a hinge effect.
3. For ducts having a static pressure classification of less than 2 inches of water column (500 Pa), additional closure systems shall not be required for continuously welded joints and seams and locking-type joints and seams. This exception shall not apply to snap-lock and button-lock type joints and seams that are located outside of conditioned spaces.

M1601.4.6 Duct insulation. Duct insulation shall be installed in accordance with the following requirements:
1. A vapor retarder having a permeance of not greater than 0.05 perm [2.87 ng/(s × m2× Pa)] in accordance with ASTM E96, or aluminum foil with a thickness of not less than 2 mils (0.05 mm), shall be installed on the exterior of insulation on cooling supply ducts that pass through unconditioned spaces conducive to condensation except where the insulation is spray polyurethane foam with a water vapor permeance of not greater than 3 perms per inch [1722 ng/(s × m2× Pa)] at the installed thickness.
2. Outdoor duct systems shall be protected against the elements.
3. Duct coverings shall not penetrate a fireblocked wall or floor.

Definitions:

BUILDING THERMAL ENVELOPE: The basement walls, exterior walls, floors, ceiling, 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 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.

CONTINUOUS AIR BARRIER: A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (ci): Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

DUCT: A tube or conduit utilized for conveying air. The air passages of self-contained systems are not to be construed as air ducts.

DUCT SYSTEM: A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans and accessory air-handling equipment and appliances.

EXTERIOR WALL: Walls including both above-grade walls and basement walls.

LABELED: Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, approved agency or other organization concerned with product evaluation that maintains periodic inspection of the production of such labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

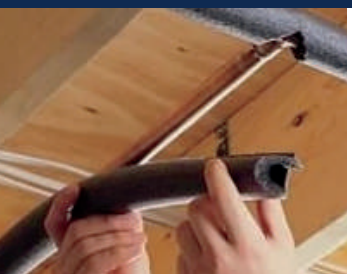
INFILTRATION: The uncontrolled inward air leakage into a building caused by the pressure effects of wind, or the effect of differences in the indoor and outdoor air density or both.

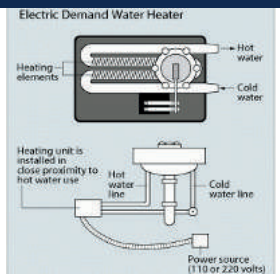
LISTED: Equipment, materials, products or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

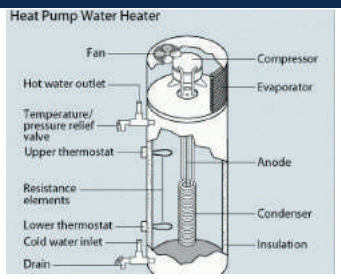
R-VALUE (THERMAL RESISTANCE): The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area (h × ft2 × °F/Btu) [(m2 × K)/W]. *Note: In more general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

Hot Water Pipe Insulation

2021 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 has changed only slightly from the 2012 to 2021 editions. Per N1103.5.2 (R403.5.2), 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 energy code only required piping larger than $^{3}/_{4}$ 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 circulation and recirculation systems other than cold water pipe return demand recirculation systems

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 $.35 per linear foot (November 2024 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]

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.

How much energy does it save? In September 2022, conservation programs managed by electric utilities in Virginia calculated[ii] that pipe insulation reduced 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 was paying $.14 per kWh (prices 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

2021 VRC/VECC Code References:

N1103.5.2 (R403.5.2) Hot water pipe insulation. Insulation for service 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 located inside the conditioned space.
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 circulation and recirculation systems other than cold water pipe return demand recirculation systems.

P2603.5 Freezing. In localities having a winter design temperature of 32°F (0°C) or lower as shown in Table R301.2 of this code, a water, soil or waste pipe shall not be installed outside of a building, in exterior walls, in attics or crawl spaces, or in any other place subjected to freezing temperature unless adequate provision is made to protect it from freezing by insulation or heat or both. Water service pipe shall be installed not less than 12 inches (305 mm) deep and not less than 6 inches (152 mm) below the frost line.

Definitions:

CIRCULATING HOT WATER SYSTEM: A specifically designed water distribution system where one or more pumps are operated in the service hot water piping to circulate heated water from the water-heating equipment to fixtures and back to the water-heating equipment.

DEMAND RECIRCULATION WATER SYSTEM: A water distribution system where one or more pumps prime the service hot water piping with heated water on demand for hot water.

MANUAL: Capable of being operated by personal intervention (see "Automatic").

OCCUPANT SENSOR CONTROL: An automatic control device that detects the presence or absence of people within an area and causes lighting, equipment or appliances to be regulated accordingly.

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].

SERVICE WATER HEATING: Supply of hot water for purposes other than comfort heating.

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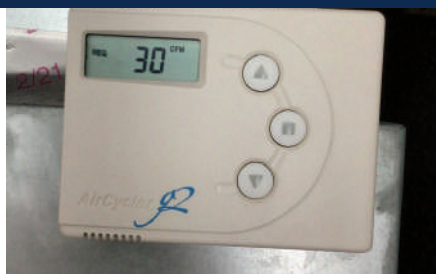
[i] https://www.energy.gov/energysaver/do-it-yourself-savings-project-insulate-hot-water-pipes.
Banner graphics from https://www.energy.gov/energysaver/water-heating; photos from Viridiant.

[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

Ventilation Equipment Performance and Efficiency

2021 VRC/VECC Update Guide

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



Required Testing of Ventilation Air Movement and Efficiency Specs for Equipment:

Summary: The Virginia Residential Code has required mechanical ventilation in new homes since the 2012 edition. 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.

Now, the 2021 code requires that the actual airflow of that equipment be confirmed to meet the targeted amount. The energy code also stipulates energy efficiency standards for ventilation fans. These standards are more rigorous with the 2021 update.

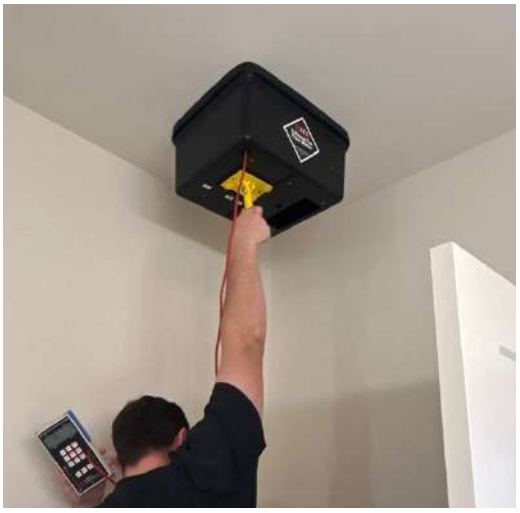


Figure 1: Measuring exhaust fan airflow with a flow-meter box and manometer

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 (2021 VRC Section: M1602.1) and outlet vents, filters, ducts, controls, and fans (2021 VRC Section: N1103.6). The strategy and equipment should take into account exterior temperature variations, desired indoor and prevalent

Figure 2: Measuring exhaust fan airflow with a balometer

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

outdoor humidity conditions, house configuration, and design objectives for the quantity and quality of air delivered.[2] The ability to test the airflow rate and the likelihood of achieving that rate should also be considered. Each system has its advantages and disadvantages, as listed in the table below.

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

Ventilation System Type	Advantages	Disadvantages
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
Supply	• Relatively inexpensive and simple to install • Allows better control than exhaust systems • Minimizes pollutants from outside living space • Prevents 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 • Can be difficult to achieve target ventilation rates without a supplemental supply fan
Balanced (Energy & Heat Recovery Ventilators)	• Reduces 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

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

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

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***

How: Fan airflow is measured using calibrated equipment such as a bolometer or a flow meter box with a manometer. Typically, measurements can be obtained by fitting these devices over the intake or exhaust point. With the fan turned on, they quickly report the CFMs moving through the system. Typically, the most challenging aspect is creating a good seal around the intake/exhaust point in order to isolate the airflow through the measuring device.

When intake/exhaust points are inaccessible or cannot be adequately sealed, it also is possible to measure airflow using a probe inserted into a duct through which only ventilation air travels. To get an accurate reading, this should be a straight section of smooth duct. Finally, some heat or energy recovery ventilators are outfitted in the factory with probe points where a technician can obtain actual airflow measurements.

Plan Review Focus: Per section N1101.5 (R103.2), whole-home mechanical ventilation equipment details should be noted on plans.

Figure 3: Image: Measuring whole-home ventilation air flow via probes in the energy recovery ventilator.

Whole-house Ventilation Equipment Examples:

Figure 4: Exhaust Ventilation Strategy – requires controls to ensure run times are met.

Figure 5: Common Supply Ventilation Systems – duct run from exterior to return plenum, automated damper, and controls

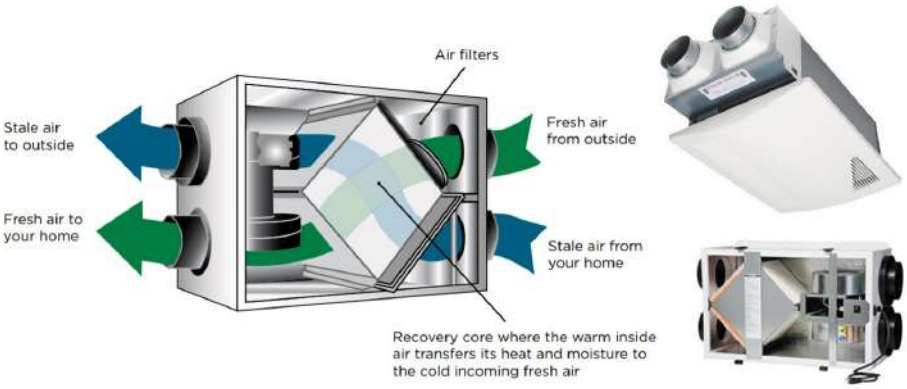


Figure 6: Balanced Ventilation Strategy utilizing heat or enthalpy recovery

Additional Resources:

- https://basc.pnnl.gov/resource-guides/testing-mechanical-ventilation-systems
- https://sws.nrel.gov/spec/6 Detailed installation guidelines

2021 VRC/VECC Code References:

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. Controls shall include text or a symbol indicating their function.

M1505.4.3 Mechanical ventilation rate. The whole-house mechanical ventilation system shall provide outdoor air at a continuous rate not less than that determined in accordance with Table M1505.4.3(1) or not less than that determined by 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)]

Exceptions:

1. Ventilation rate credit. The minimum mechanical ventilation rate determined in accordance with Table M1505.4.3(1) or Equation 15-1 shall be reduced by 30 percent, provided that both of the following conditions apply:
   - 1.1. A ducted system supplies ventilation air directly to each bedroom and to one or more of the following rooms:
     - 1.1.1. Living room.
     - 1.1.2. Dining room.
     - 1.1.3. Kitchen.
   - 1.2. The whole-house ventilation system is a balanced ventilation system.
2. Programmed intermittent operation. 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), by Equation 15-1 or by Exception 1 is multiplied by the factor determined in accordance with Table M1505.4.3(2).

N1103.6 (R403.6) Mechanical ventilation. The buildings complying with Section N1102.4.1 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.

N1103.6.1 (R403.6.1) Heat or energy recovery ventilation. Dwelling units shall be provided with a heat recovery or energy recovery ventilation system in Climate Zones 7 and 8. The system shall be balanced with a minimum sensible heat recovery efficiency of 65 percent at 32°F (0°C) at a flow greater than or equal to the design airflow.

N1103.6.2 (R403.6.2) Whole-dwelling mechanical ventilation system fan efficacy. Fans used to provide whole-dwelling mechanical ventilation shall meet the efficacy requirements of Table N1103.6.2 at one or more rating points. Fans shall be tested in accordance with HVI 916 and listed. The airflow shall be reported in the product listing or on the label. Fan efficacy shall be reported in the product listing or shall be derived from the input power and airflow values reported in the product listing or on the label. Fan efficacy for fully ducted HRV, ERC, balanced and in-line fans shall be determined at a static pressure of not less than 0.2 inch water column (49.82 Pa). Fan efficacy for ducted range hoods, bathroom, and utility room fans shall be determined at a static pressure of not less than 0.1 inch water column (24.91 Pa).

TABLE N1103.6.2 (R403.6.2) WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM FAN EFFICACYa

SYSTEM TYPE	AIRFLOW RATE (CFM)	MINIMUM EFFICACY (CFM/WATT)
HRV, ERV; or balanced	Any	1.2 cfm/watt
Range hood	Any	2.8 cfm/watt
In-line supply or exhaust fan	Any	3.8 cfm/watt
Other exhaust fan	< 90	2.8 cfm/watt
	≥ 90	3.5 cfm/watt
Air-handler that is integrated to tested and *listed* HVAC equipment	Any	1.2 cfm/watt

For SI: 1 cubic foot per minute = 28.3 L/min.

a. Design outdoor airflow rate/watts of fan used.

N1103.6.3 (R403.6.3) Testing. Mechanical ventilation systems shall be tested and verified to provide the minimum ventilation flow rates required by Section N1103.6. Testing shall be performed according to the ventilation equipment manufacturer's instructions, or by using a flow hood or box, flow grid, or other airflow measuring device at the mechanical ventilation fan's inlet terminals or grilles, outlet terminals or grilles, or in the connected ventilation ducts. Where required by the code official, testing shall be conducted by an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the code official. Exception: Kitchen range hoods that are ducted to the outside with 6-inch (152 mm) or larger duct and not more than one 90-degree (1.57 rad) elbow or equivalent in the duct run.

Definitions:

AUTOMATIC. Self-acting, operating by its own mechanism when actuated by some impersonal influence, as, for example, a change in current strength, pressure, temperature or mechanical configuration (see "Manual").

CONDITIONED FLOOR AREA. The horizontal projection of the floors associated with the conditioned space.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly 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.

DWELLING UNIT ENCLOSURE AREA. The sum of the area of ceiling, floors, and walls separating a dwelling unit's conditioned space from the exterior or from adjacent conditioned or unconditioned spaces. Wall height shall be measured from the finished floor of the dwelling unit to the underside of the floor above.

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.

LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, approved agency or other organization concerned with product evaluation that maintains periodic inspection of the production of such labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

LISTED. Equipment, materials, products or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

MANUAL. Capable of being operated by personal intervention (see "Automatic").

OCCUPANT SENSOR CONTROL. An automatic control device that detects the presence or absence of people within an area and causes lighting, equipment or appliances to be regulated accordingly.

VENTILATION. The natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space.

VENTILATION AIR. That portion of supply air that comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.

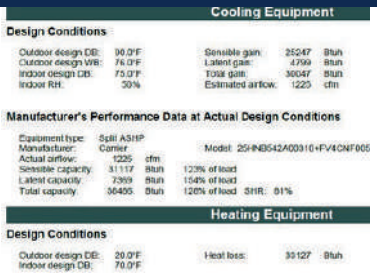
VISIBLE TRANSMITTANCE (VT). The ratio of visible light entering the space through the fenestration product assembly to the incident visible light. Visible Transmittance includes the effects of glazing material and frame and is expressed as a number between 0 and 1.

WHOLE HOUSE MECHANICAL VENTILATION SYSTEM. An exhaust system, supply system, or combination thereof that is designed to mechanically exchange indoor air with outdoor air when operating continuously or through a programmed intermittent schedule to satisfy the whole house ventilation rates.

ZONE. A space or group of spaces within a building with heating or cooling requirements that are sufficiently similar so that desired conditions can be maintained throughout using a single controlling device.

Heating/Cooling Design, Equipment, and Installation

2021 VRC/VECC Code Guide



Resources for code-compliant heating and cooling design and installation:

For residential heating/cooling, the Air Conditioning Contractors of America Association, Inc. – commonly known as ACCA – publishes Manual J, Manual S, and Manual D, which contain protocols and formulas to guide load calculation, equipment selection, and duct design respectively. Virginia Residential Code has required the use of all three of these manuals – or approved substitutes – since the 2009 edition.

The following pages provide a variety of resources for designers, installers, and code officials to help ensure that calculations associated with a particular home are accurate and complete – and that the ensuing installation is completed in compliance with code requirements.

- Brochures on Manual J, S, and D from ACCA, the Air Conditioning Contractors of America
- "Understanding and Using the HVAC Design Review Form" and a sample HVAC Design Review Form – both from ACCA
- Viridiant's "Understanding Select Fields on the Residential Plans Examiner Review Form for HVAC System Design"
- Viridiant's "TECH TIPS: HVAC Installation"

Additional Resources:

- https://www.acca.org/viewdocument/hvac-brochures-for-code-officials
- https://www.acca.org/viewdocument/residential-system-design-review-forms-examples
- https://www.acca.org/viewdocument/hvac-quality-installation-specification-english-1

2021 VRC/VECC Code References:

N1103.7 (R403.7) (M1401.3) Equipment and appliance sizing. Heating and cooling equipment and appliances shall be sized in accordance with ACCA Manual S or other approved sizing methodologies based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies.

Exception: Heating and cooling equipment and appliance sizing shall not be limited to the capacities determined in accordance with Manual S or other approved sizing methodologies where any of the following conditions apply:

1. The specified equipment or appliance utilizes multistage technology or variable refrigerant flow technology and the loads calculated in accordance with the approved heating and cooling methodology fall within the range of the manufacturer's published capacities for that equipment or appliance.

2. The specified equipment or appliance manufacturer's published capacities cannot satisfy both the total and sensible heat gains calculated in accordance with the approved heating and cooling methodology and the next larger standard size unit is specified.
3. The specified equipment or appliance is the lowest capacity unit available from the specified manufacturer.

M1411.6.1 Refrigerant line insulation protection. Refrigerant piping insulation shall be protected in accordance with Section N1103.4.1.

N1103.4 (R403.4) Mechanical system piping insulation. Mechanical system piping capable of carrying fluids greater than 105°F (41°C) or less than 55°F (13°C) shall be insulated to an R-value of not less than R-3.

N1103.4.1 (R403.4.1) Protection of piping insulation. Piping insulation exposed to weather shall be protected from damage, including that caused by sunlight, moisture, equipment maintenance and wind. The protection shall provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall be prohibited.

M1601.1 Duct design. Duct systems serving heating, cooling and ventilation equipment shall be installed in accordance with the provisions of this section and ACCA Manual D, the appliance manufacturer's installation instructions or other approved methods.

M1601.6 Independent garage HVAC systems. Furnaces and air-handling systems that supply air to living spaces shall not supply air to or return air from a garage.

M1602.1 Outdoor air openings. Outdoor intake openings shall be located in accordance with Section R303.5.1. Opening protection shall be in accordance with Section R303.6

M1602.2 Return air openings. Return air openings for heating, ventilation and air-conditioning systems shall comply with all of the following:

1. Openings shall not be located less than 10 feet (3048 mm) measured in any direction from an open combustion chamber or draft hood of another appliance located in the same room or space.
2. The amount of return air taken from any room or space shall be not greater than the flow rate of supply air delivered to such room or space.
3. Return and transfer openings shall be sized in accordance with the appliance or equipment manufacturer's installation instructions, Manual D or the design of the registered design professional.
4. Return air shall not be taken from a closet, bathroom, toilet room, kitchen, garage, mechanical room, boiler room, furnace room or unconditioned attic.

   Exceptions:

   1. Taking return air from a kitchen is not prohibited where such return air openings serve the kitchen only, and are located not less than 10 feet (3048 mm) from the cooking appliances.
   2. Dedicated forced-air systems serving only the garage shall not be prohibited from obtaining return air from the garage.

5. For other than dedicated HVAC systems, return air shall not be taken from indoor swimming pool enclosures and associated deck areas except where the air in such spaces is dehumidified.
6. Taking return air from an unconditioned crawl space shall not be accomplished through a direct connection to the return side of a forced-air furnace. Transfer openings in the crawl space enclosure shall not be prohibited.
7. Return air from one dwelling unit shall not be discharged into another dwelling unit. **Exception**: The return air within a two-family dwelling constructed without fire separations in accordance with Exception 3 of Section R302.3 shall be permitted to discharge into either dwelling unit.

Definitions:

CLIMATE ZONE. A geographical region based on climatic criteria as specified in this code.

CONDITIONED FLOOR AREA. The horizontal projection of the floors associated with the conditioned space.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly 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.

DUCT. A tube or conduit utilized for conveying air. The air passages of self-contained systems are not to be construed as air ducts.

DUCT SYSTEM. A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans and accessory air-handling equipment and appliances.

THERMAL DISTRIBUTION EFFICIENCY (TDE). The resistance to changes in air heat as air is conveyed through a distance of air duct. TDE is a heat loss calculation evaluating the difference in the heat of the air between the air duct inlet and outlet caused by differences in temperatures between the air in the duct and the duct material. TDE is expressed as a percent difference between the inlet and outlet heat in the duct.

THERMAL ISOLATION. Physical and space conditioning separation from conditioned spaces. The conditioned spaces shall be controlled as separate zones for heating and cooling or conditioned by separate equipment.

THERMOSTAT. An automatic control device used to maintain temperature at a fixed or adjustable setpoint.

VENTILATION. The natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space.

VENTILATION AIR. That portion of supply air that comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.

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