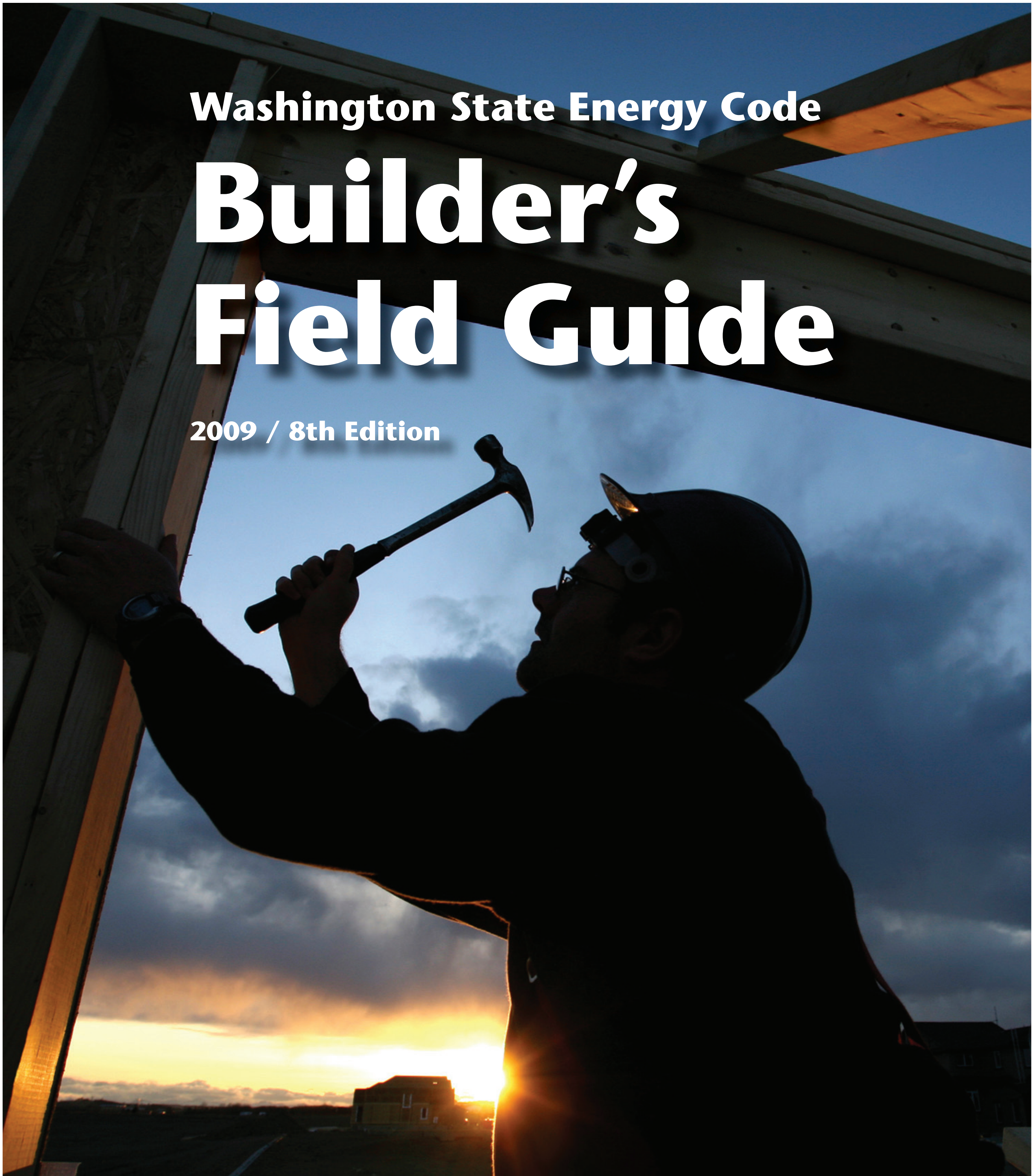
Washington State Energy Code

Builder's Field Guide

2009 / 8th Edition



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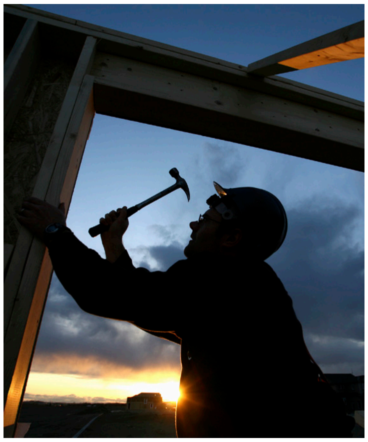

Washington State Energy Code

Builder's Field Guide

2009 / 8th Edition

For use with the 2009 Washington State Energy Code.
Applies to all building permits issued on or after January 1, 2011.

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Chapter Contents

Introduction

The 8th edition of the *Builder's Field Guide* outlines acceptable construction practices that meet the 2009 *Washington State Energy Code* (WSEC).

The current edition of the WSEC was adopted effective January 1, 2011. The Code applies to all building jurisdictions in the State for residential construction. For non-residential construction, the code applies everywhere in the state, except Seattle, where municipal versions of the code have been adopted.

The *Builder's Field Guide* covers only residential practices and requirements. A similar guide for non-residential buildings is available from the Northwest Energy Efficiency Council. ***www.neec.net***

The Guide is available online in an effort to provide broad access and to reduce paper consumption. The online version of the Guide is provided to the public free of charge, and all users may print out copies as necessary. You may also want to consider downloading the electronic version of the WSEC, also available online. The *Builder's Field Guide*, and the WSEC can be downloaded from ***www.energy.wsu.edu/code*** See the copyright notice on the back side of the title page.

Code Review Process

These codes, and all Washington State Building Codes, are developed by the Washington State Building Code Council (SBCC). The SBCC oversees a public process that reviews all codes. The building community, utilities, local government, and state agencies participate in the public process through technical advisory groups organized around each code. The WSEC is updated every three years.

If you are interested in participating in the next code review process, please contact the SBCC at (360) 725-2966 or go to ***https://fortress.wa.gov/ga/apps/sbcc/default.aspx***.

While the practices included in this Guide are generally acceptable for Code compliance, your local building official has the final say as to what meets code in specific applications. Alternative practices not illustrated may be acceptable, but must be approved by the local jurisdiction.

The illustrations contained in this Guide reflect Code requirements. Occasionally, however, recommended practices that go beyond Code requirements are included.

*The "**good practices**" are labeled as such and should not be construed as Code requirements.*

Code References in the Guide

[502.4.3]

References to the 2009 WSEC are placed in the left margin similar to this sample.

What's New In this Edition?

The 2009 WSEC has numerous changes, additions and some deletions from the 2006 WSEC. This edition of the *Builder's Field Guide* reflects those changes. Previous editions had chapters dedicated to radon and ventilation requirements. Those chapters have been deleted because the stand-alone *Ventilation and Indoor Air Quality Code* has been repealed and the requirements have been incorporated into the *International Residential Code* (IRC), *International Mechanical Code* (IMC), and the *International Building Code* (IBC). Two new chapters – 9 (Credits) and 11 (Lighting) – have been added. Illustrations have also been updated. Since this Guide is published in a searchable PDF format, a detailed table of contents and index has been deleted.

If you have questions, comments or other input about the Guide, feel free to email us at ***energycode@energy.wsu.edu***

Acknowledgements

Funding for maintenance of the *Builder's Field Guide* has been provided by the Northwest Energy Efficiency Alliance and the U.S. Department of Energy.

The 2009 version of the *Builder's Field Guide* was updated by Washington State University Extension Energy Program staffers Gary Nordeen (project lead), Luke Howard, Emily Salzberg, Tanya Beavers, and Gerry Rasmussen (graphic design), and supervised by Todd Currier (Division Manager).

List of Acronyms Used in the WSEC

ABS	Acrylonitrile Butacliene Styrene
ACCA	Air Conditioning Contractors of America Association, Inc.
ACH	Air Changes per Hour
AFUE	Annual Fuel Utilization Efficiency (DOE)
APA	American Plywood Association (now called *APA – The Engineered Wood Association*)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BTU (Btu)	British Thermal Units
CFM (cfm)	Cubic Feet per Minute
Code	Washington State Energy Code
COP	Coefficient of Performance
DOE	U.S. Department of Energy
EF	Energy Factor
EPA	U.S. Environmental Protection Agency
EPS	Expanded Polystyrene
HRV	Heat Recovery Ventilator
HSPF	Heating Season Performance Factor
HUD	U.S. Department of Housing and Urban Development
HVAC	Heating, Ventilation and Air Conditioning
HVI	Home Ventilating Institute
IBC	International Building Code

IC rated	Insulation Cover Rated
ICF	Insulated Concrete Form
IMC	International Mechanical Code
IRC	International Residential Code
NAECA	National Appliance Energy Conservation Act (1987)
NFRC	National Fenestration Rating Council
SBCC	Washington State Building Code Council
SHGC	Solar Heat Gain Coefficient
SEER	Seasonal Energy Efficiency Ratio
SLA	Specific Leakage Area
SMACNA	Sheet Metal & Air Conditioning Contractors National Association
sq.ft.	Square Foot/Feet
SRCC	Solar Rating Certification Corporation
UA	U-Factor x Area
UL 181	Underwriter's Laboratory Test #181
WSEC	Washington State Energy Code
XPS	Extruded Polystyrene

Chapter 1: Compliance

[101]

Who Must Comply?

All new residential construction must comply with the *Washington State Energy Code* (WSEC).

Exceptions. Exempt from envelope requirements but needing to comply with other Code provisions are:

[101.3.1.1]
- Buildings with peak design energy usage for space conditioning less than 1 watt (3.4 Btu/hour) per square foot of floor area. May apply to garage, shop or similar part of building.

[101.3.1.2]
- Buildings neither heated nor cooled by a non-renewable energy source (for the purposes of the Code, wood heat is not considered renewable, and must comply).

[101.3.1.3]
- Greenhouses isolated from any conditioned space and not intended for occupancy.

[101.3.2.1 - 101.3.2.8] Additions and remodeling to existing buildings must comply. See pages 1-15 through 1-18 for specific conditions.

Three Compliance Approaches

The Code allows three possible approaches to demonstrate compliance:

[101.2] **Prescriptive Approach.** Follows prescribed building component efficiency levels. [WSEC Chapter 6]

Component Performance Approach. Compares building envelope heat loss rates of the proposed house design to a Code-defined reference house. [WSEC Chapter 5]

System Analysis Approach. Compares an estimate of annual building energy use of the proposed house design to that of a Code-defined reference house.
[WSEC Chapter 4]

You must meet the requirements of only ***one*** approach to comply.

All three compliance options require that the project meet requirements concerning heating systems, water heating and ventilation systems. These requirements are detailed in other chapters of this Guide.

[502.2.1] Buildings constructed using log walls must use "other" fuels to apply the exception noted in Section 502.2.1 UA Calculations.

In addition to meeting the Prescriptive or Component Performance requirements of the Code, a single family or duplex dwelling must develop one credit from Chapter 9. Chapter 9 lists 14 measures that can be used to obtain one credit. The designer, builder or homeowner can choose which measure best applies to their house. If a Systems Analysis Approach is used, compliance with Chapter 9 is met by demonstrating that the proposed building energy use is 8 percent less than the target building energy use.

[502.2.2]

The WSEC defines two fuel types:

Electric Resistance. Includes baseboard units, radiant units, boilers, and forced air units using more than 1kW per dwelling unit or 1 watt/ft.^{2}, whichever is greater. This applies whether units are primary or secondary sources of heat.

Other. Includes all gas, wood, oil, and propane heating systems, unless electric resistance is used as a secondary heating system (see above), and **all heat pump** heating systems.

The prescriptive approach does not distinguish between fuel types. All fuels have the same requirements for building envelope.

Climate Zones

[302.3] The WSEC divides the state into two Climate Zones, shown in Figure 1-1.

Figure 1-1

Washington State Energy Code Climate Zones I & II

Prescriptive Approach

The Easiest Way

The prescriptive approach dictates the minimum insulation level required for each building component. Each component must meet or exceed the listed performance value to qualify.

[601.1] The two prescriptive tables reproduced on pages 1-5 and 1-6 are taken from Chapter 6 of the WSEC. To select the correct table, simply determine your Climate Zone.

How To Use The Prescriptive Tables

Example House:

- Location: .... Olympia
- Occupancy: .... R-3, Single Family
- Conditioned floor area (measured to outside of exterior walls): .... 1000 sq.ft.
- Glazing area (measured window rough openings): .... 260 sq.ft.
- Glazing to floor area ratio: .... 260/1000 = 26%

Process:

- Zone Map (Figure 1-1) identifies Olympia as Zone 1.
- Single Family (R-3) may use the prescriptive approach.
- 26 percent glazing area limits us to Option III, unlimited glazing.

[602.6] Glazing in doors and skylights are treated like any other window. When a door contains over 50 percent glass, the entire rough opening is included in the glazing area.

If a portion of the glazing area is over the allowable U-factor, and a portion is under, you may use an area weighted average U-factor to show compliance with your prescriptive option. To determine the average U-factor, find the corresponding glazing area for each distinct U-factor. Multiply the U-factor by the corresponding glazing area (U x A). Add together the U x A for each distinct U-factor, and divide by the total glazing area. Glazing in the reference calculation is limited to 15 percent of the conditioned floor area.

Example of Area Weighted U-Factor Calculation

Window #1 area 10 sq.ft. U = .32	U x A = 3.2
Window #2 area 15 sq.ft. U = .28	U x A = 4.2
Total area 25 sq.ft.	Total U x A = 7.4

Area weighted average 7.4/25 = 0.29

WSEC Table 6-1

Prescriptive Requirements[0,1] for Group R Occupancy Climate Zone 1

<table>
<tr><th rowspan="2">Op-tion</th><th rowspan="2">Glazing Area[10]: % of Floor</th><th colspan="2">Glazing U-Factor</th><th rowspan="2">Door [9] U-Factor</th><th rowspan="2">Ceiling[2]</th><th rowspan="2">Vaulted Ceiling[3]</th><th rowspan="2">Wall[12] Above Grade</th><th rowspan="2">Wall• int[4] Below Grade</th><th rowspan="2">Wall• ext[4] Below Grade</th><th rowspan="2">Floor[5]</th><th rowspan="2">Slab[6] on Grade</th></tr>
<tr><th>Verti-cal</th><th>Over-head[11]</th></tr>
<tr><td>I.</td><td>13%</td><td>0.34</td><td>0.50</td><td>0.20</td><td>R-49 or R-38 adv</td><td>R-38</td><td>R-21 int[7]</td><td>R-21 TB</td><td>R-10</td><td>R-30</td><td>R-10 2′</td></tr>
<tr><td>II.*</td><td>25%</td><td>0.32</td><td>0.50</td><td>0.20</td><td>R-49 or R-38 adv</td><td>R-38</td><td>R-21 int[7]</td><td>R-21 TB</td><td>R-10</td><td>R-30</td><td>R-10 2′</td></tr>
<tr><td>III.</td><td>Unlim-ited</td><td>0.30</td><td>0.50</td><td>0.20</td><td>R-49 or R-38 adv</td><td>R-38</td><td>R-21 int[7]</td><td>R-21 TB</td><td>R-10</td><td>R-30 U=0.029</td><td>R-10 2′</td></tr>
</table>

** Reference Case*

0. *Nominal R-values are for wood frame assemblies only or assemblies built in accordance with Section 601.1.*
1. *Minimum requirements for each option listed. For example, if a proposed design has a glazing ratio to the conditioned floor area of 13%, it shall comply with all of the requirements of the 13% glazing option (or higher). Proposed designs which cannot meet the specific requirements of a listed option above may calculate compliance by Chapters 4 or 5 of this Code.*
2. *Requirement applies to all ceilings except single rafter or joist vaulted ceilings complying with note 3. 'Adv' denotes Advanced Framed Ceiling.*
3. *Requirement applicable only to single rafter or joist vaulted ceilings.*
4. *Below grade walls shall be insulated either on the exterior to a minimum level of R-10 continuous, or on the interior as a framed wall. Exterior insulation installed on below grade walls shall be a water resistant material, manufactured for its intended use, and installed according to the manufacturer's specifications. See Section 602.2.*
5. *Floors over crawl spaces or exposed to ambient air conditions.*
6. *Required slab perimeter insulation shall be a water resistant material, manufactured for its intended use, and installed according to manufacturer's specifications. See Section 602.4. For slabs inside a foundation wall, the insulation shall be installed to provide a thermal break (TB) between the slab edge and the foundation. Monolithic slabs shall include insulation, installed outside the foundation wall, and shall extend downward from the top of the slab for a minimum distance of 24 inches or downward and then horizontally for a minimum combined distance of 24 inches. Monolithic slabs shall also include R-10 insulation under the non-load-bearing portions of the slab.*
7. *Int. denotes standard framing 16 inches on center with headers insulated with a minimum of R-10 insulation.*
8. *Reserved.*
9. *Doors, including all fire doors, shall be assigned default U-factors from Table 10-6C.*
10. *Where a maximum glazing area is listed, the total glazing area (combined vertical plus overhead) as a percent of gross conditioned floor area shall be less than or equal to that value. Overhead glazing with U-factor of U=0.35 or less is not included in glazing area limitations.*
11. *Overhead glazing shall have U-factors determined in accordance with NFRC 100 or as specified in Section 502.1.5.*
12. *Log and solid timber walls with a minimum average thickness of 3.5″ are exempt from this insulation requirement.*

WSEC Table 6-2

Prescriptive Requirements[0,1] for Group R Occupancy
Climate Zone 2

Option	Glazing Area[10]: % of Floor	Glazing U-Factor: Vertical	Glazing U-Factor: Overhead[11]	Door[9] U-Factor	Ceiling[2]	Vaulted Ceiling[3]	Wall[12] Above Grade	Wall• int[4] Below Grade	Wall• ext[4] Below Grade	Floor[5]	Slab[6] on Grade
I.	12%	0.32	0.50	0.20	R-49 or R-38 adv	R-38	R-21 int[7]	R-21 TB	R-12	R-30	R-10 2′
II.*	15%	0.32	0.50	0.20	R-49 or R-38 adv	R-38	R-19 + R-5	R-21 TB	R-12	R-30	R-10 2′
III.	Unlimited	0.30	0.50	0.20	R-49 or R-38 adv	R-38	R-19 + R-5	R-21 TB	R-12	R-30	R-10 2′

** Reference Case*

0. *Nominal R-values are for wood frame assemblies only or assemblies built in accordance with Section 601.1.*
1. *Minimum requirements for each option listed. For example, if a proposed design has a glazing ratio to the conditioned floor area of 13%, it shall comply with all of the requirements of the 15% glazing option (or higher). Proposed designs which cannot meet the specific requirements of a listed option above may calculate compliance by Chapters 4 or 5 of this Code.*
2. *Requirement applies to all ceilings except single rafter or joist vaulted ceilings complying with note 3. 'Adv' denotes Advanced Framed Ceiling.*
3. *Requirement applicable only to single rafter or joist vaulted ceilings.*
4. *Below grade walls shall be insulated either on the exterior to a minimum level of R-12 continuous, or on the interior as a framed wall. Exterior insulation installed on below grade walls shall be a water resistant material, manufactured for its intended use, and installed according to the manufacturer's specifications. See Section 602.2.*
5. *Floors over crawl spaces or exposed to ambient air conditions.*
6. *Required slab perimeter insulation shall be a water resistant material, manufactured for its intended use, and installed according to manufacturer's specifications. See Section 602.4. For slabs inside a foundation wall, the insulation shall be installed to provide a thermal break (TB) between the slab edge and the foundation. Monolithic slabs shall include insulation, installed outside the foundation wall, and shall extend downward from the top of the slab for a minimum distance of 24 inches or downward and then horizontally for a minimum combined distance of 24 inches. Monolithic slabs shall also include R-10 insulation under the non-load-bearing portions of the slab.*
7. *Int. denotes standard framing 16 inches on center with headers insulated with a minimum of R-10 insulation.*
8. *Reserved.*
9. *Doors, including all fire doors, shall be assigned default U-factors from Table 10-6C.*
10. *Where a maximum glazing area is listed, the total glazing area (combined vertical plus overhead) as a percent of gross conditioned floor area shall be less than or equal to that value. Overhead glazing with U-factor of U=0.35 or less is not included in glazing area limitations.*
11. *Overhead glazing shall have U-factors determined in accordance with NFRC 100 or as specified in Section 502.1.5.*
12. *Log and solid timber walls with a minimum average thickness of 3.5" are exempt from this insulation requirement.*

Single Rafter Joist

Single Rafter Joist or “vaulted” ceilings are required to be insulated to R-38. If standard R-38 batts are used, a 14-inch I-joist is necessary to allow for the full depth of the insulation and a 1-inch airspace between the top of the insulation and the underside of the roof sheathing. If “high density” R-38 batts are used, a 2 x 12 or 11-7/8-inch I-joist may be used. Check the insulation manufacturer’s specifications regarding insulation depth to insure full depth insulation can be installed while still allowing for a 1-inch (min.) ventilated space.

Remember that this requirement applies to single rafter joist type roof assemblies only. Scissor trusses and sloped ceilings are not considered vaulted ceilings.

Component Performance Approach

[502.1] **Calculations Required**

If none of the prescriptive options are suitable for your house design, you may be able to show compliance using the component performance approach. This process allows trading off the thermal efficiency of one component for another; for example, more attic insulation may allow less wall insulation.

To calculate energy performance, you must determine each building component's area and U-factor (default U-factors for common building practices are listed in Chapter 10 of the WSEC and summarized in Chapter 10 of this Guide). Multiply the U-factor for each component by the component area. That gives a component UA. Add component UAs to find overall UA for the proposed building.

The overall UA must be compared to a target value based on WSEC specifications, found in WSEC Table 5-1. The overall target UA is calculated by multiplying the component areas from the proposed design by prescribed U-factors from the Code. Glazing in the reference calculation is limited to 15 percent of the conditioned floor area. The proposed overall UA must be less than or equal to the target UA to show compliance. In addition, a house using the Component Performance Approach must develop one credit from the list of options in Chapter 9 of the WSEC.

To choose the correct target from WSEC Table 5-1, identify the Climate Zone for the home.

The WSU Extension Energy Program developed spread sheets that simplify the component performance calculations. They are discussed in more detail at the end of this chapter.

WSEC Table 5-1

Target Component Values for Group R Occupancy

Component	Climate Zone	
	1	2
Glazing % Floor Area	15%	15%
Vertical Glazing U-Factor	U = 0.30	U = 0.30
Overhead Glazing U-Factor	U = 0.50	U = 0.50
Doors	U = 0.200	U = 0.200
Ceilings	U = 0.027	U = 0.027
Walls	U = 0.056	U = 0.056
Floors	U = 0.029	U = 0.029
Slab on Grade	F = 0.36	F = 0.36
Below Grade		
Wall R-Value	R-21	R-21
2' Depth: Walls	U = 0.042	U = 0.042
Slab	F = 0.59	F = 0.59
3.5' Depth: Walls	U = 0.041	U = 0.041
Slab	F = 0.64	F = 0.64
7' Depth: Walls	U = 0.037	U = 0.037
Slab	F = 0.57	F = 0.57

Log and solid timber walls that have a minimum average thickness of 3.5" in spaces with space heating by "other fuels" are exempt from wall target UA and proposed UA calculations.

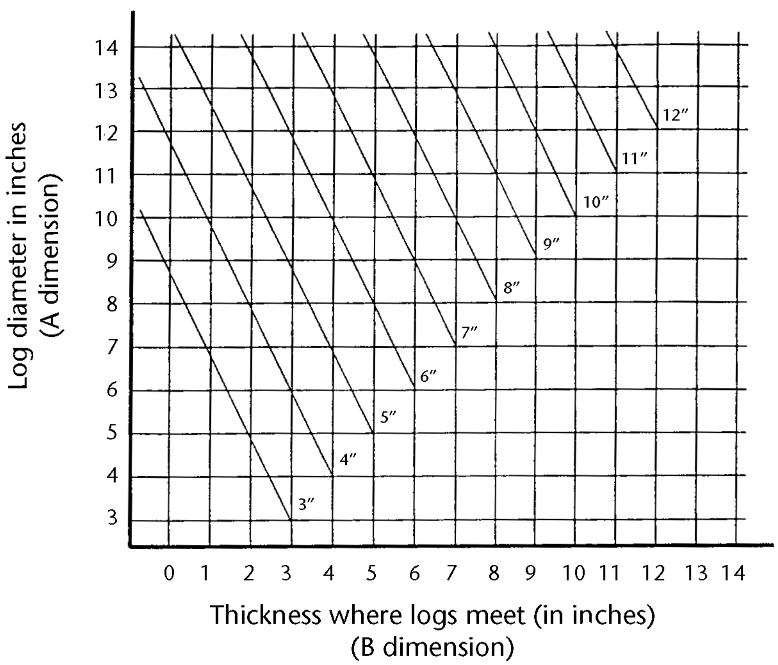
Log Walls

Footnote 12 of Tables 6-1 and 6-2 and Footnote 1 of Table 5-1 provide an exemption for log walls with a minimum average thickness of 3.5". The home must be heated with "other fuels" to qualify for this exception.

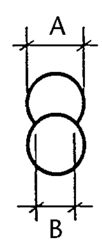
Figure 1-3 provides a method for determining average thickness, based on the log diameter, and the thickness of where two logs meet.

Figure 1-3

Average Thickness For Round Log Walls



Example:
A = 11"
B = 5"



From chart:
Average thickness = 7"

Systems Analysis

Computer Simulation Recommended

[402.1.2] The Systems Analysis Approach requires a calculation of the annual energy use of the proposed design. If the calculation demonstrates that the proposed design uses 8 percent less energy than the Code defined target home, it meets the envelope requirements of the Code. No additional credits from Chapter 9 are required when using systems analysis. The proposed house using 8 percent less energy than the target house accounts for the additional measures required under the Prescriptive and Component Performance Paths.

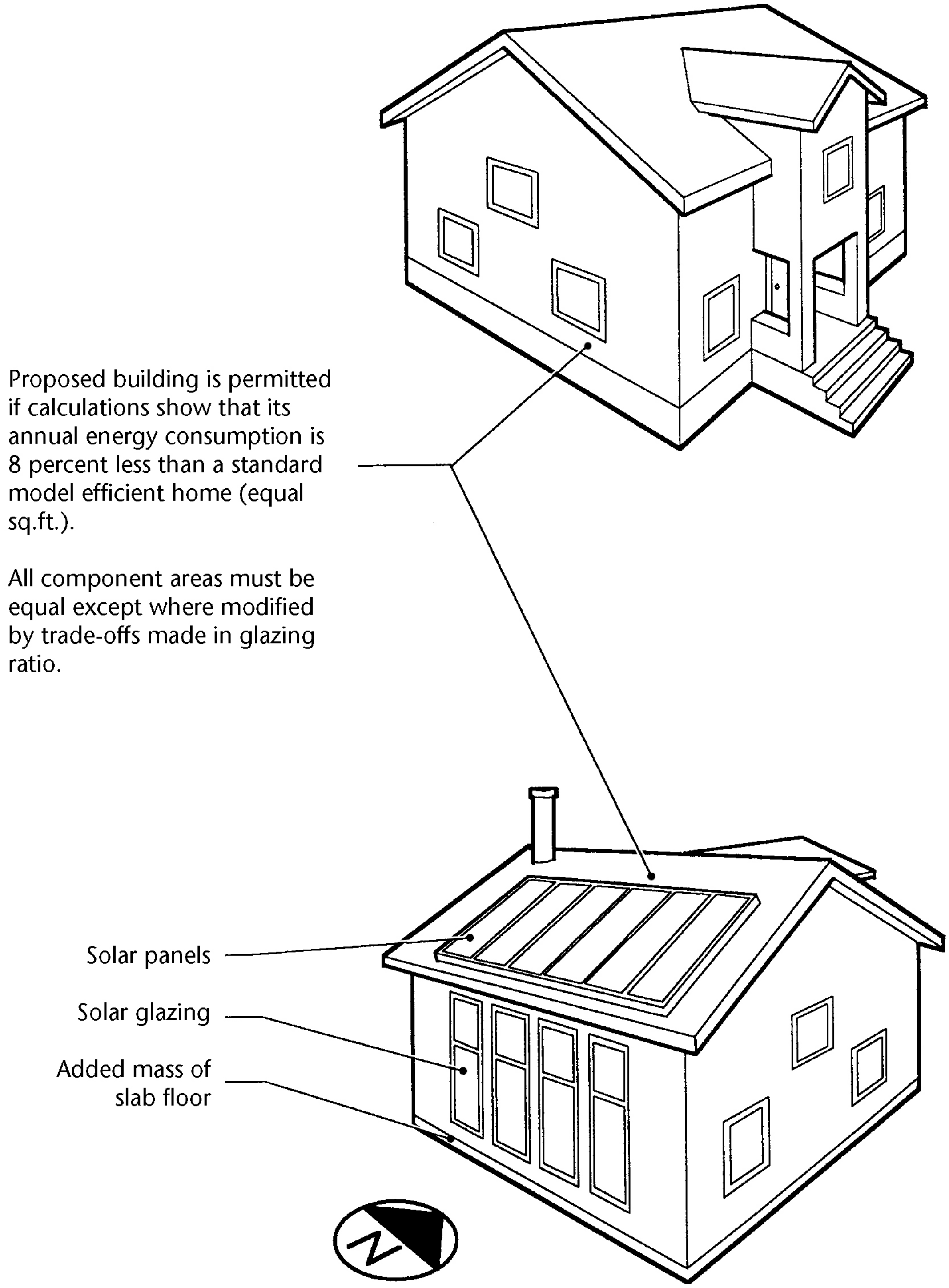
The calculation must be done as described in Chapter 4 of the Code. It must account for local weather data, air infiltration, heating system efficiencies, solar gains, and internal gains including occupancy loads, as well as the building shell insulation. The envelope requirements for the home are based on the component performance target UA. For other systems, refer to WSEC Chapter 4.

When your design includes high efficiency heating equipment, or solar gain and thermal mass, systems analysis may allow trades between other components. The calculation is complex, however, and should be done using a computer program that is capable of documenting all of the building system interactions. This may require the help of a design professional.

WSEC Chapter 8 suggests software that may be used for systems analysis. The WSU Extension Energy Program suggests that users interested in demonstrating compliance using the systems analysis approach use one of the many variations of DOE-2 software. Additional information on documenting code compliance is included at the end of this chapter.

Figure 1-4

Systems Analysis



Additions and Remodeling

[101.3.2.1-8] Additions and remodeling to a home must meet requirements of the WSEC.

Table 1-1

Remodeling Requirements

Replacement of:	Requirement
Combustion Furnace	Minimum AFUE 78 percent.
Heat Pump	Minimum HSPF 7.7
Water Heater	Meet 1987 National Appliance Energy Conservation Act (NAECA). Set to 120° F.
Electric Water Heaters	R-10 insulated pad in unconditioned space or on uninsulated slabs.
Window Replacement	Required U-factor – *Varies*
Insulation Walls & Ceilings	Exposed cavities must be filled to the requirements of Table 6-1 or 6-2, or have an average UA that complies with the requirements of Table 5-1. Where structural elements limit the level of insulation that can be applied to less than the code requirements, the cavities must be filled to code requirements in 101.3.2.5. Roof decks must be insulated to the requirement of the code if a complete roof tear-off is part of the work.

[101.3.2.2] There are a few exceptions (historical buildings and other special cases) when the WSEC may not be fully enforced. Check with your local jurisdiction.

Table 1-2

Additions Requirements

Size	Code Compliance for Additions
Under 750 sq.ft.	Addition can comply with the WSEC either by prescriptive approach, or by using tradeoffs with existing building for WSEC compliance.*
Over 750 sq.ft.	Addition must show full WSEC compliance as a stand alone project.

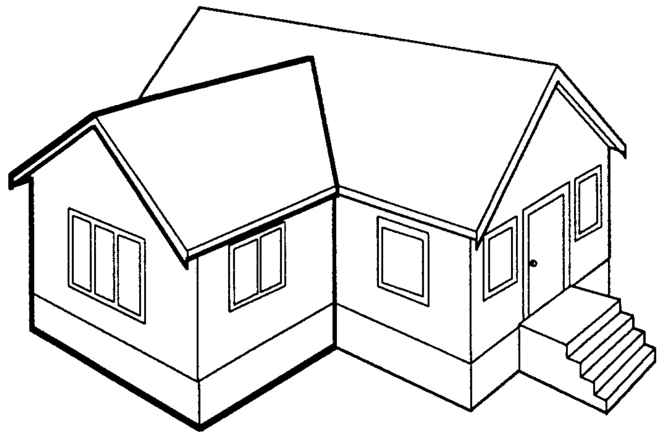
**See component performance approach.*

The need to perform complicated tradeoffs for additions was reduced considerably with the introduction of unlimited glazing options in the prescriptive approach. Consider the prescriptive approach first.

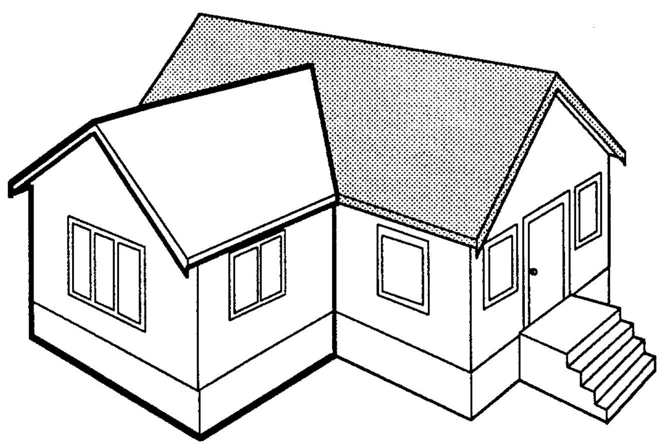
Figure 1-5

Energy Code Requirements for Additions

If an addition complies with the Code, no change is required in the existing buuilding.



A non-complying addition < 750 sq. ft. is permitted if improvements made to existing building (increase ceiling insulation) to compensate for a non-complying addition.



Documenting Code Compliance

To obtain a building permit you will be required to provide the local building department with a description of the Code compliance approach that will be used. This will include details on the plans and documentation required to demonstrate compliance with the code requirements. This will typically include energy code compliance forms, and a description of the chosen ventilation systems.

Plans and Specifications

The Code requires that sufficient detail be included on the plan set to assure that the energy code requirements are implemented during construction. This *Builder's Field Guide* book includes many examples of insulation and air sealing details. A similar level of detail should be included as part of the plan set. A few examples of areas needing good details follow.

Framing:

- Show framing with sufficient depth to accommodate the required insulation.
- Detail header insulation when insulated headers are required.

Roof Ventilation:

- Show minimum 1-inch air space in single rafter joist systems. Provide details for ventilation openings on the top and bottom on all roof sections.

  If an unvented attic is being proposed, the plans need to show how the requirements allowing unvented attic spaces are being met. When constructing an unvented attic space, careful attention to the details of the WSEC is necessary to minimize any potential moisture problems.

Slab Insulation:

- Detail insulation integration with the foundation and floor system. Show insulation protection when installed on the exterior. Show the thermal break on the vertical edge of below grade heated slabs.

Vapor Retarder:

- Indicate the type and location of vapor retarders.

Air Sealing:

- Detail difficult areas, including attic knee walls, cantilevered floor systems, mechanical and plumbing chases, etc.

Ducts:

- Provide framing details with specific space for major duct runs.

The Prescriptive Approach

The prescriptive approach for the *Washington State Energy Code* is the simplest method of code compliance. The WSU Extension Energy Program has created an Excel® spreadsheet to help provide documentation of the prescriptive building envelope requirement sections of the code. This worksheet also helps provide documentation required to meet the heating system sizing requirements of IRC section M1401.3. To select the correct worksheet, you will need know the climate zone. The worksheet is available from the WSUEEP website at ***www.energy.wsu.edu/code***

Component Performance Approach

The WSU Extension Energy Program developed a package of Excel® worksheets designed to document the qualification of building designs by the Component Performance (CP) approach described in Chapter 5 of the WSEC.

There is one Excel® workbook for both climate zones. The workbook contains both the CP worksheet and the *CP Library* which contains all of the component descriptions in Chapter 10 of the WSEC. This workbook can be downloaded from the WSU Extension Energy Program website at ***www.energy.wsu.edu/code***

Systems Analysis Approach

The WSU Extension Energy Program no longer provides software that supports a systems analysis approach. Select a DOE-2 based software package for this type of analysis. Use the WSU Extension Energy Program Component Performance worksheet to develop a target and proposed building envelope as required by the Code, then load this information into a DOE-2 product and perform the systems analysis.

Chapter 2: Foundations

Crawlspace

[V502.1.2] **Vents.** Vents in the crawlspace help keep floor insulation and floor framing dry. Crawlspace vents also reduce the potential for radon buildup under the floor.

Ventilation required is equivalent to the Washington State amendments to the *International Residential Code* (IRC) requirement (1 sq.ft. of net free vent area for each 300 sq.ft. of crawlspace area, or 1/300 sq.ft.).

Vents must be placed below floor insulation (see Figure 2-1) or they must be properly baffled (see Figure 2-2).

Insulation. If you choose a prescriptive compliance path, the *Washington State Energy Code* (WSEC) requires that the floor over the crawlspace be insulated to the required value determined by using WSEC Tables 6-1 or 6-2.

Figure 2-1

Foundation Vent

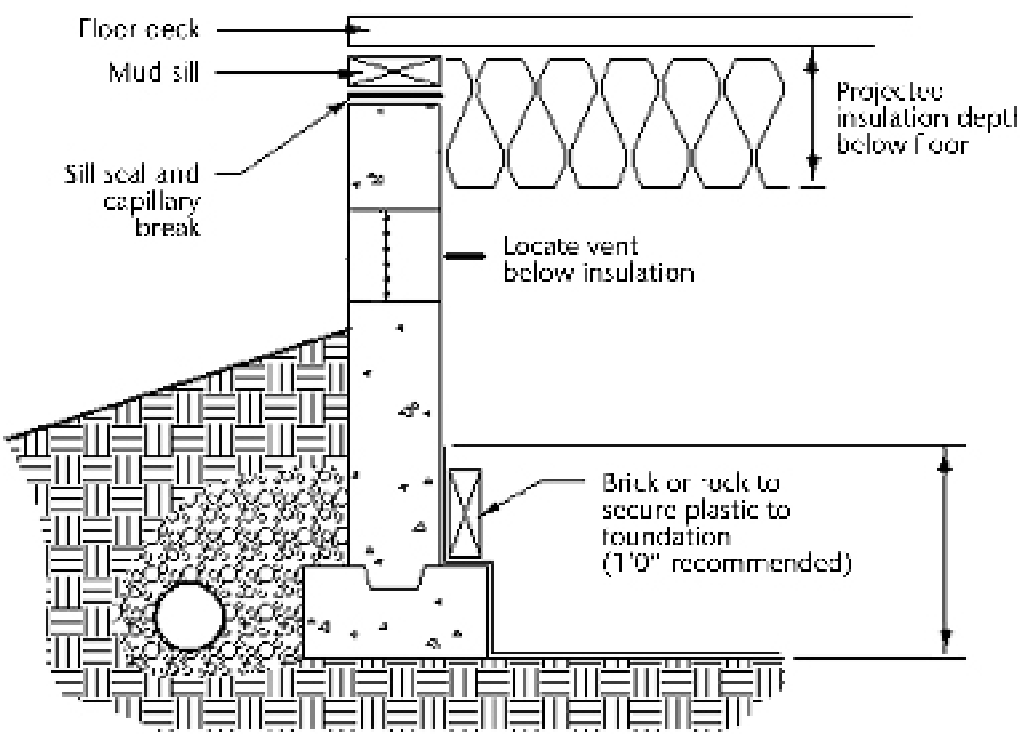
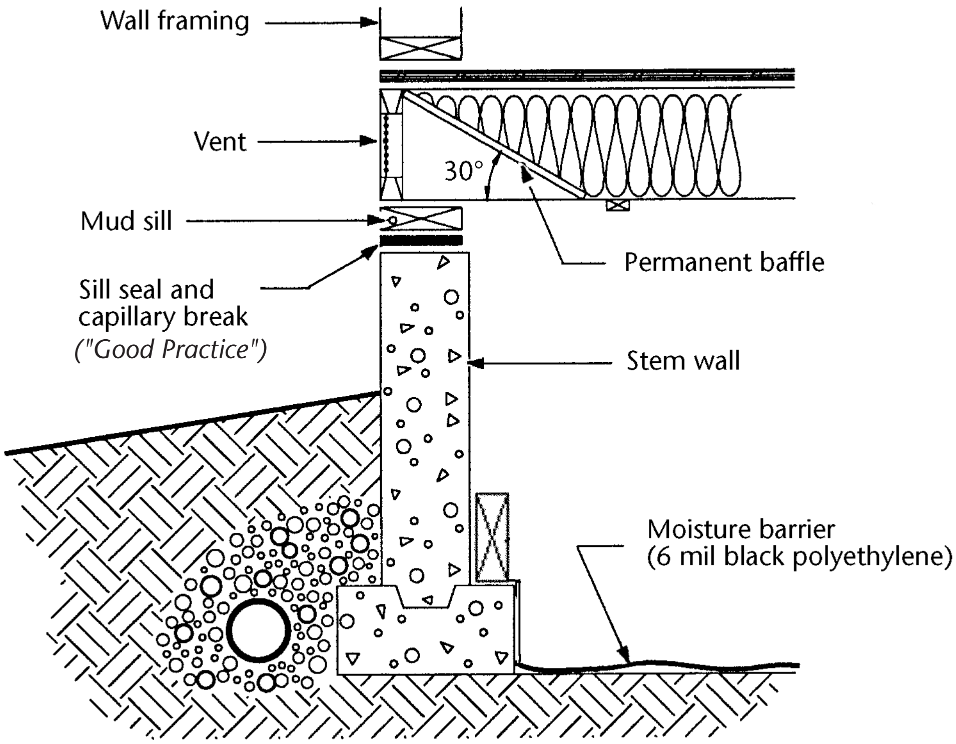


Figure 2-2

Baffled Foundation Vent



[502.1.4.8] **Thermal Break.** Where a crawlspace stem wall abuts a slab-on-grade within a conditioned space, insulation must be used to create a thermal break (see Figure 2-3 for possible detail.)

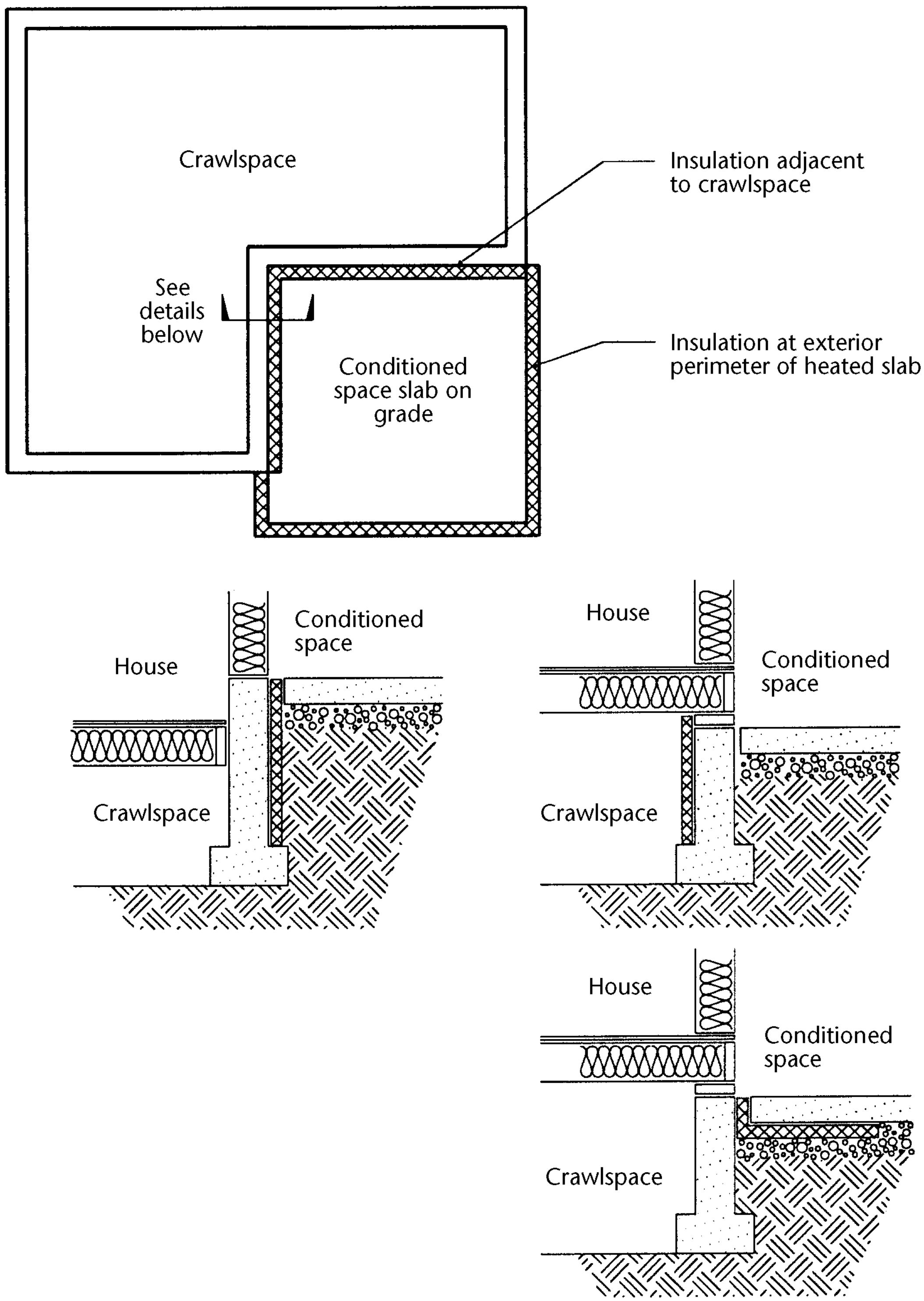
[502.1.6.7] **Ground Cover.** Six-mil black polyethylene (or approved equal) must be laid over the ground within all crawlspaces.

The ground cover:

- Must extend to the foundation wall.
- Seams must be lapped 12 inches (see Figures 2-1 and 4-6).
- May be omitted if a minimum 3-1/2-inch concrete slab is poured in the crawlspace.

Figure 2-3

Thermal Breaks



Slab-On-Grade

[201.1] Defined by the Code as any slab with its top surface less than 24 inches below the final exterior grade (see Figures 2-4, 2-5, and 2-7). In such cases, you must:

- Maintain a thermal break at the edge of a slab. Slabs must not run continuously from heated to unheated areas (See Figures 2-8 and 2-9).
- [502.1.4.8] Extend R-10 insulation for a total of 24 inches either vertically or a combination of vertically and horizontally around the entire on-grade perimeter.
- Install water-resistant insulation material manufactured for this purpose.
- Install a cover flashing or parging to protect the insulation from moisture and physical damage above grade.

[502.1.4.9] **Radiant Slabs.** If a radiant heating system is to be installed in a slab, a minimum of R-10 insulation (all zones) is required under the slab. The entire area of radiant slab in contact with the ground must be thermally isolated (see Figure 2-6).

Notes:
Ducts. Any heating system ductwork in or under a slab must be insulated to R-5 with insulation manufactured for this use.

Pipes. Any hot water pipes buried under a slab must be insulated to the value noted in Table 5-12. (R-3.6 for <= 2" pipe, R-5.4 for > 2")

Combustion Air. Installation of a wood stove or other solid fuel combustion appliance in a basement must provide combustion air to the appliance.

Figure 2-4

Slab Construction Perimeter Insulation

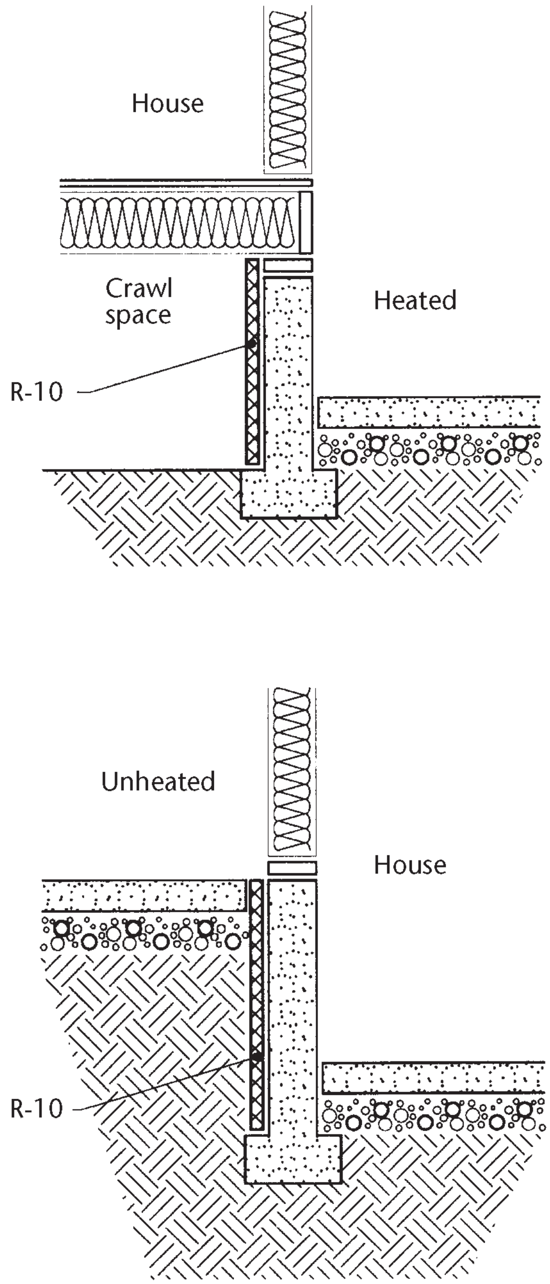


Figure 2-5

Slab-on-Grade

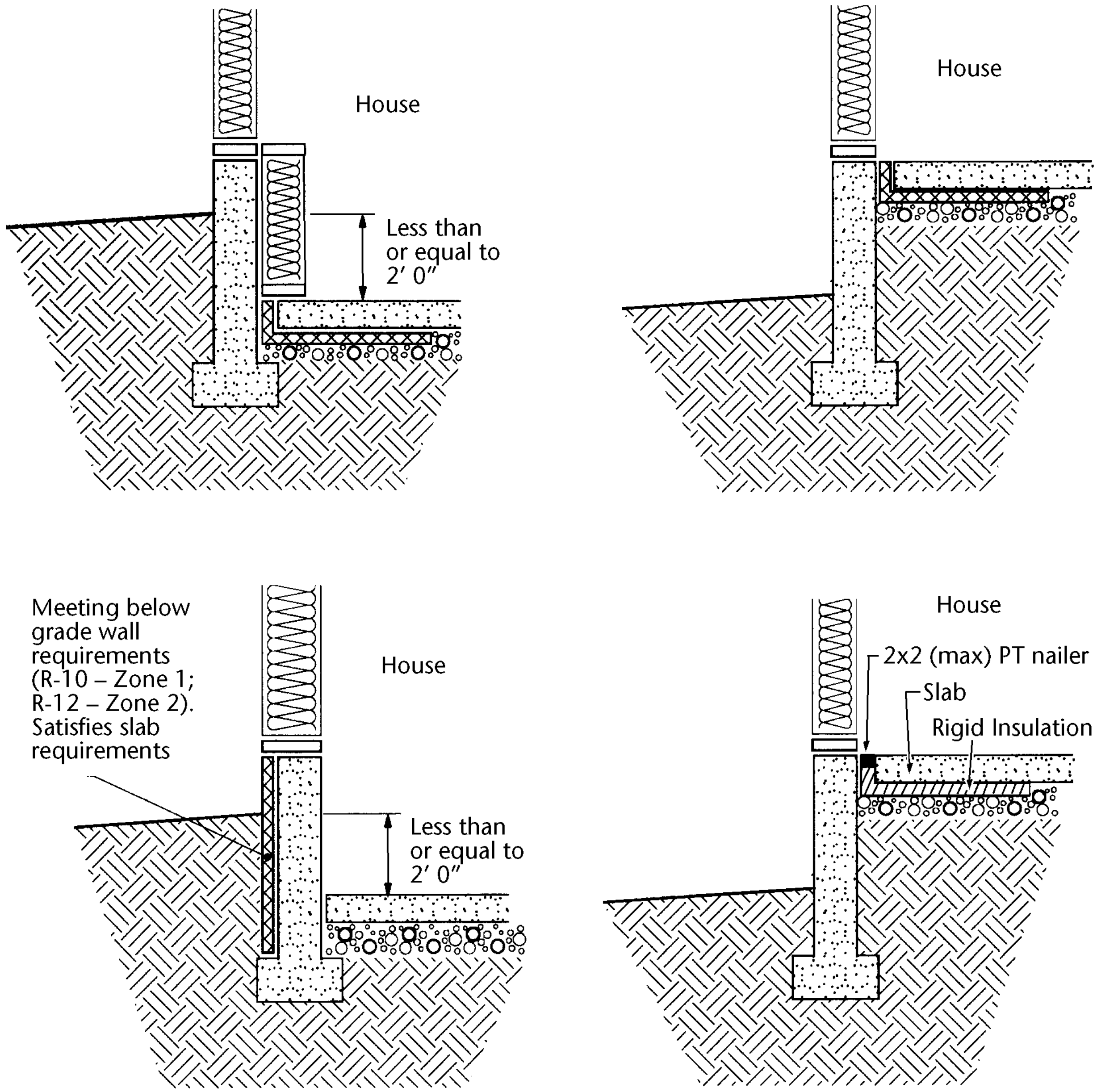


Figure 2-6

Monolithic Slab-on-Grade

Typical Slab with No Radon Source Control

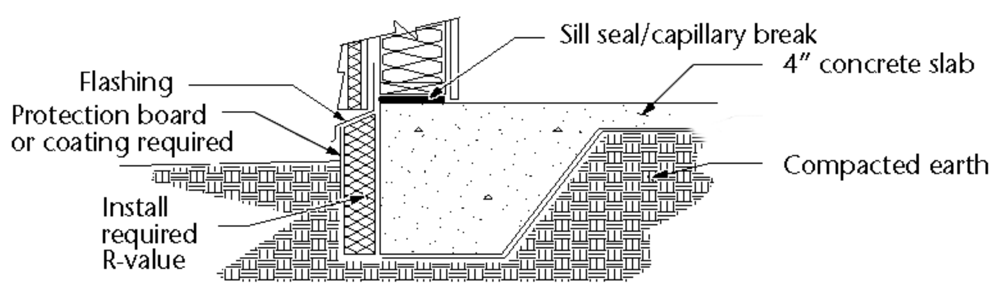


Figure 2-7A

Interior Insulation

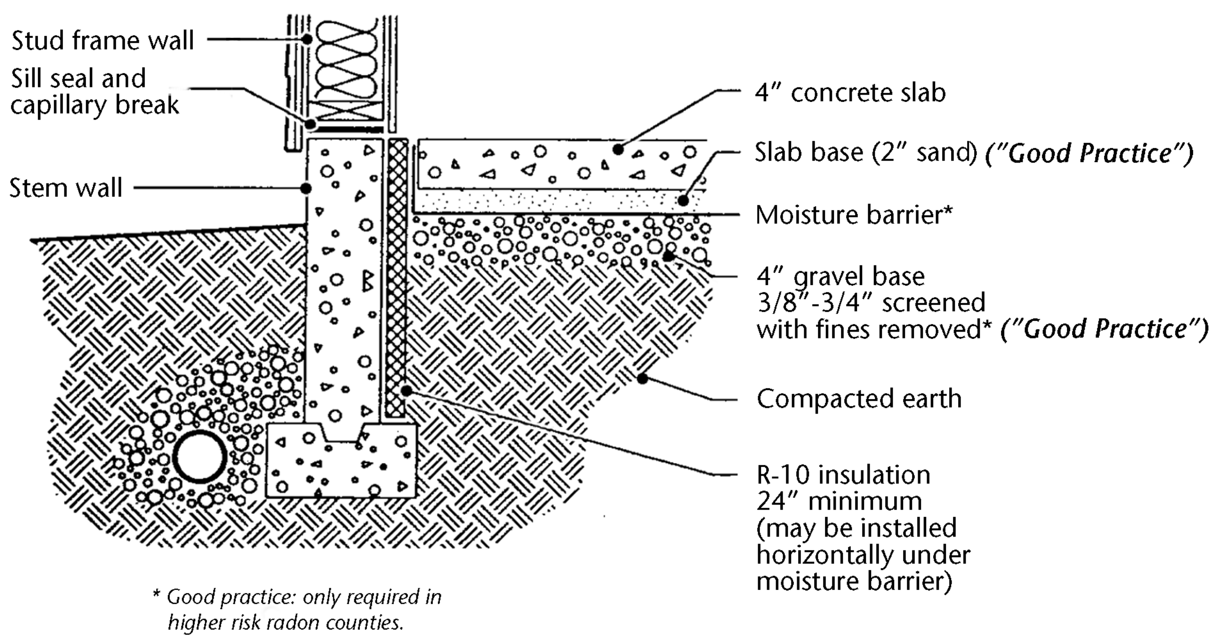
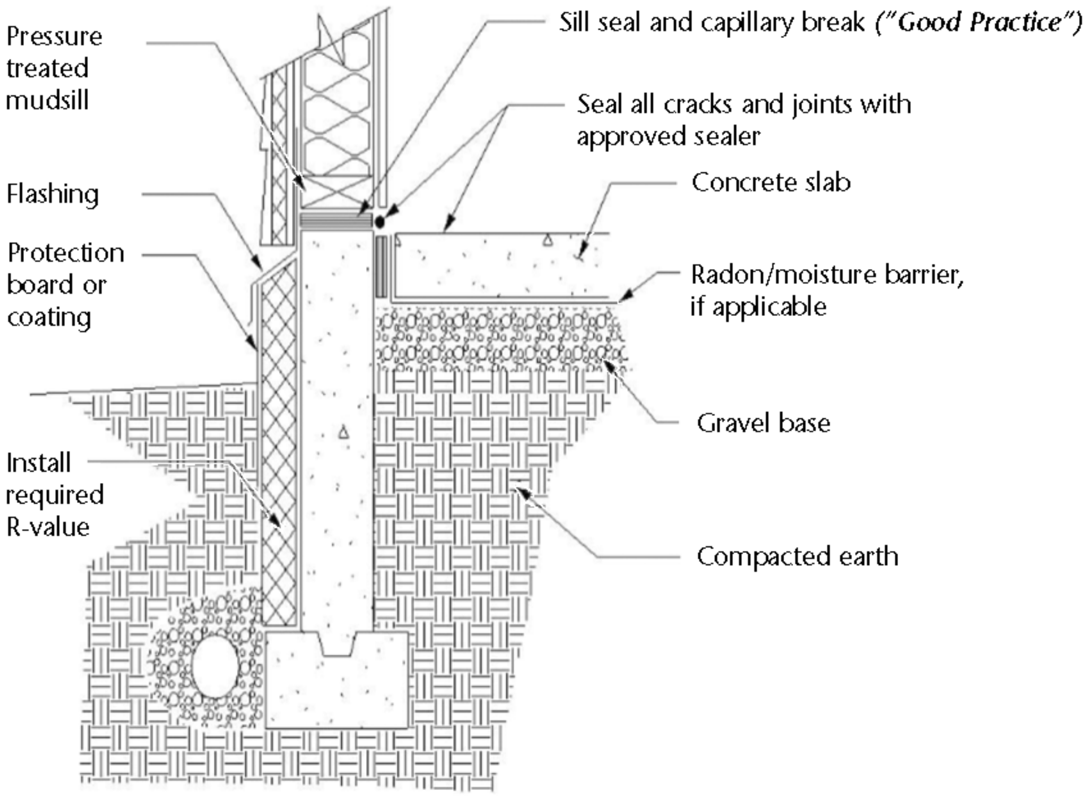


Figure 2-7B

Exterior Insulation



Note: *See Appendix F of the International Residential Code for membrane requirements in radon counties.*

Figure 2-8

Possible Slab Insulation Details

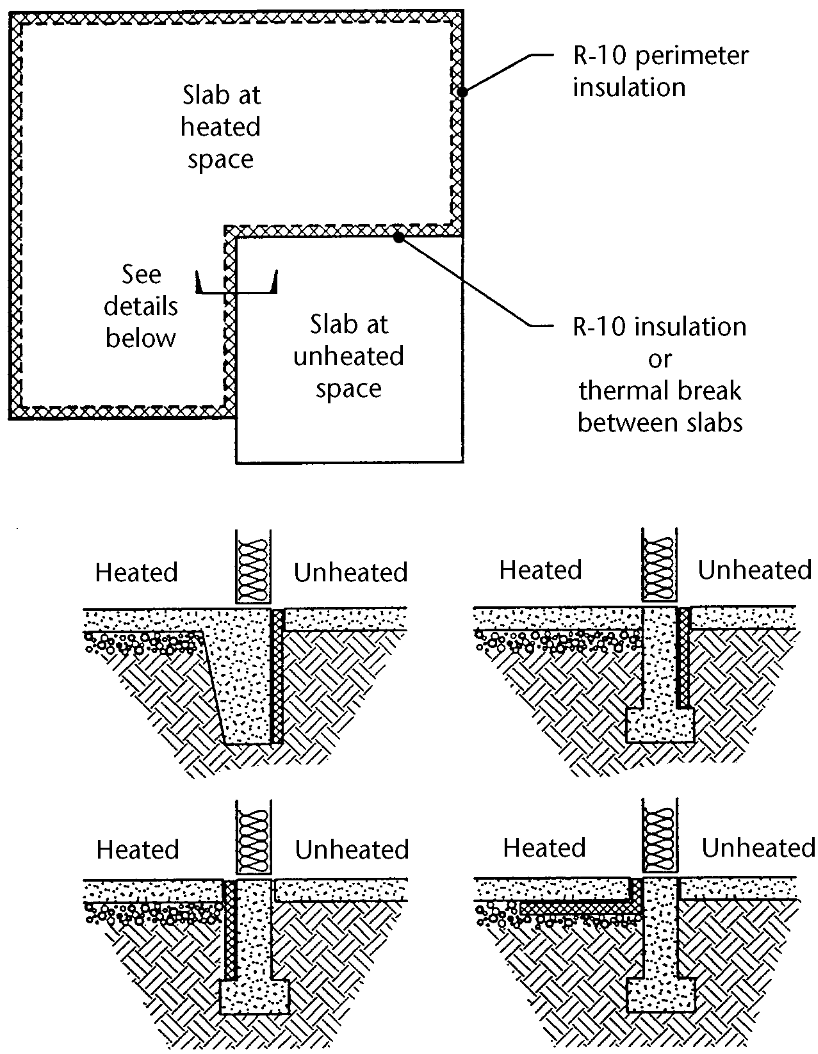
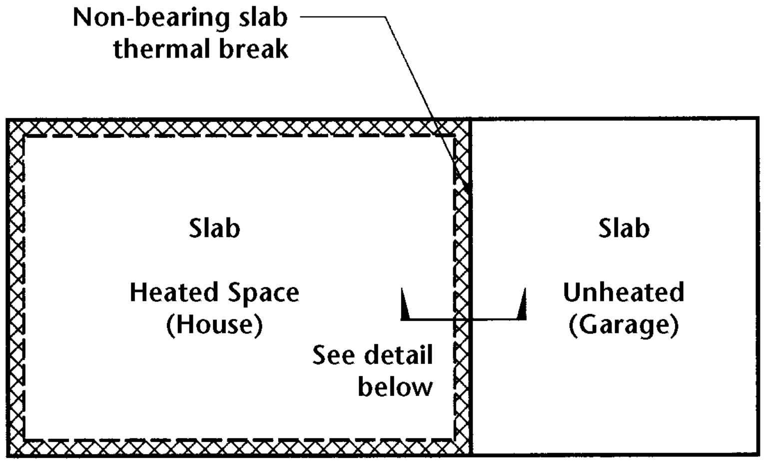
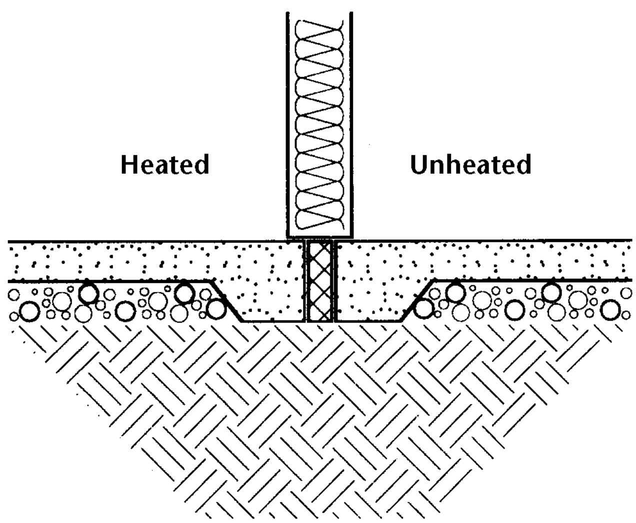


Figure 2-9

Non-Bearing Slab Thermal Break





Basements

Any basement with a heat source must have insulated walls. For a basement to be considered unheated and not require wall insulation, there must be no heat supplied. An unheated basement must be thermally isolated from adjoining conditioned spaces. This would include:

- Ceiling insulation (i.e. the floor above).
- Insulated stairwell walls.
- A weatherstripped access door.
- Insulated and sealed ducts and pipes.

[502.1.4.10] **Below-Grade Walls.** For the purposes of the Code, wall sections that extend 24 inches or less above grade may be considered below-grade walls.

Insulation:

- May be placed on either the interior or the exterior of the wall.
- The minimum required R-value is determined by the compliance path chosen.

Exterior insulation must:

- Be approved for below-grade installation.
- Extend from the top of the below-grade wall to the top of the footing.
- Be protected where it extends above grade (see Figure 2-10).

Interior insulation must:

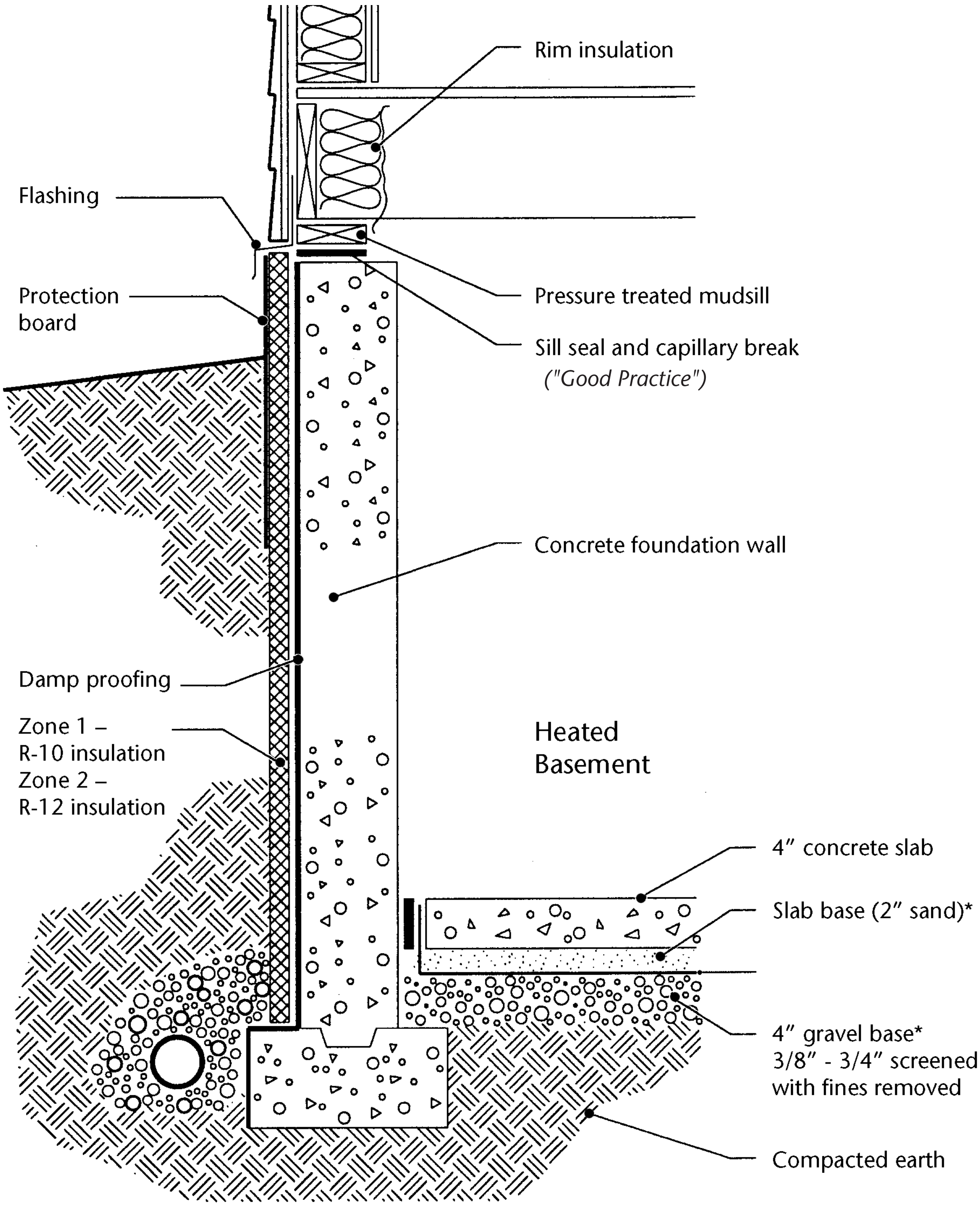
- Extend from the top of the below-grade wall to the top of the below-grade floor (see Figure 2-11).

Daylight Basement. Pay attention to corner details when insulating a daylight basement (see Figures 2-12 and 2-13 for examples). Anywhere the slab in a daylight basement is within 24 inches of the finish grade, perimeter slab insulation is required.

> **Note:**
> Ducts and pipes in the slab and combustion air requirements are the same for heated basements as they are for slab-on-grade. Unheated basements require R-8 duct insulation. Any hot water pipes buried under a slab must be insulated to the value noted in Table 5-12. (R-3.6 for > 2" pipe, R-5.4 for >/= 2", see ***Notes*** on page 2-4).

Figure 2-10

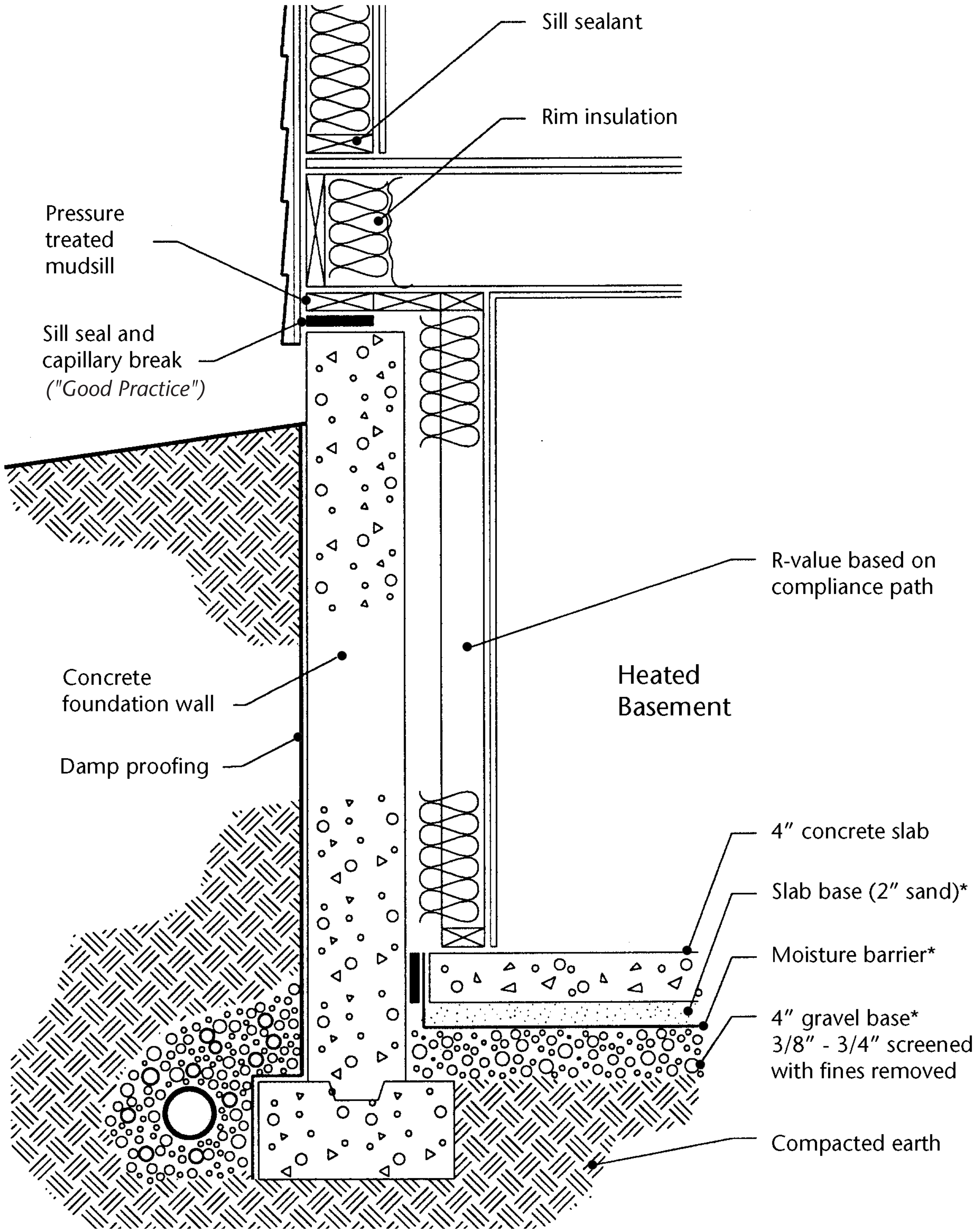
Heated Basement: Exterior Insulation



** Good practice: required only in higher risk radon counties.*

Figure 2-11

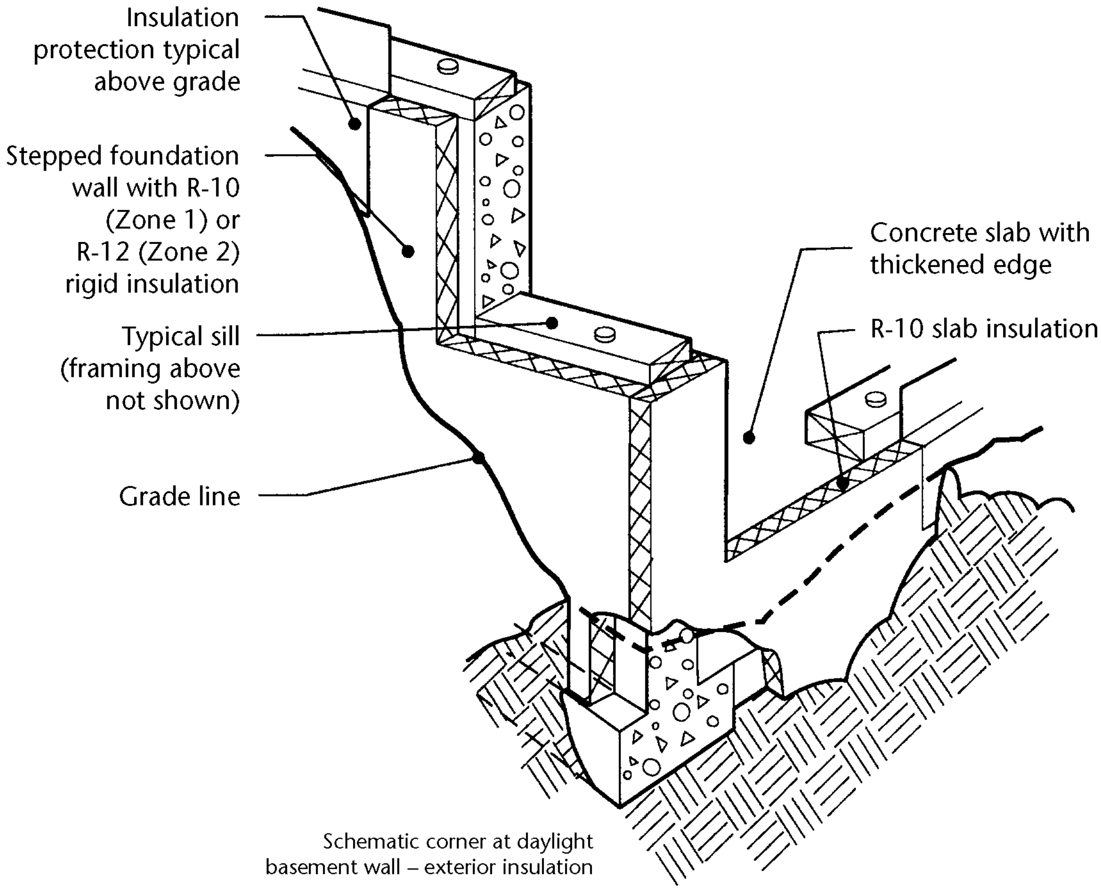
Heated Basement: Interior Insulation



** Good practice: required only in higher risk radon counties*

Figure 2-12

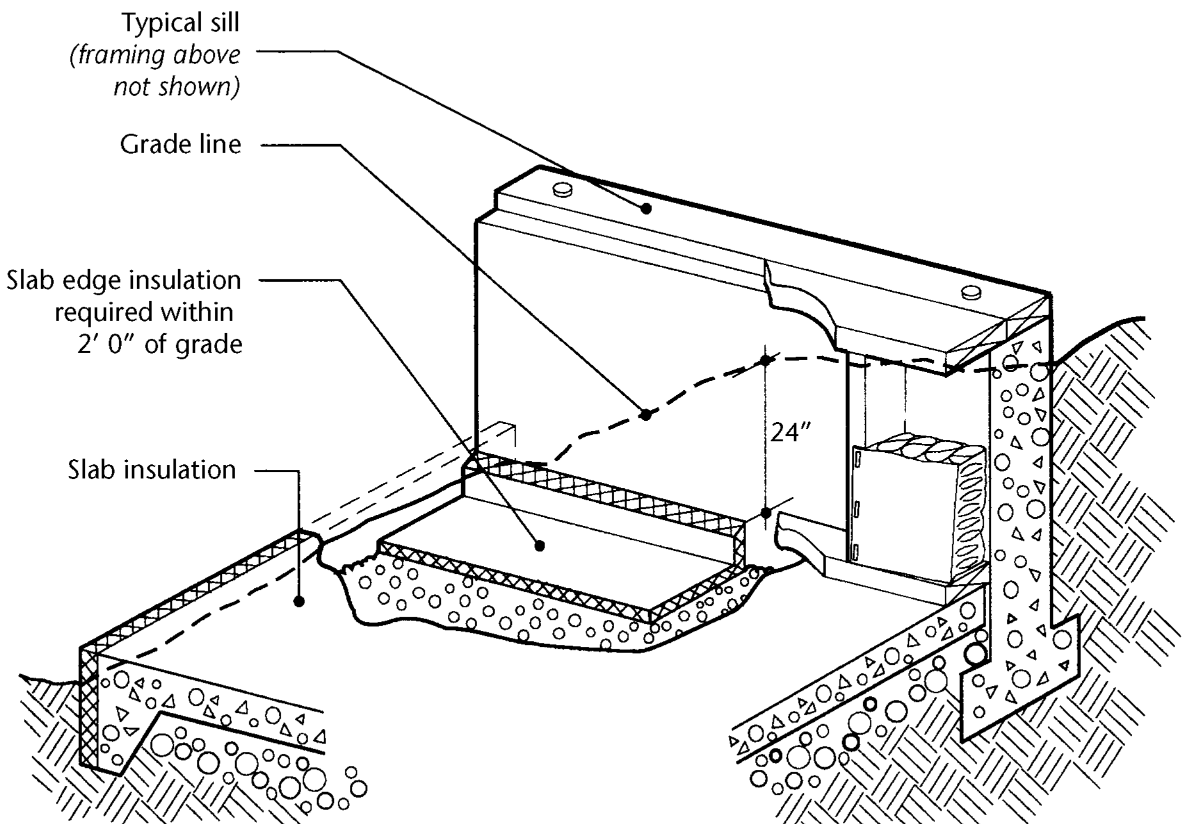
Heated Daylight Basement: Exterior Insulation



Schematic corner at daylight basement wall – exterior insulation

Figure 2-13

Heated Daylight Basement: Interior Insulation



Schematic corner at daylight
basement wall – interior insulation

Chapter 3: Framing

Framing Methods

The *Washington State Energy Code* (WSEC) recognizes three types of wall framing methods: Standard, Intermediate and Advanced.

Standard Framing is defined as studs framed on 16-inch centers with double top plate and single bottom plate. Corners use three studs and each opening is framed using two studs. Headers consist of double 2x or single 4x material with an air space left between the header and the exterior sheathing. Interior partition wall/exterior wall intersections use two studs in the exterior wall.

Intermediate Framing is defined as studs framed on 16-inch centers with double top plate and single bottom plate. Corners use two studs or other means of fully insulating corners and each opening is framed by two studs. Headers consist of double 2x material with R-10 insulation between the header and exterior sheathing. Interior partition wall/exterior wall intersections are fully insulated in the exterior wall. Although the WSEC defines "Intermediate Framing" as having the headers insulated between the header and the sheathing, a "sandwich" header may be a preferred option. A sandwich header provides a nailing surface on both the inside and the outside for attaching siding, sheetrock and trim (see Figure 3-14). Interior partition wall/exterior wall intersections are fully insulated in the exterior wall.

Advanced Framing is defined as studs framed on 24-inch centers with double top plate and single bottom plate. Corners use two studs or other means of fully insulating corners and one stud is used to support each header. Headers consist of double 2x material with R-10 insulation between the header and exterior sheathing. Sandwich headers are common using advanced framing techniques.

Intermediate Framing Materials. Most prescriptive options require intermediate wall framing. Credit for the added thermal efficiency gained by advanced framing is also allowed if a project follows the component performance or systems analysis approach. To meet the requirements of intermediate wall framing, installation of foam insulation for headers is required (see Figure 3-14).

Advanced Framing Materials. If you're planning to do advanced wall framing, be sure to order sheathing, siding, and wallboard rated for a 24-inch on-center framing.

The WSEC does not require advanced framing for walls, but will credit the added thermal efficiency gained by advanced framing if your project follows a component performance or systems analysis approach (see pages 1-7 and 1-11).

Advanced Framed Ceilings. The WSEC requires "advanced" roof/ceiling framing for some prescriptive paths and will credit the added thermal efficiency gained by advanced framing if your project follows the component performance or systems analysis approach. Advanced framing is defined as having full and even depth insulation extending to the outside edge of exterior walls. This may be accomplished by using a raised heel truss, using an oversized truss or using a high R-value foam product at the wall line (see figure 3-15).

Windows. Before you order or install windows, make sure the windows meet Code requirements (see Chapter 1).

Heat loss through windows, per square foot, is very high compared to most other building envelope components. Decisions about window type, glazing area, and orientation can be the most important energy performance choices you make for the home.

U-Factors are a measure of window energy performance. The lower the U-factor, the lower the rate of heat transfer, and the better the energy performance of the window. The total window area and the area weighted U-factor (see page 1-4) for all windows must meet the compliance path chosen. Always check with your building jurisdiction before adding additional windows or changing window type. Unapproved changes may result in unnecessary construction delays while compliance is reverified.

All windows and skylights should be tested to establish U-factors. Only National Fenestration Rating Council (NFRC) Standard 100-2004 test results from a certified laboratory will be acceptable. NFRC Residential Model Size must be used. If a test result is not available, you must use the appropriate default U-factor listed in the Code for Compliance (see WSEC Table 10-6A and Table 10-6B).

Solar heat gain coefficient (SHGC) will also be needed if a Systems Analysis Approach is being utilized.

For more information on NFRC labeling, visit the Efficient Windows Collaborative web site:
www.efficientwindows.org/nfrc.html

Note: The Code considers a sliding glass door a window.

Some windows may require special jamb extensions because of added wall thickness needed to accommodate required insulation levels.

Exterior Doors. The following doors must meet the chosen compliance path required U-factor for exterior doors:

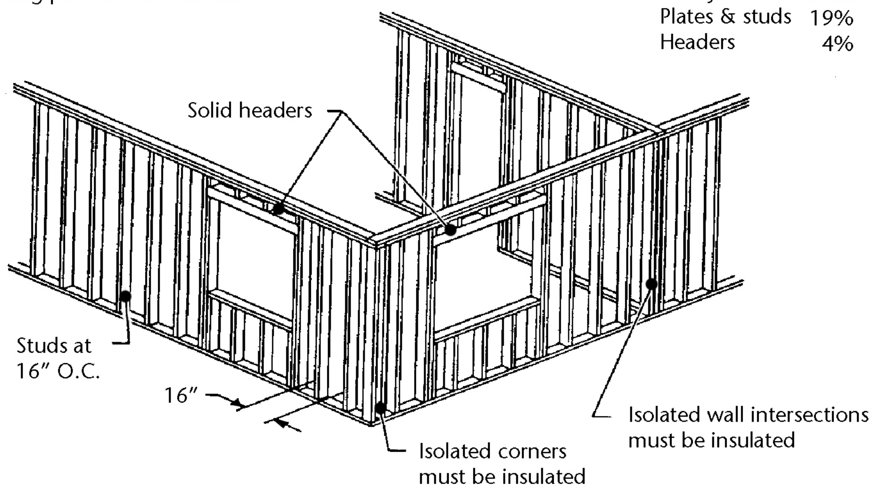
- Entry doors.
- Garage passage doors.
- Interior doors to unheated basements.
- Doors joining any heated space with an unheated space.
- [502.1.5.2, Exception 3] One swinging door of not more than 24 square feet may be exempted from the door U-factor requirement.

Figure 3-1

Standard, Intermediate, and Advanced Framing

Standard Framing
Framing placed at 16″ on center

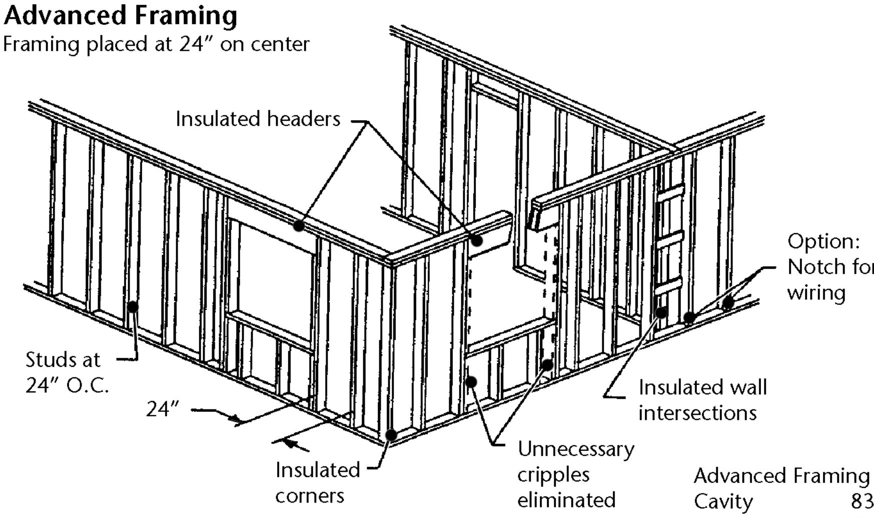
Standard Framing
Cavity 77%
Plates & studs 19%
Headers 4%



Intermediate Framing
Framing placed at 16″ on center
Insulated headers, corners and intersections

Intermediate Framing
Cavity 78%
Plates & Studs 18%
Headers 4%

Advanced Framing
Framing placed at 24″ on center



Advanced Framing
Cavity 83%
Plates & Studs 13%
Headers 4%

Note: Approximately 25% less wood in advanced frame walls.

If a tested value for the door assembly you plan to use is not available, then use the default values in WSEC Table 10-6C.

Note: The area of glazing that is part of any swinging door is included in the total glazing area of the house as determined for prescriptive compliance. The U-factor of this door glazing, however, is counted as part of the doors overall U-factor (see WSEC Table 10-6C).

Skylights. Skylights are included in the total glazing percentage for the home. Skylights must meet U-factor requirements specific to overhead glazing. Default U-factors for overhead glazing are listed in WSEC Table 10-6E.

Energy-Efficient Floor Framing

Framed floors over unconditioned space must be able to accommodate the levels of insulation required (see Chapter 4 for insulation details).

[502.4.3] **Sealing Air Leaks.** The WSEC requires that all openings, joints, and penetrations in the thermal envelope of the building must be sealed, caulked, gasketed or weatherstripped to limit air leakage.

The first floor rim joist area over a basement and the rim joist area between floors may require special attention during framing (see Figures 3-2, 3-3 and Chapter 5, Air Leakage and Moisture Control).

[502.1.6.2] **Vapor Retarders.** Floors over unconditioned space must include a vapor retarder. Manufactured flooring materials (plywood, etc.) with exterior grade glues meet this requirement. Flooring systems such as 2x6 decking that do not include plywood or similar materials must use kraft paper, poly sheathing or some other rated material as a vapor retarder (see Figure 3-4).

Figure 3-2
Basement Rim Air Barrier

[502.4.3]

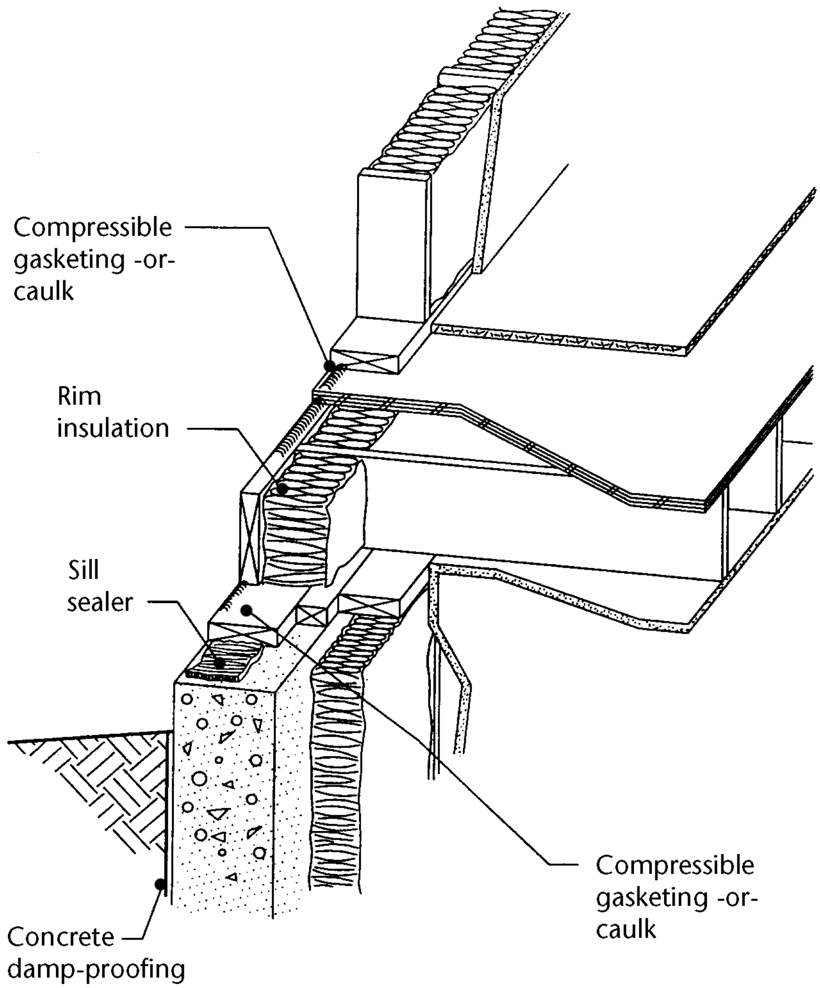


Figure 3-3

Standard Rim Air Barrier

[502.4.3]

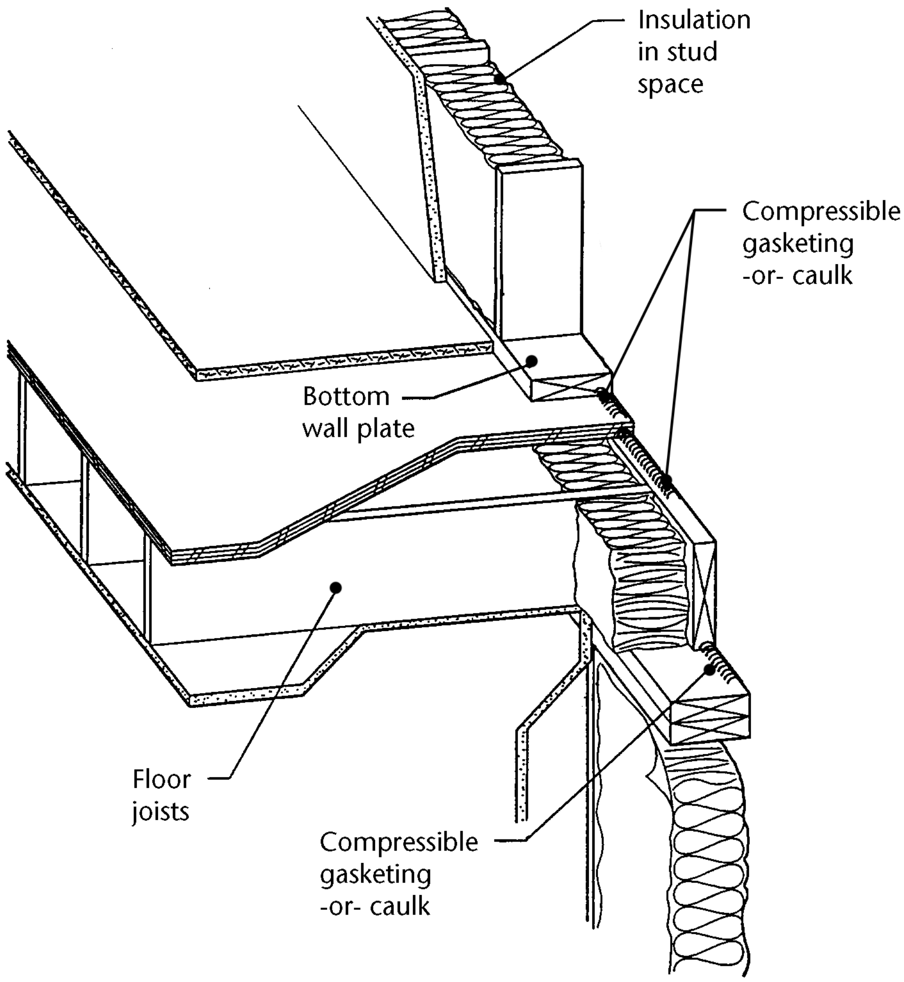
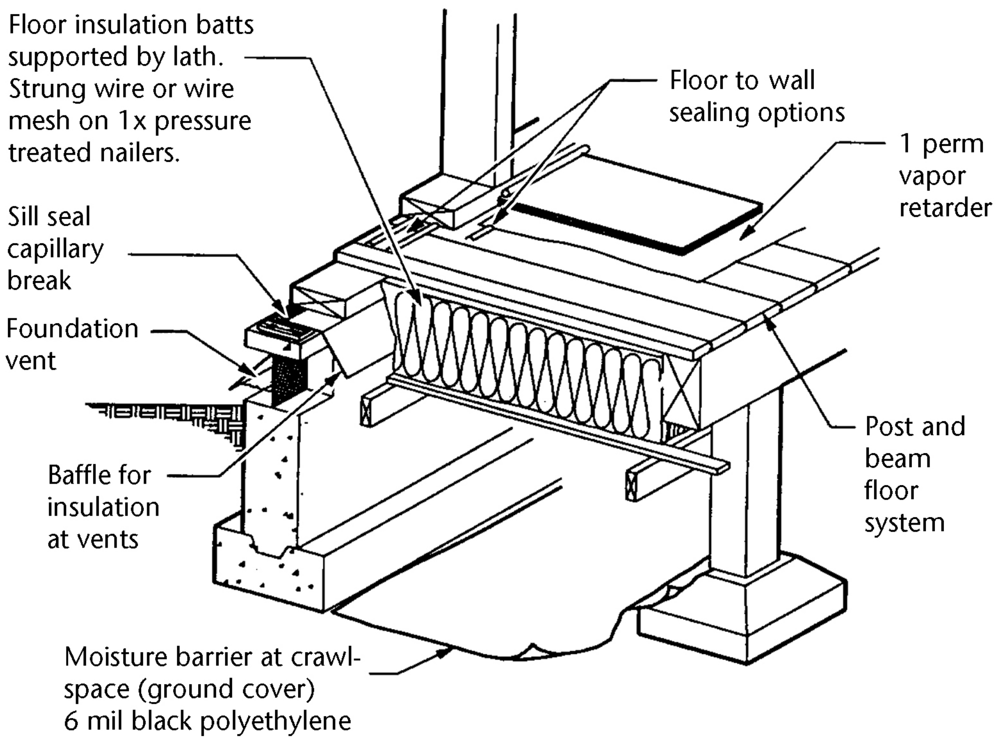


Figure 3-4

Post and Beam Air Sealing



Energy-Efficient Wall Framing

You may use any wall detail that has an insulation nominal R-value equal to or exceeding your chosen compliance path (see Figure 3-5 and Chapter 1).

[602.2] **Wall Details.** The Prescriptive Approach identifies four alternatives as equivalent to the nominal R-21 wall (see Figures 3-5 and 3-6). In addition, the Component Performance and Systems Analysis Approaches credit the use of higher R-value walls (see Figure 3-7). The use of double framed walls or stressed-skin panels are among other options that may work (see Figure 3-8).

Insulated Sheathing. Insulated sheathing may be used to increase the R-value of a wall. Insulated sheathing can be used to meet the requirements in Prescriptive Paths II and III in Table 6-2. If the insulated sheathing is used in place of structural sheathing, additional wall bracing will be required. Consult the *International Residential Code* (IRC) for bracing requirements in your area.

Rigid foam insulation may be applied to either the interior or exterior surface of the exterior wall (see Figures 3-9, 3-10 and 3-11). Applying foam to the exterior is the preferred option.

Additional references, prepared by the APA Engineered Wood Association, may also be useful. Check the various resources available on the APA website: ***www.apawood.org***

Insulation. The Code requires all cavities in the thermal envelope of the building be filled with insulation. Corners and wall intersection can easily be filled during the normal placement of wall insulation using certain details (see Figures 3-12 and 3-13).

Headers. Headers must always be properly sized to meet loading conditions. All Prescriptive Path Options in Climate Zone 1 and Prescriptive Path Option 1 in Climate Zone 2 require Intermediate framed walls. Intermediate wall framing requires R-10 insulated headers unless structural requirements specify a 6x header.

Figure 3-5

Acceptable R-21 Walls

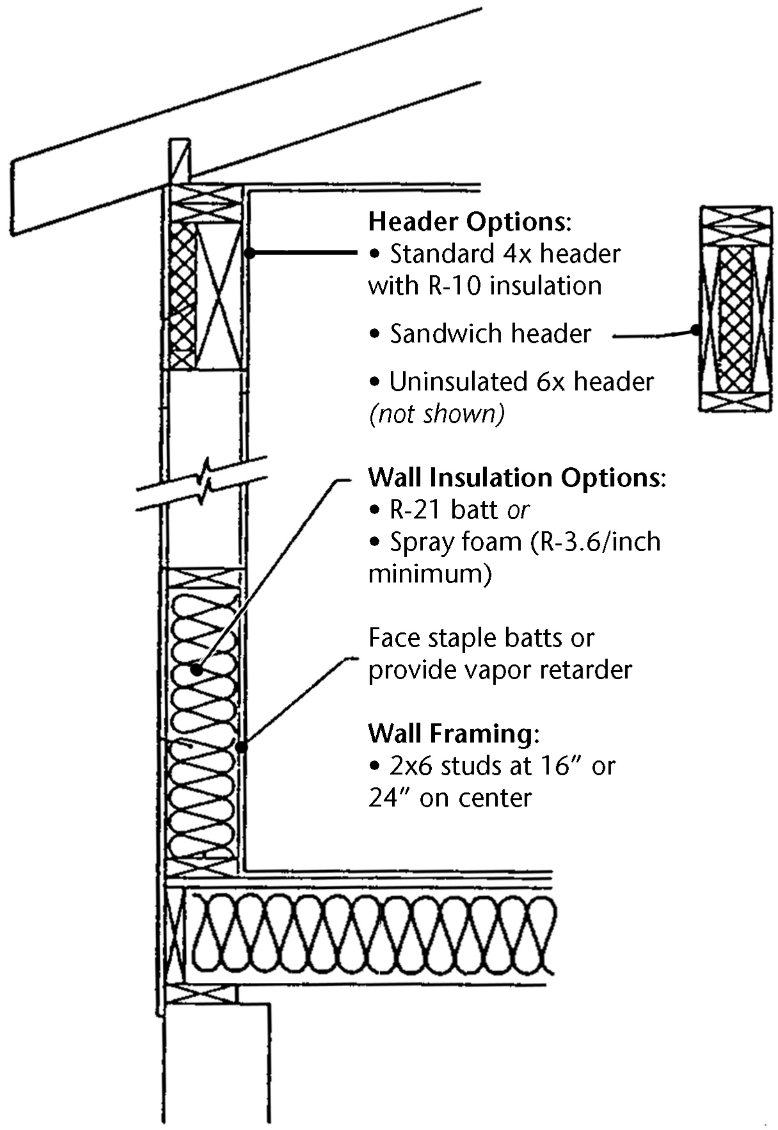
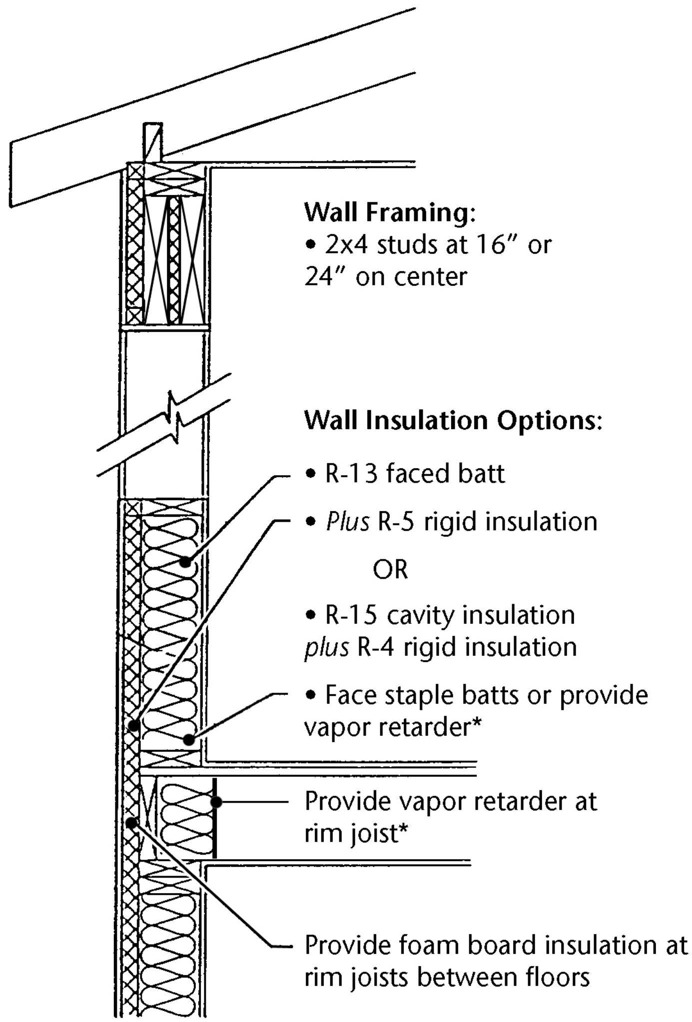


Figure 3-6

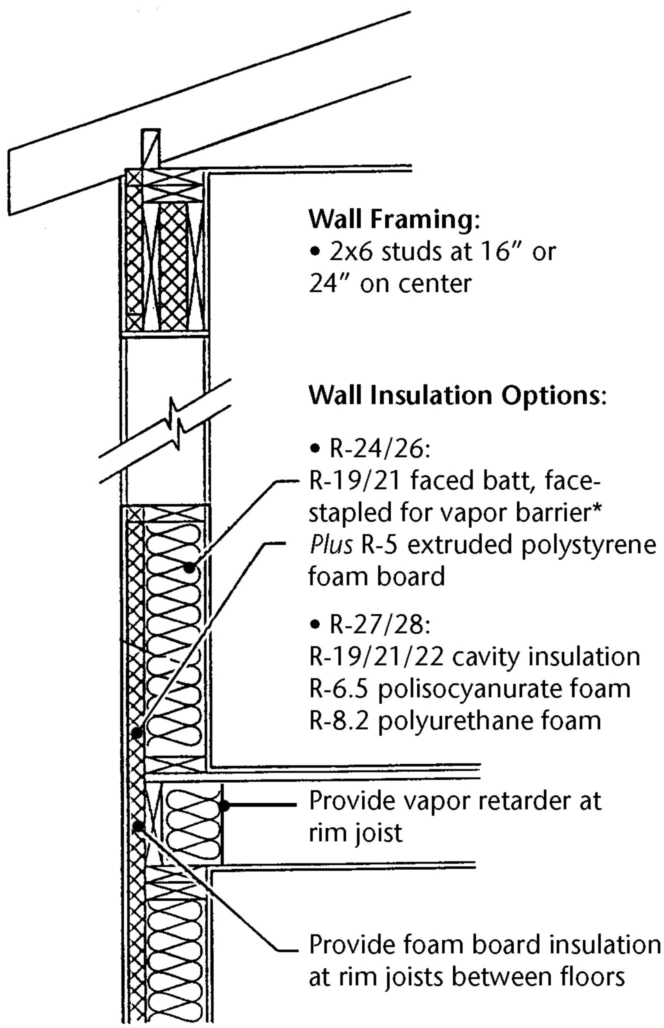
Acceptable Prescriptive Substitutes for R-21 Walls



** Vapor retarder is not required if R-5 rigid insulation is installed in Climate Zone 1 (R-7.5 for Climate Zone 2).*

Figure 3-7

R-24 & Above Walls



** Vapor retarder is not required if R-5 rigid insulation is installed in Climate Zone 1 (R-7.5 for Climate Zone 2).*

Figure 3-8

Double Wall

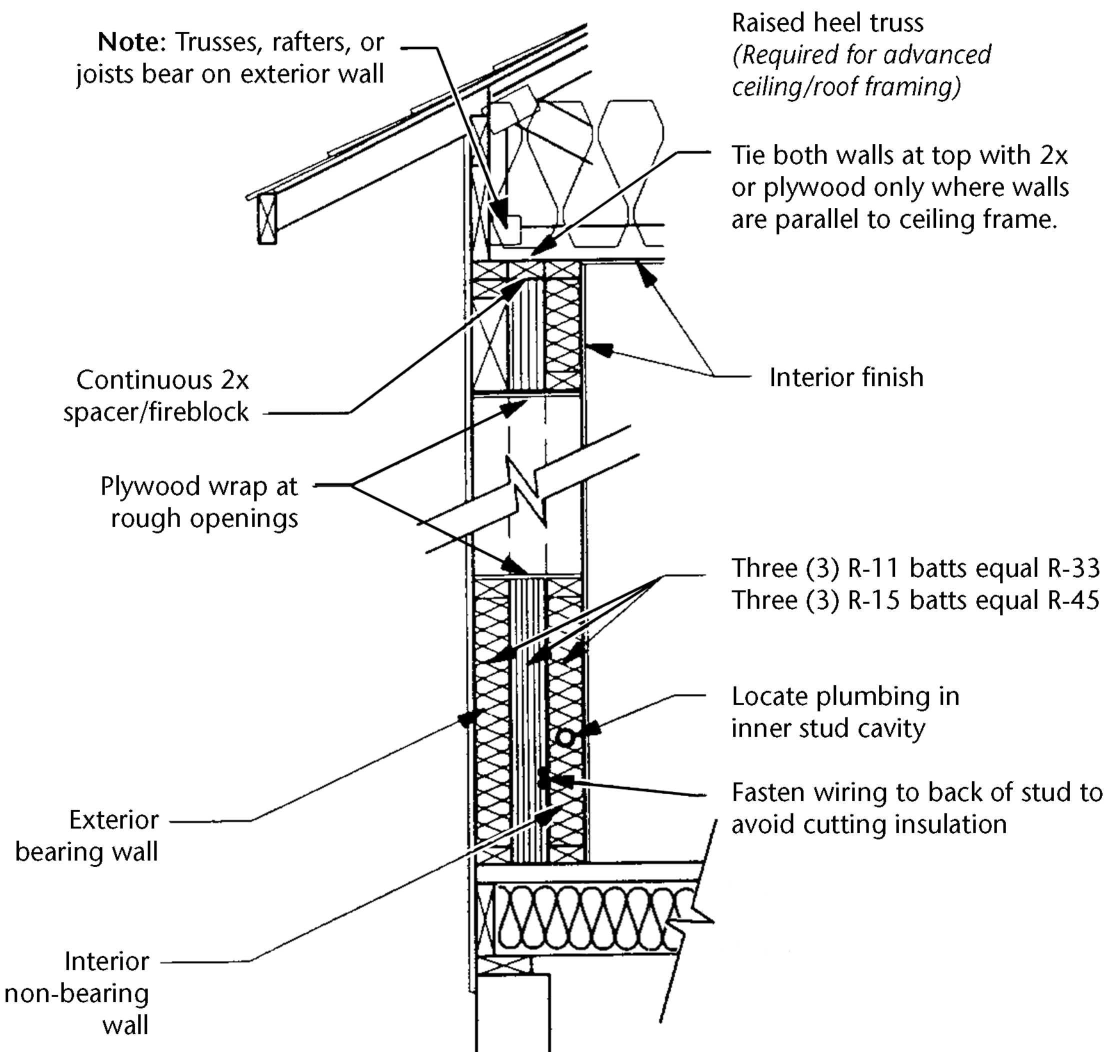


Figure 3-9

Above-Grade Wall: Interior Rigid Insulation

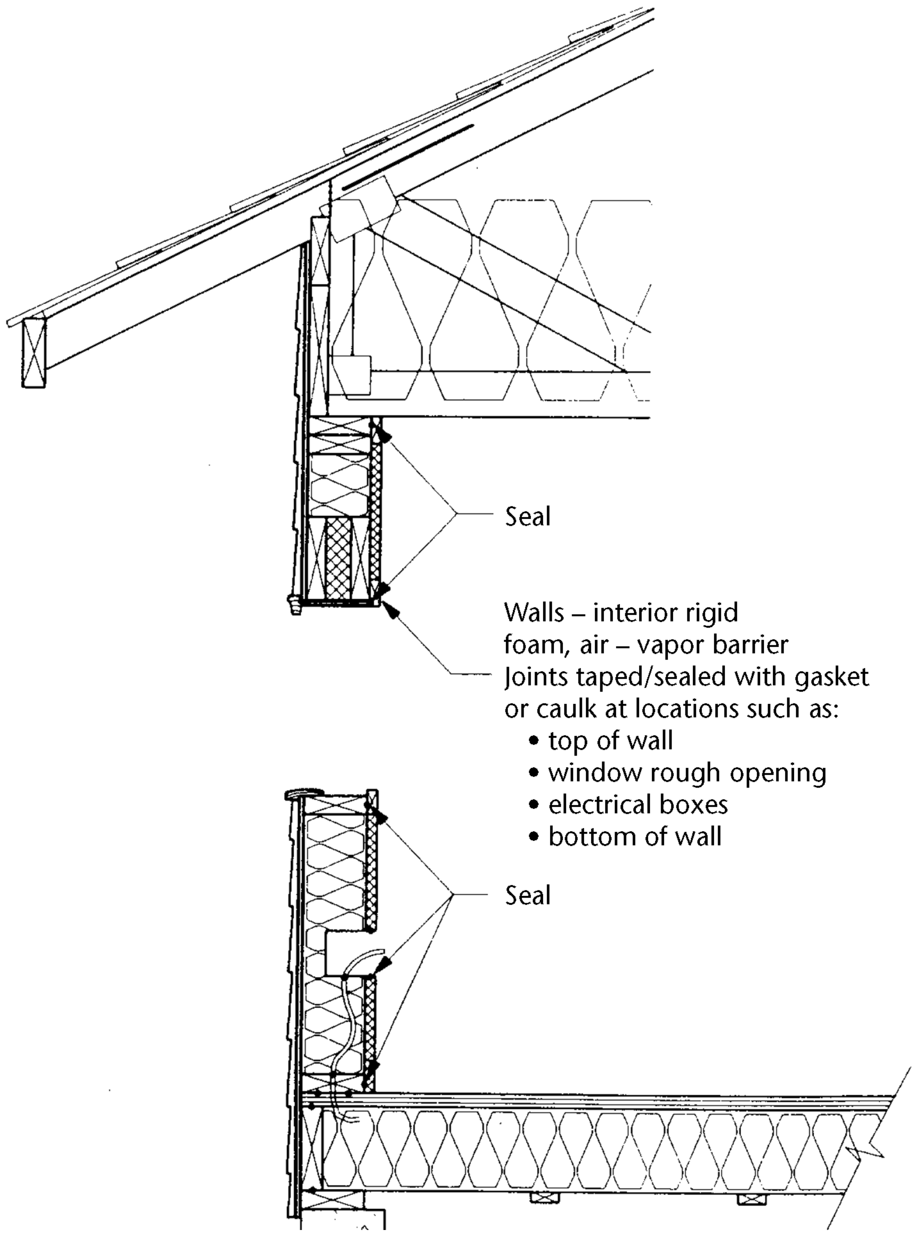


Figure 3-10

Interior Rigid Foam Framing Details

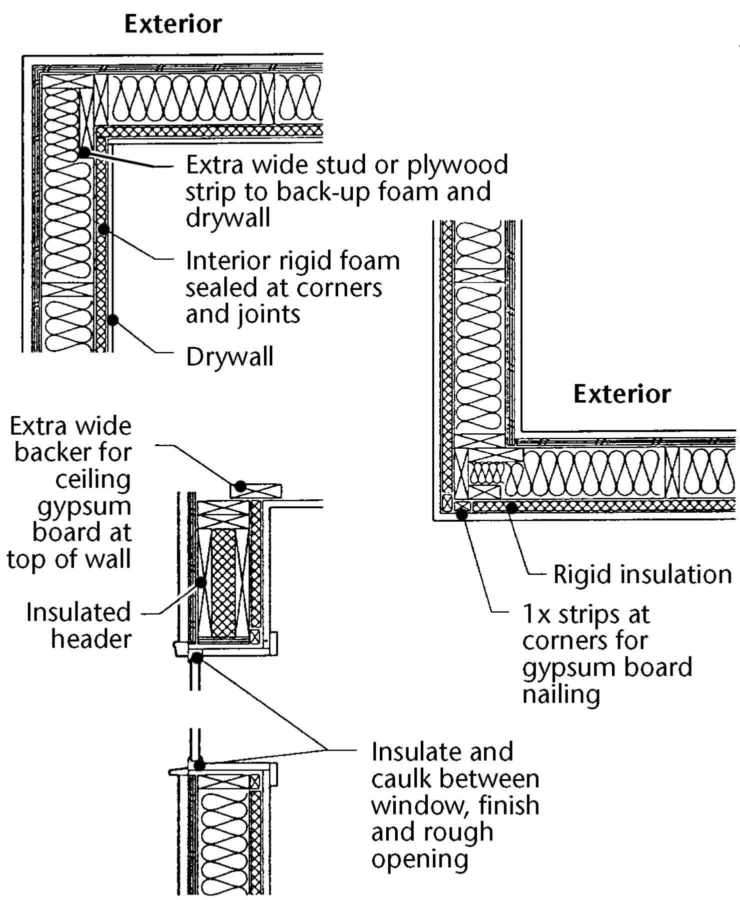


Figure 3-11a

Corner Trim Detail for Exterior Rigid Insulation

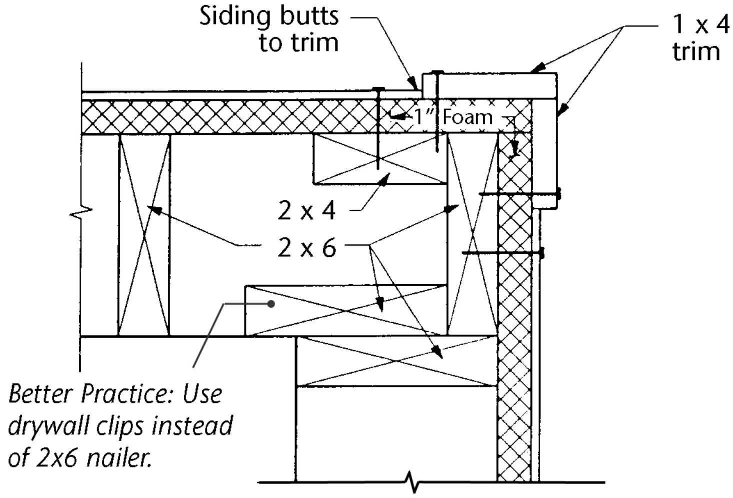


Figure 3-11b

Door Reinforcement for Exterior Rigid Insulation

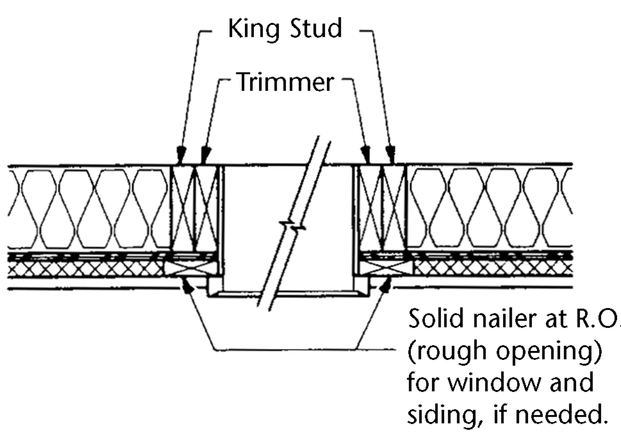
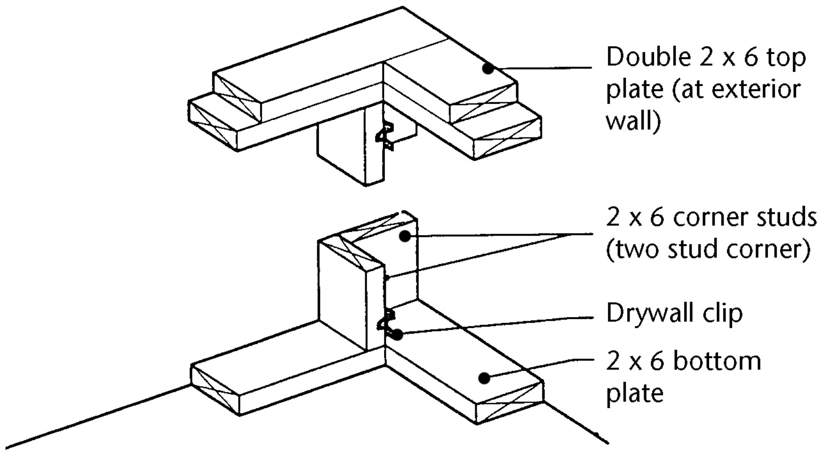


Figure 3-12

Optional Details Allowing Easy Placement of Insulation - 1

Two Stud Corner – Preferred Option



Modified Corner

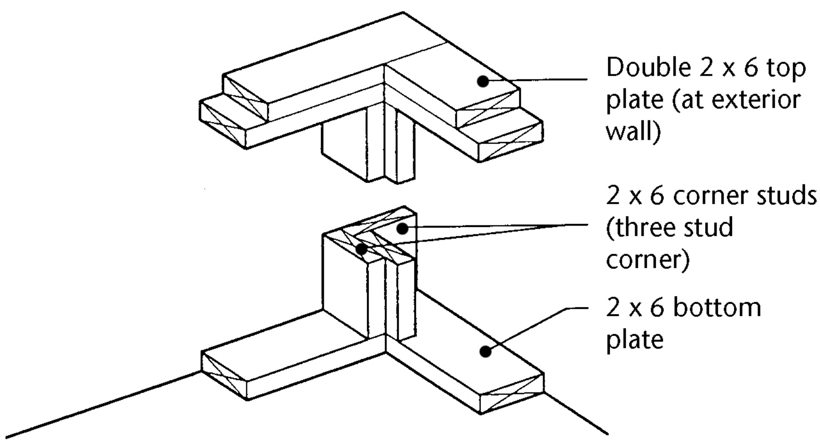


Figure 3-13

Optional Details Allowing Easy Placement of Insulation - 2

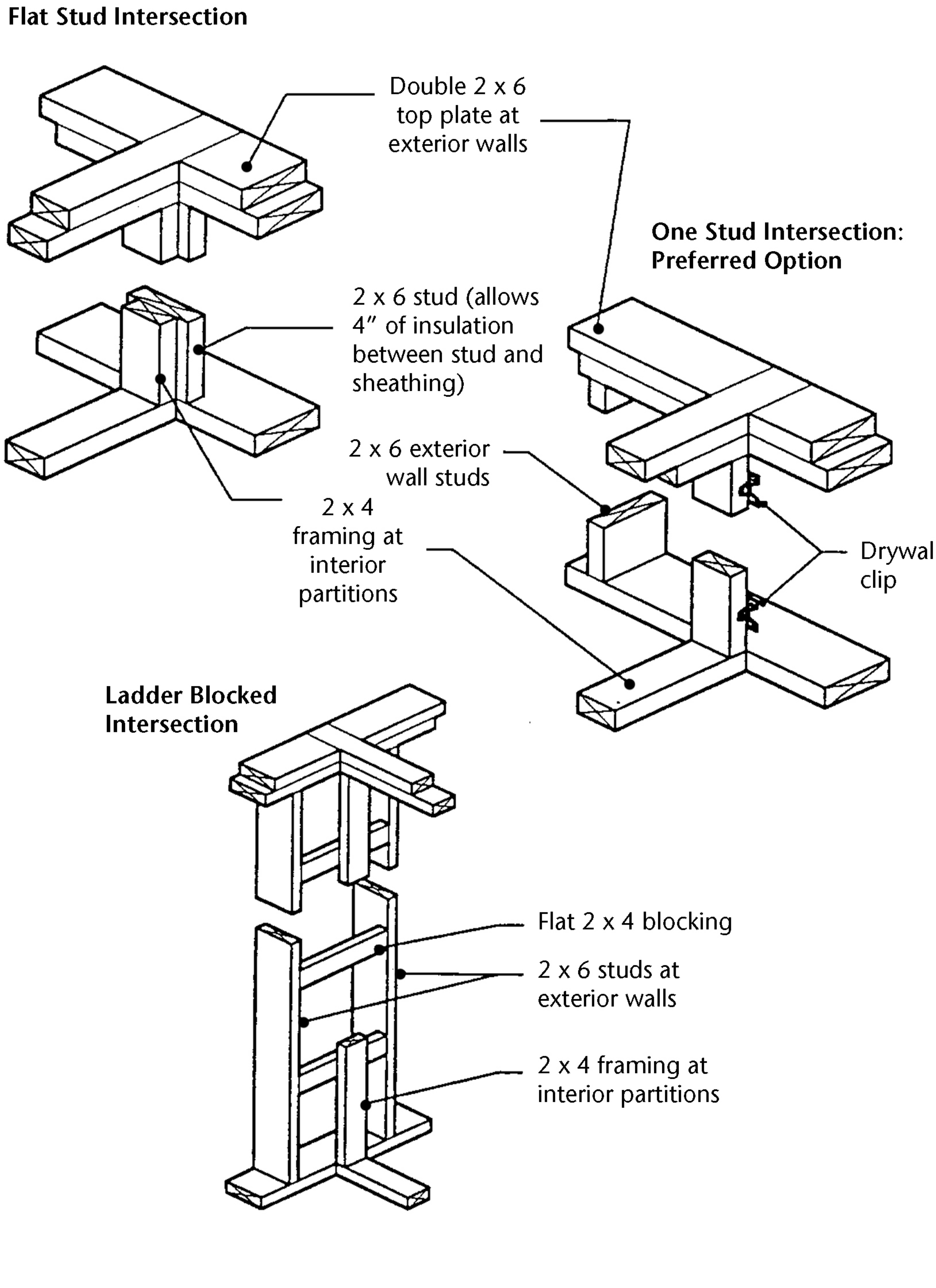
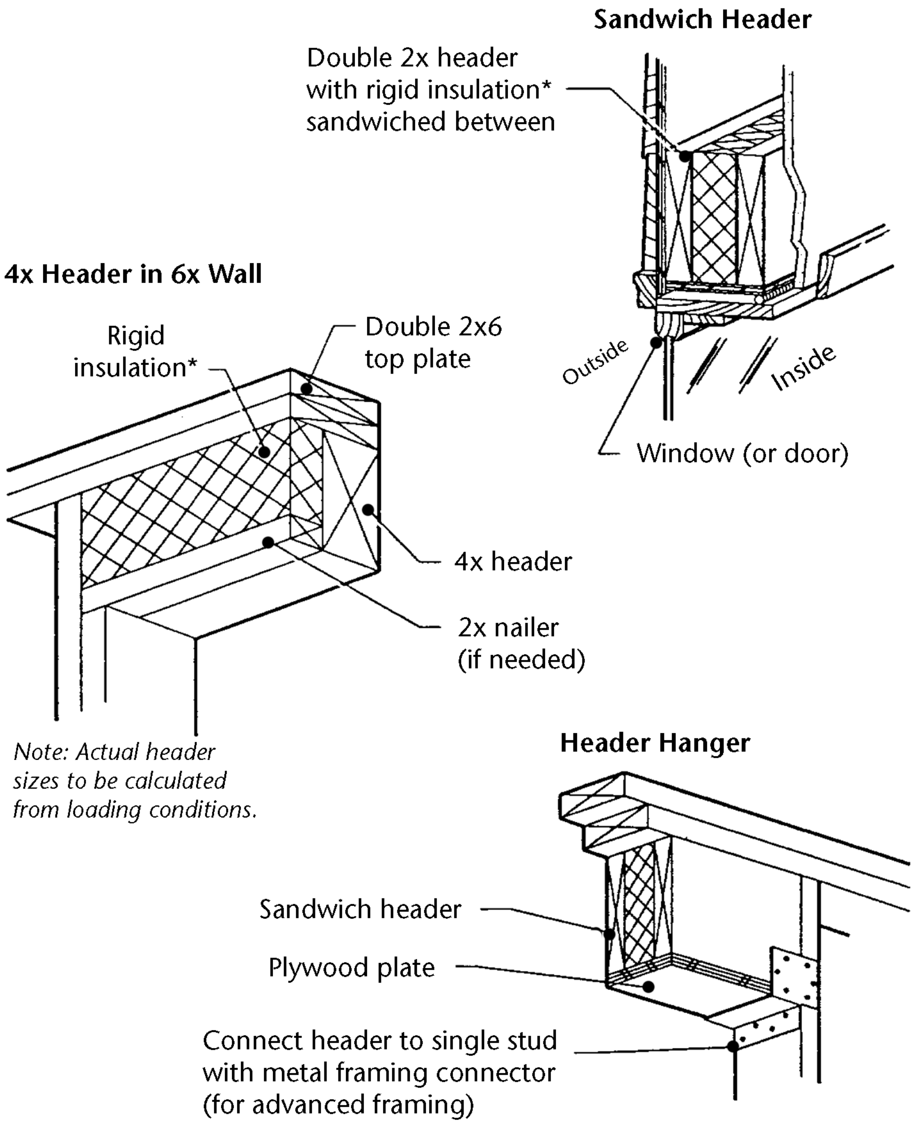


Figure 3-14

Header Details

(Required for Intermediate and Advanced Framing)



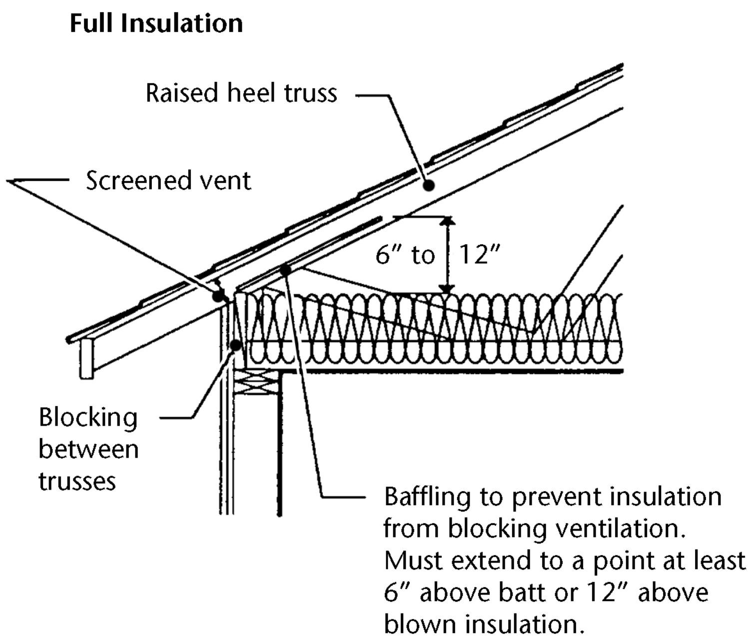
** Rigid insulated headers (R-10) required for intermediate and advanced framing.*

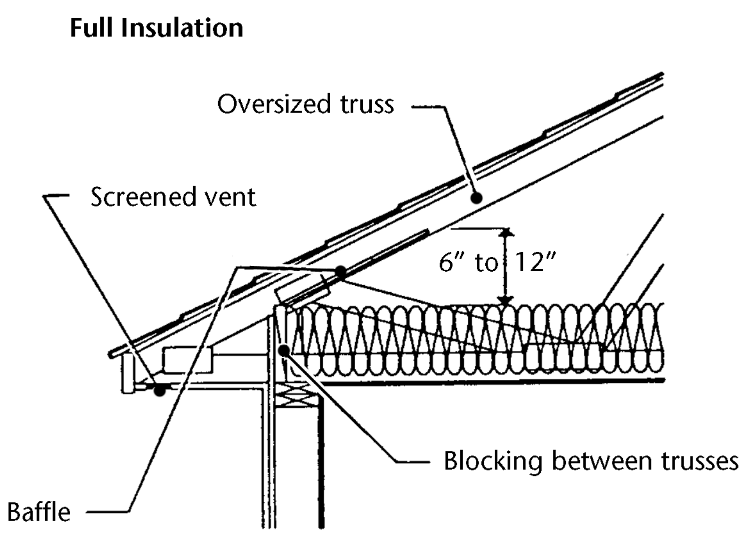
Energy-Efficient Ceiling/Roof Framing

Advanced Framing. An oversized or raised heel truss replaces the standard truss to avoid compressing insulation at the exterior wall (see Figure 3-15).

Figure 3-15

Options to Maintain Full Heel Insulation
(Advanced Frame Ceiling)





[502.1.4.3, 502.1.4.5] **Attic Venting.** Venting must meet IRC requirements. When venting is placed at the eaves, special consideration must be given to baffling the insulation in order to maintain a minimum 1 inch of free area for air movement from the vent into the attic (see Figure 4-4).

Exception for Attic Venting

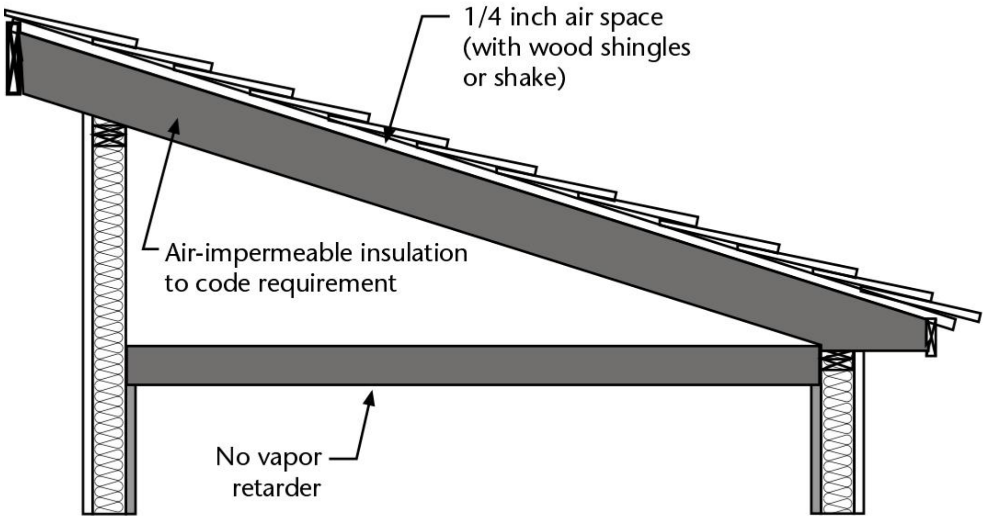
The WSEC allows an unvented attic under certain conditions. Unvented attics are created when a spray foam insulation product is applied directly to the underside of the roof sheathing or when rigid board insulation is installed directly over the structural roof sheathing. It is critical that Code requirements are met to avoid potential moisture problems, including:

- The unvented attic space is completely contained within the building thermal envelope.
- No interior vapor retarders are installed on the ceiling side (attic floor) of the unvented attic assembly.
- Where wood shingles or shakes are used, a minimum 1/4-inch (6 mm) vented air space separates the shingles or shakes and the roofing underlayment above the structural sheathing.
- Any air-impermeable insulation shall be a vapor retarder, or shall have a vapor retarder coating or covering in direct contact with the underside of the insulation, unless regid insulation board is install over the structural roof sheathing.

There are three methods for constructing unvented attic spaces. With all three methods, it is important to check that the insulation's listing allows it to be installed to the prescriptive required R-value. If not, a Component Performance or Systems Analysis Approach must be used. Also check the listing to see if a fire retardant material needs to be applied to the exposed insulation. Figure 3-16 shows the installation of air-impermeable insulation installed directly to the underside of the roof deck. This typically requires a closed cell product.

Figure 3-16

Air-Impermeable Insulation Only, In Direct Contact with Roof Sheathing



The second method shown in Figure 3-17 is used when applying an air-permeable product directly to the underside of the roof decking. This method requires rigid board or sheet insulation on the top of the roof deck. The required R-values of the rigid insulation are R-10 in Climate Zone 1 and R-25 in Climate Zone 2.

The third method is used when combining air-impermeable and air-permeable insulation (see Figure 3-18). This is sometimes referred to as a “hybrid” system. Air-impermeable insulation is applied directly to the underside of the roof deck. As with the previous method, the air-impermeable insulation must be installed to a minimum of R-10 in Climate Zone 1 and R-25 in Climate Zone 2. Air-permeable insulation may now be installed to reach required R-values.

Figure 3-17

Air-Impermeable and Air Permeable Insulation Interior

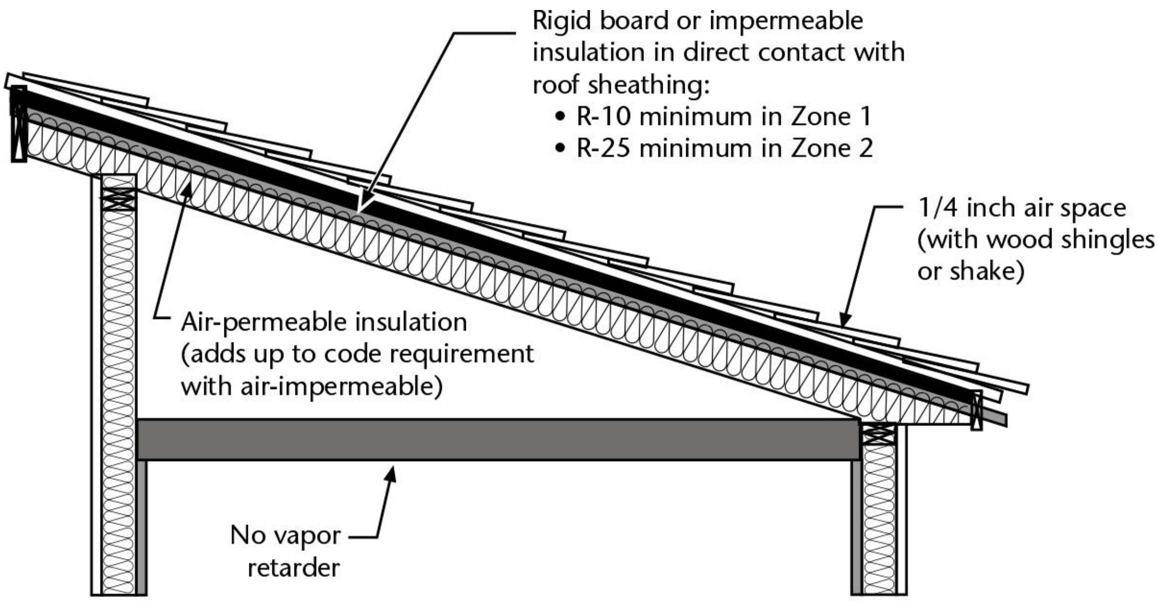
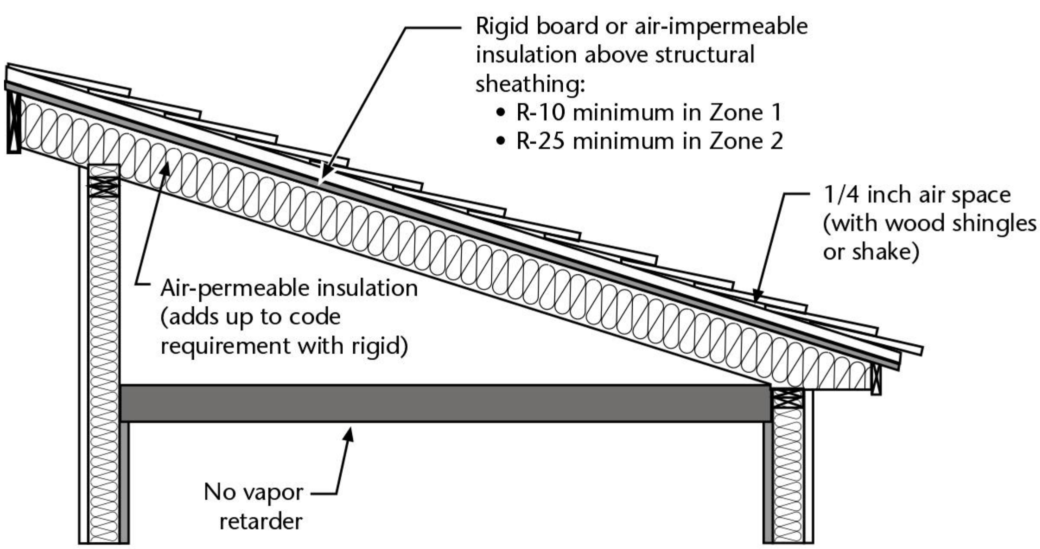


Figure 3-18

Air-Permeable Insulation Interior, Air Impermeable Exterior



Vaulted Ceilings*. Following some prescriptive paths, single rafter vaults require R-38 insulation. Component performance compliance may allow less than R-38 if another component makes up the difference (see Chapter 5). Various options for framing vaulted ceilings to obtain high levels of insulation are available (see Figure 3-19).

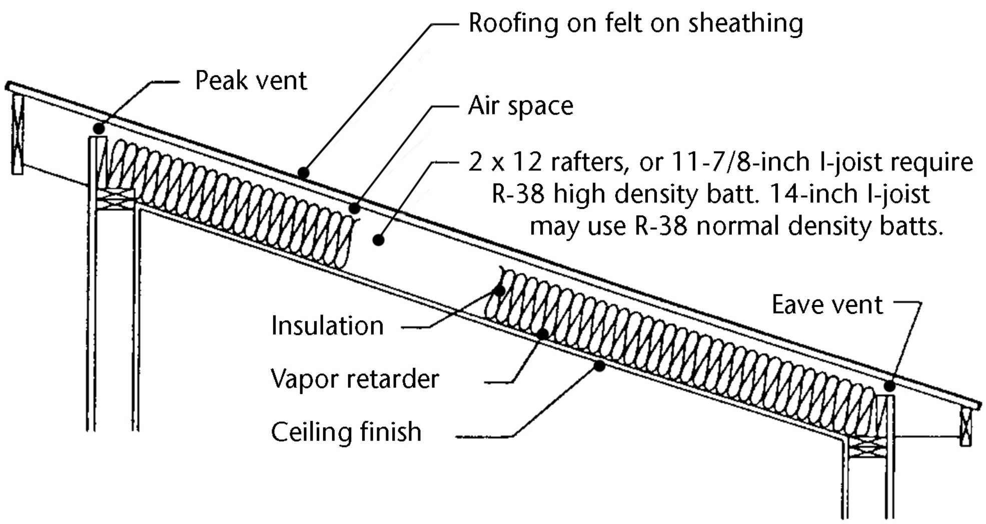
** A vaulted ceiling is defined as a ceiling where enclosed joist or rafter space is formed by ceilings applied directly to the underside of roof joists or rafters. A sloped ceiling of a scissor truss is not considered a vaulted ceiling.*

[502.1.6.3] **Vault Cavity Ventilation.** Most ceilings with insulation beneath the structural sheathing, including vaults, must provide a minimum 1-inch air space above the insulation (see Figure 3-20).

Figure 3-19

Vaulted Ceilings

Stick Frame (R-38)



Flat Truss (R-38/R-60)

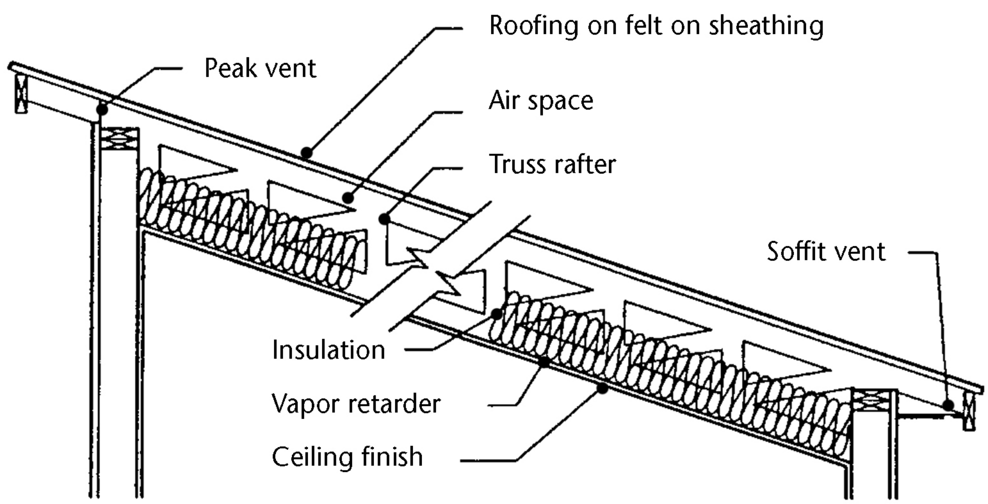
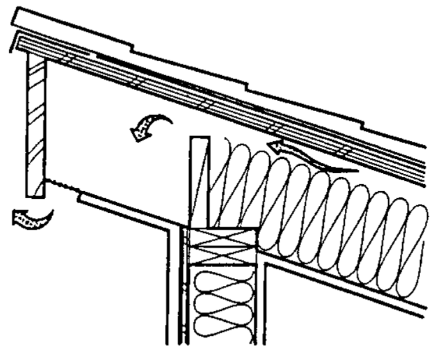
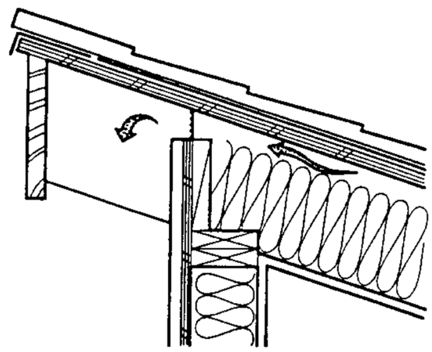


Figure 3-20

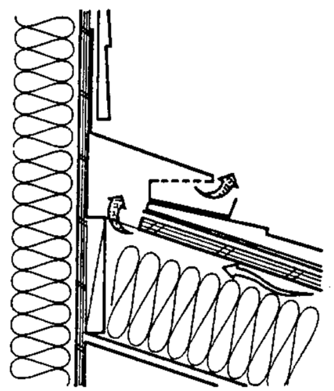
Venting Vaulted Ceilings



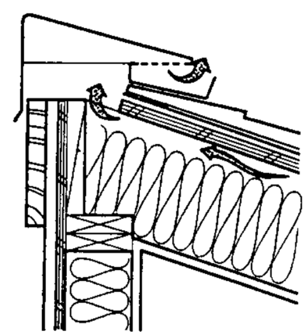
Shed Peak With Soffit



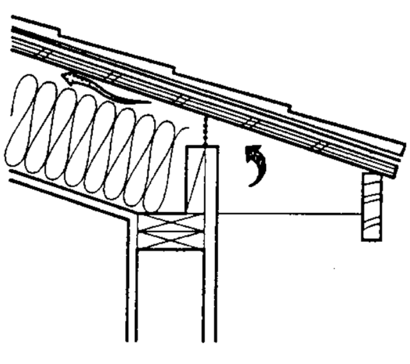
Shed Peak Without Soffit



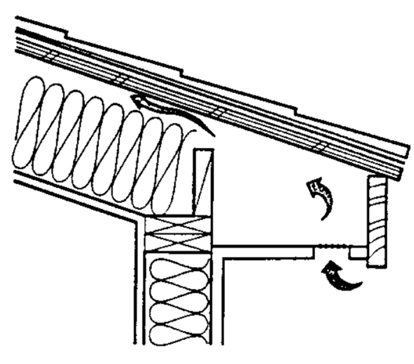
Shed Roof at Wall



Shed Peak: No Overhang



Eave Without Soffit



Eave With Soffit

Chapter 4: Insulation

In the *Washington State Energy Code* (WSEC), insulation levels expressed in R-values are determined by the compliance path as explained in Chapter 1, *Compliance*. For below-grade walls and slab-on-grade insulation details see Chapter 2, *Foundations*. For above-grade wall construction and insulation details, see Chapter 3, *Framing*. General insulation requirements, regardless of compliance path, are outlined in this chapter.

Installing the proper amount of insulation is important, but correct installation techniques are of equal importance to achieve specified R-values.

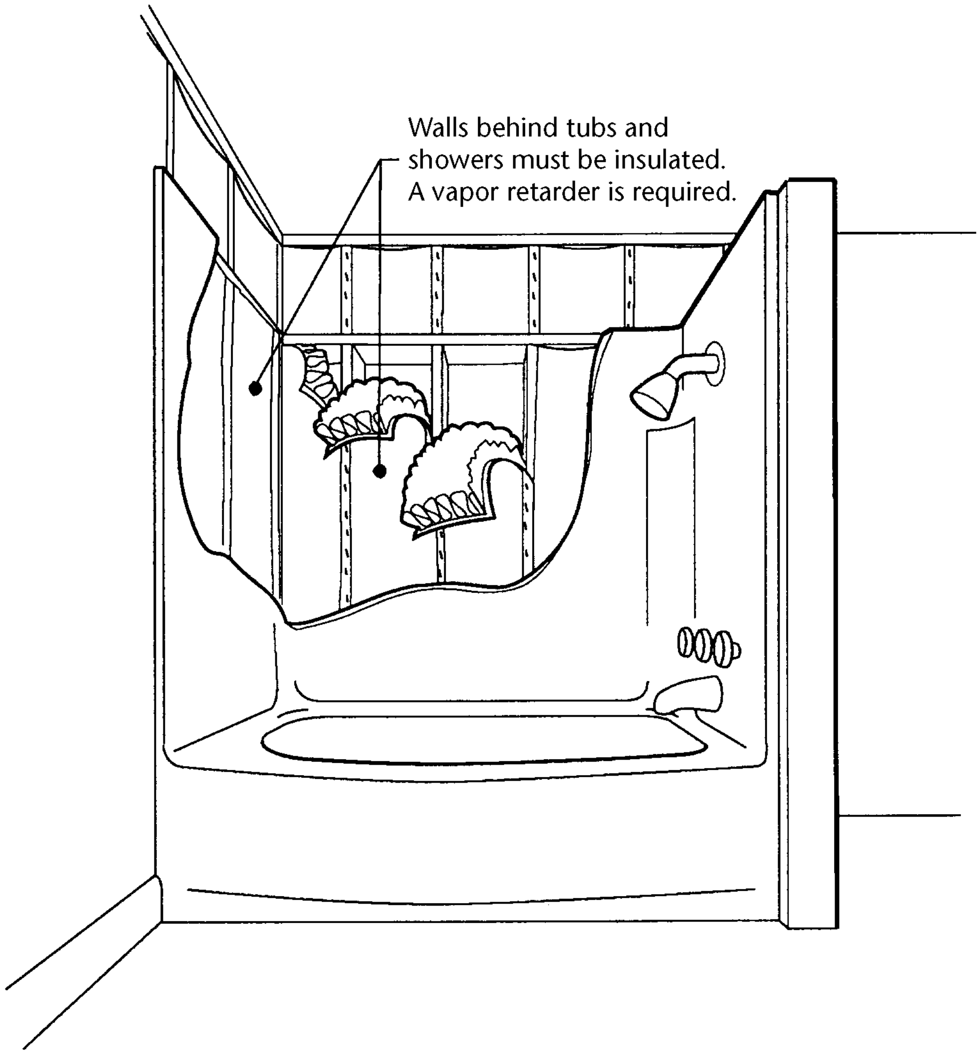
[502.1.4.6] **Completely Fill All Exterior Wall Cavities and Insulate to the Full Required R-Value.** Exterior wall cavities are considered to be any wall separating a heated space from an unheated space. Areas that are sometimes overlooked are:

- Behind shower or bathtub enclosures (see Figure 4-1).
- Where interior and exterior walls meet.
- Corners.
- Stairwells to unheated basements.
- Skylight chases through attics.
- HVAC ductwork in exterior walls, floors and ceilings cannot displace required insulation.

> ***Exception:***
> A framed cavity can be empty or partially filled, provided both of the following conditions are met:
> - The wall assembly calculations are performed along with a completed performance calculation for the whole building.
> - Insulation installed in partially filled cavities is not included in the performance calculation.

Figure 4-1

Tub Enclosure on Exterior Wall



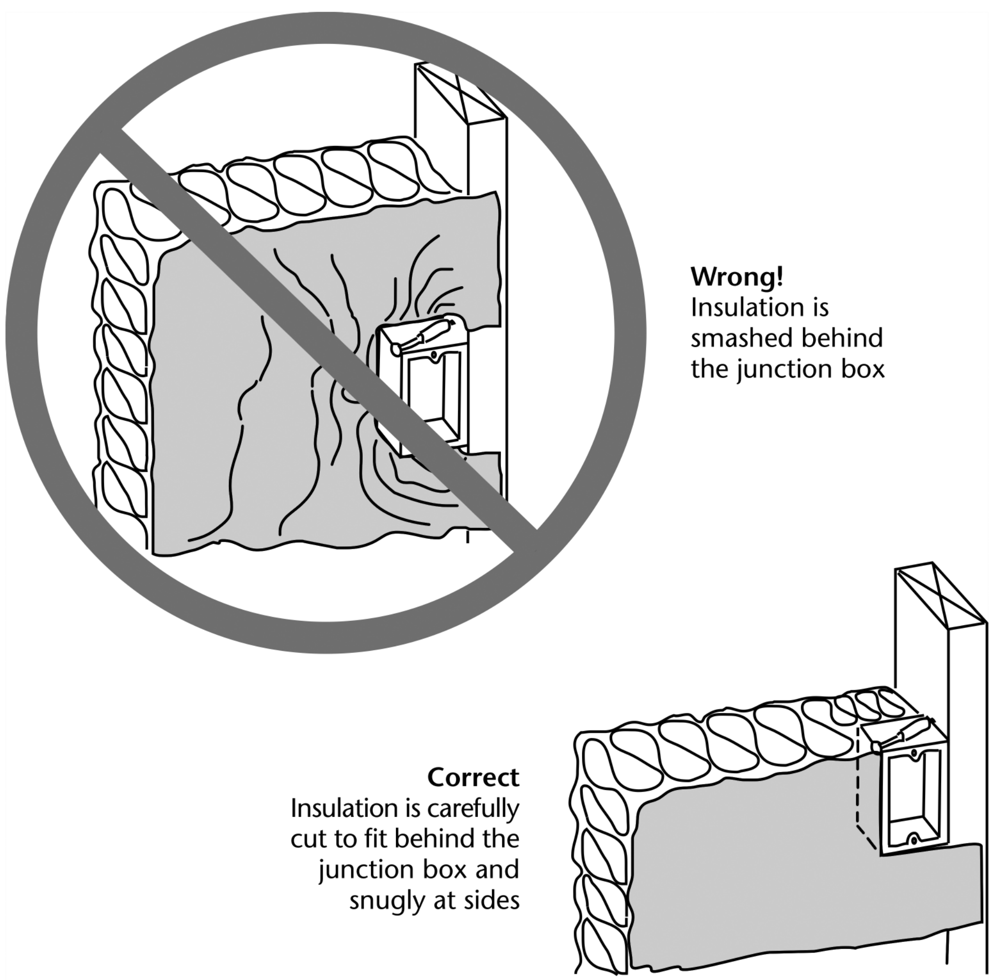
[502.1.4.1] **Don't Compress the Insulation.** Compression of insulation will cause it to be less efficient. For example, if you compress an R-19 batt in half, you reduce the R-value by almost 50 percent. Common areas of compression are:

- Behind outlet and switch boxes.
- Behind plumbing pipes and wiring.

Compression problems can be avoided in these situations by cutting and fitting insulation around outlet and switch boxes (see Figure 4-2). Slicing about halfway through a batt will allow it to fit around a wire or pipe.

Figure 4-2

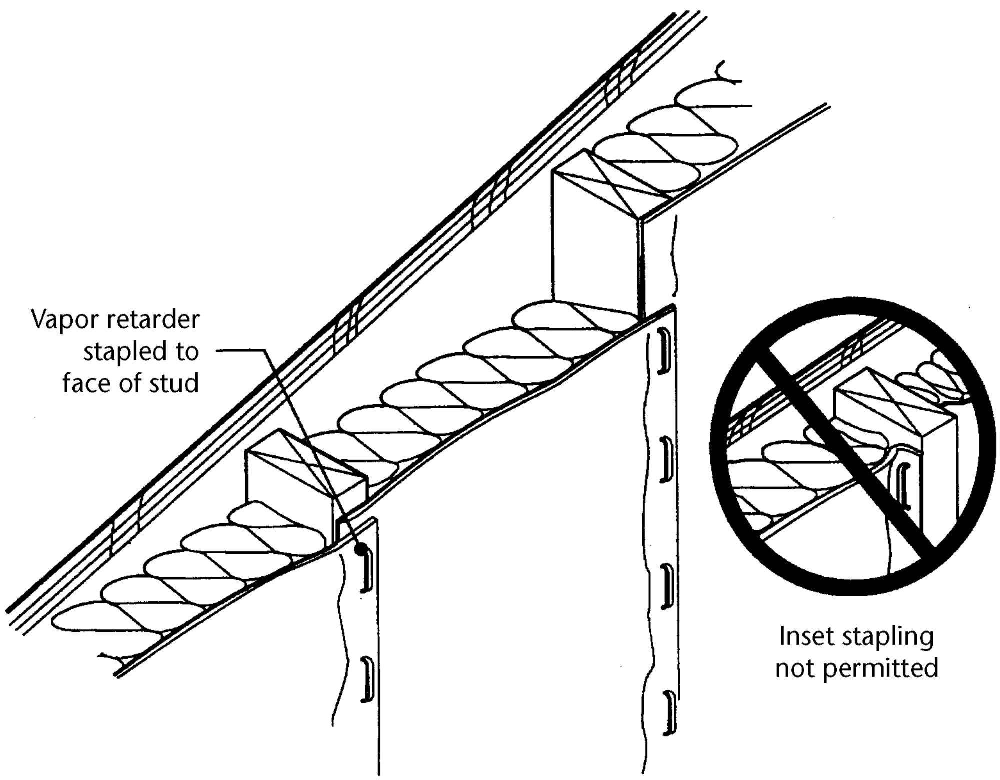
Electrical Box Insulation Details



[502.1.4.6] **Inset Stapling Faced Batts is not Allowed.** If faced batts are used (kraft paper or foil facing material) and if they have a stapling tab, they must be stapled directly to the face of the stud. Stapling to the side of the stud compresses the insulation and creates a convective air channel that reduces the effectiveness of the insulation (see Figure 4-3).

Figure 4-3

Face Stapling



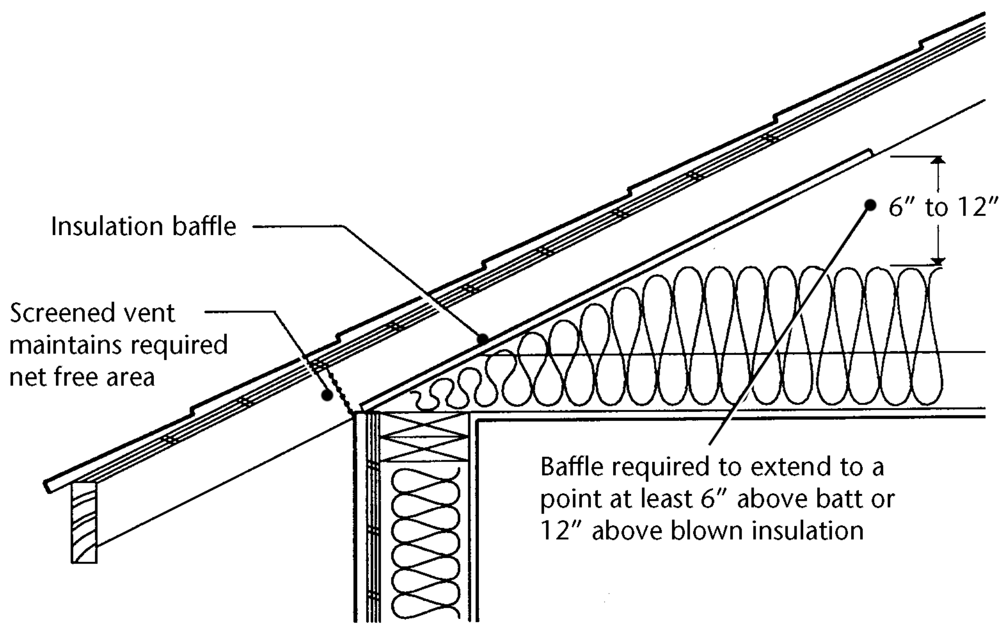
[502.1.4.5] **Attic Baffles.** Baffles are necessary to maintain airspace between the insulation and the roof sheathing when soffit or bird block venting is used (see Figure 4-4). This promotes cross-ventilation of the attic, helping to remove unwanted moisture. It minimizes potential rot problems, and ice damming in winter.

Baffles are made of weather resistant material, typically wax-impregnated cardboard. Baffles must extend:

- 6 inches (vertically) above non-compressed batt type insulation.
- 12 inches (vertically) above full depth blown-in insulation.

Figure 4-4

Attic Baffles in Standard Frame Ceiling

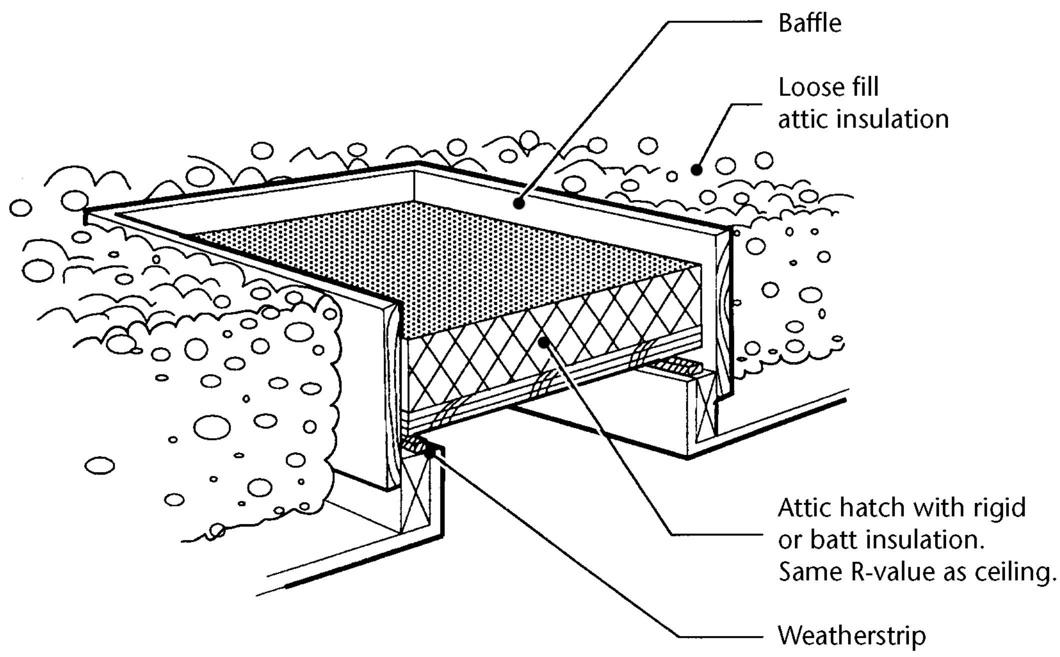


[502.1.4.4] **Attic Access.** A baffle or dam around an attic access hatch is also required when loose-fill or blown-in insulation is installed (see Figure 4-5). Requirements for access hatches and doors are:

- Wood frame, or equivalent, baffle installed around the opening. Cardboard is not acceptable.
- The hatch must be insulated to the same R-value as the surrounding ceiling with batt or rigid insulation.
- The hatch must be weatherstripped to stop air leakage between the attic and the interior.

Figure 4-5

Attic Hatch

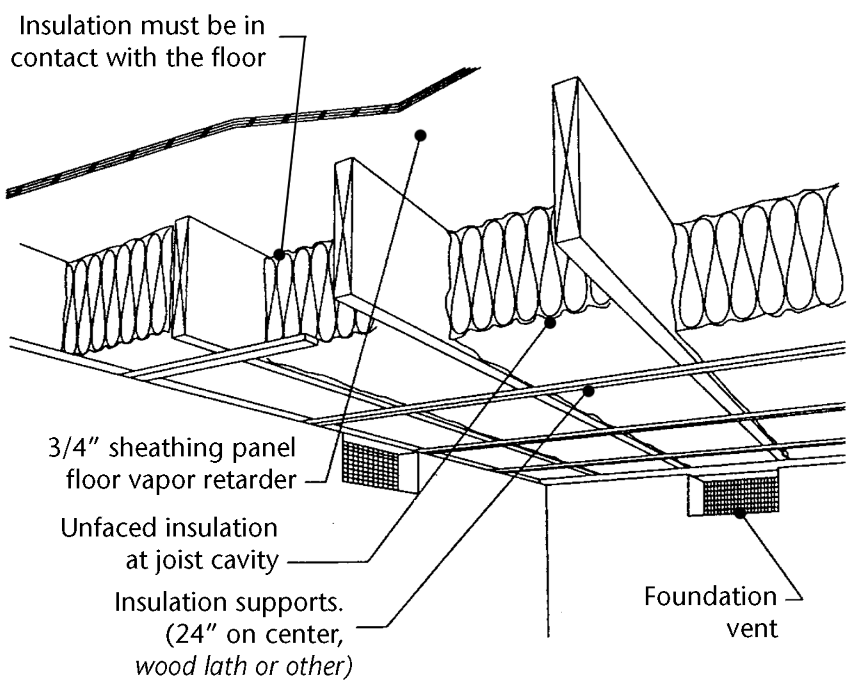


[502.1.4.1, 502.1.4.7] **Floor Insulation Supports.** Floor insulation must be installed in a permanent manner and in substantial contact with the surface being insulated (see Figures 4-6, 4-7 and 4-8). Insulation can be held in place using:

- Polyethylene twine.
- Lath.
- Other approved material.

Figure 4-6

Floor Insulation Supports

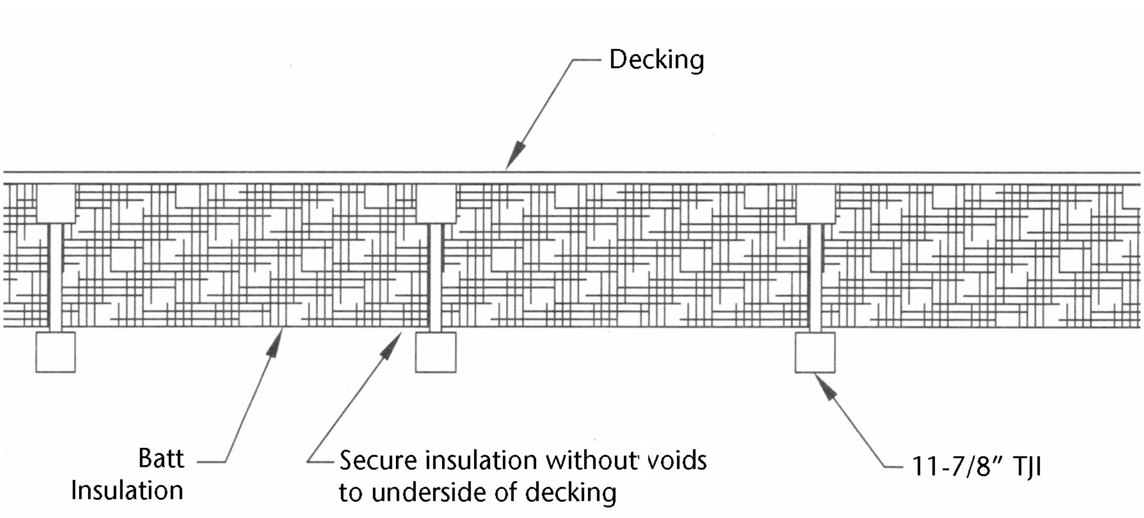


Supports are required to be a maximum of 24 inches apart. If the insulation thickness is more or less than the depth of the joist, hangers are available to hold the insulation to the floor surface without compressing it. Metal rods or other supports that compress the insulation are not acceptable.

If insulation depth is less than the depth of the joist, inset twining or supports are required (see Figure 4-7).

Figure 4-7

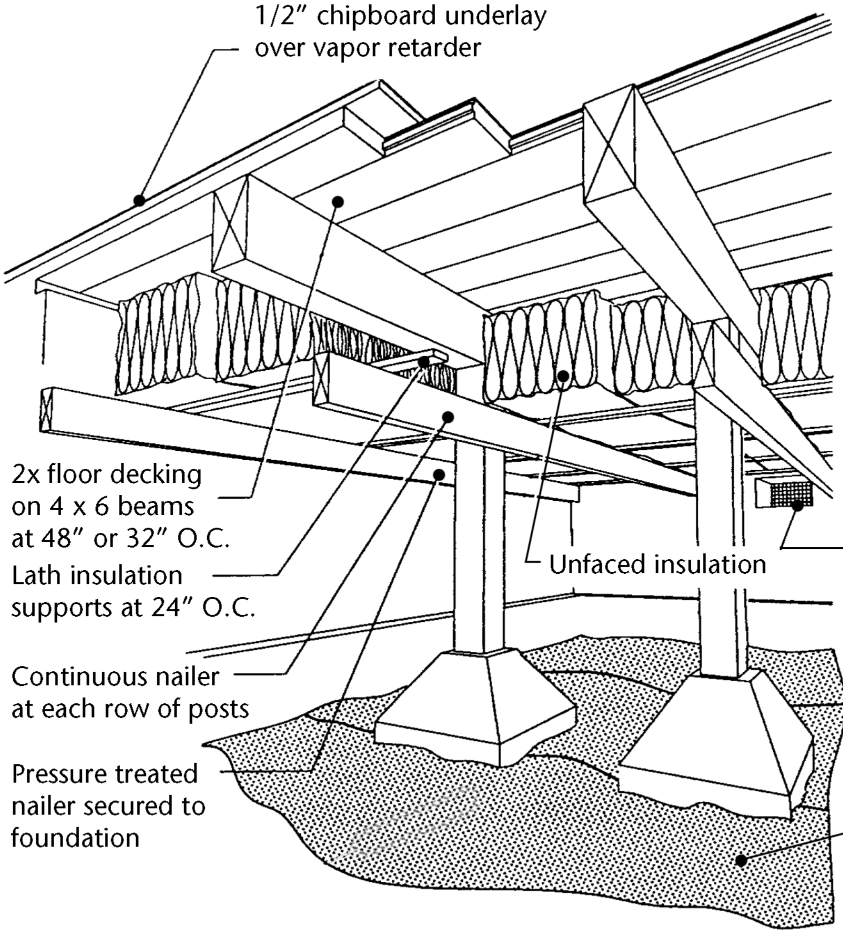
Underfloor Insulation



Post and beam floors require a different insulation attachment approach. The insulation is supported by lath and supports are attached to the posts and foundation wall (see Figure 4-8).

Figure 4-8

Post and Beam Insulation Supports



[502.1.4.7, Exception]

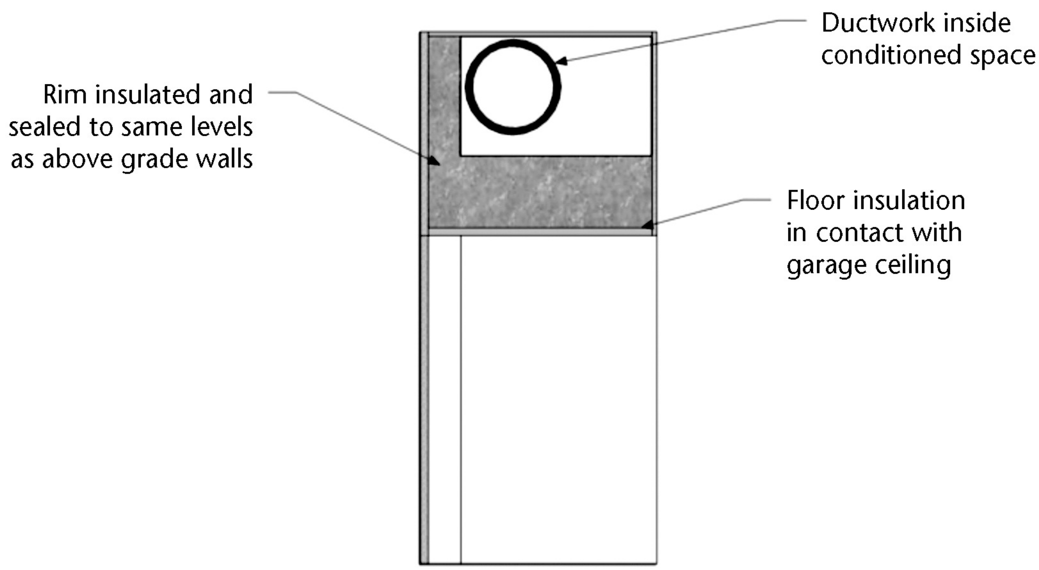
In either type of floor, when insulation abuts a foundation vent, a baffle must be installed to deflect the incoming air below the insulation level. These baffles are typically made of plywood or wax impregnated cardboard installed at a 30° angle (refer back to Figure 2-2).

[502.1.4.7, Exception]

Substantial contact with the surface being insulated is not required in a floor/ceiling assembly containing ductwork when full depth insulation is installed between the duct and exterior surfaces. This exception only applies to enclosed floor/ceiling assemblies with an air barrier exterior of the insulation, separating the assembly from unconditioned space (see Figure 4-9).

Figure 4-9

Substantial Contact Exception



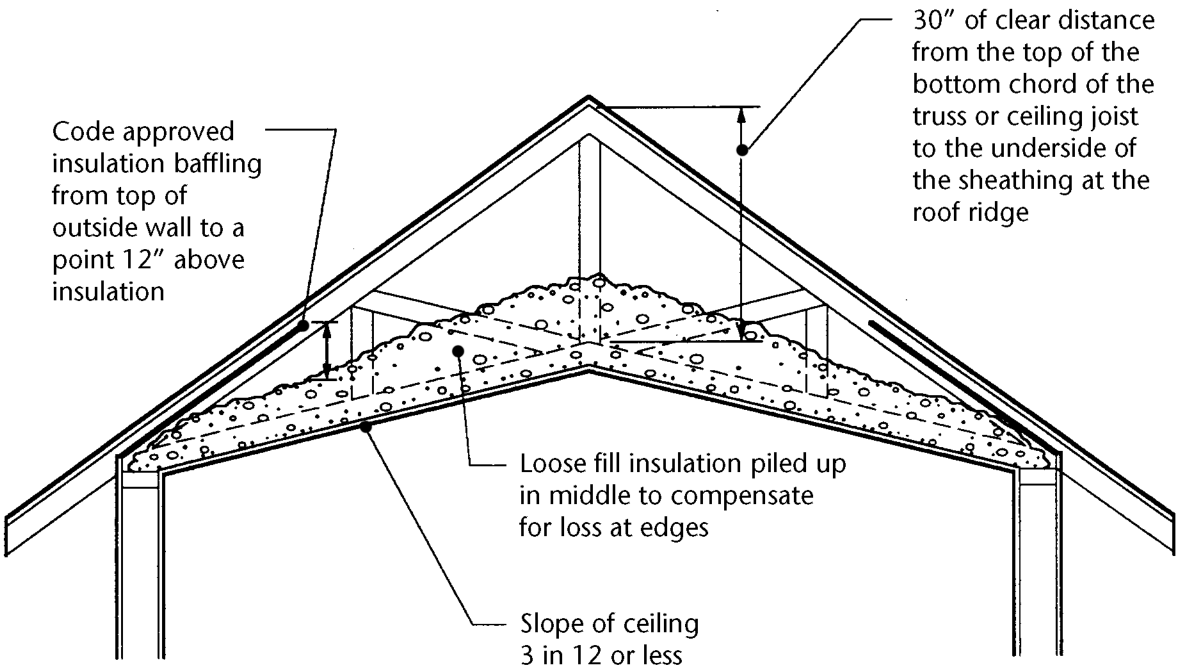
[502.1.4.5, 502.1.4.1]

Loose-Fill Insulation. Loose-fill or blown-in insulation is commonly installed in ceilings (see Figure 4-10). The following requirements apply when using loose-fill insulation:

- The ceiling pitch must be 3-in-12 or less.
- Code-approved baffles must be installed.
- There must be a minimum of 30 inches of clear distance from the bottom chord of the truss to the sheathing at the ridge.
- The insulation material must comply with the IBC for flame spread and smoke density requirements.
- R-value markers must be installed every 300 sq.ft.

Figure 4-10

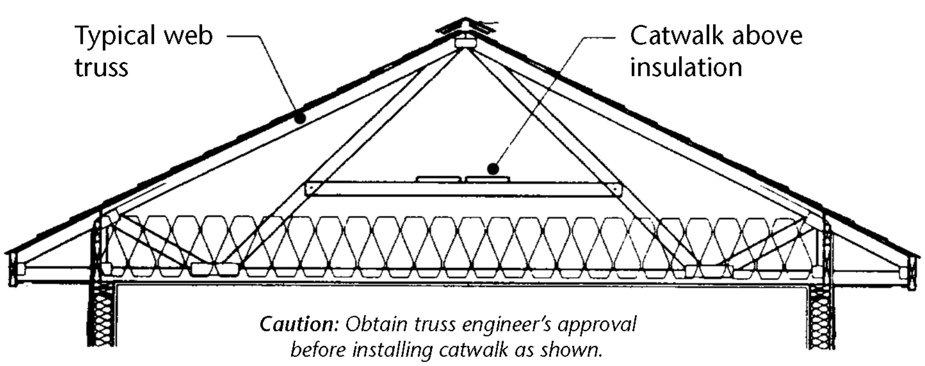
Loose-fill Insulation Requirements



[502.1.4.4] If areas of the attic need to be accessible for equipment maintenance, a catwalk should be constructed and supported above the loose-fill insulation (see Figure 4-11).

Figure 4-11

Cat Walk



Skylight Walls. Skylight walls are insulated to the same level as the other walls in the house. Due to construction methods and close proximity of roof trusses, these walls are more difficult to insulate than a standard exterior wall.

A common skylight wall insulation technique is to tack insulation batts on the outside of the framed walls and secure it in place with twine. *Remember, a vapor retarder is required.* The vapor retarder faces the inside, or warm side, as explained in Chapter 5, page 5-1.

[502.1.4.5] When two or more layers of rigid board insulation are used in a roof assembly, the vertical joints between each layer are staggered.

Chapter 5: Air Leakage and Moisture Control

[502.1.6] **Vapor Retarders.** A vapor retarder is a material placed to minimize vapor movement through the diffusion process. Types of vapor retarders include:

- Kraft paper or foil facings on insulation.
- 4-mil or thicker polyethylene.
- Vapor retarder rated paint.

To meet the *Washington State Energy Code* (WSEC), vapor retarders need to be rated at 1 perm dry cup or less. This is a rating of how permeable to vapor movement a given material is (see Table 5-1 for perm ratings).

Table 5-1

Permeance Values for Common Building Materials*

Materials	Permeance
Polyethylene (4 mil)	0.08
Latex Primer/Sealer	6.28
Vapor Retarder Paint	0.45
Polyvinyl Acetate Latex (PVA)	5.5
Kraft Paper (Asphalt Impregnated)	0.03
15 lb. Asphalt Felt Paper	1.0
Gypsum Wall Board (3/8 inch)	50
Plywood (1/4 inch with exterior glue)	0.7

*2005 ASHRAE Handbook of Fundamentals

Materials must be applied in accordance with the manufacturer's instructions to achieve specified permeance ratings.

Components of the house requiring a vapor retarder are:

- Floors between heated and unheated spaces.
- Walls – on the inside (warm side in winter).
- Ceilings averaging less than 12 inches of ventilated area above the insulation.

[502.1.6.1, Exception] Vapor retarders must be installed either on the warm side (in winter) of insulation or with not more than 1/3 of the nominal R-value between it and the conditioned space.

[502.1.6.2.] **Floors.** Floors that separate a heated space from an unheated space are required to have a vapor retarder. Usually the floor decking itself meets the perm rating and qualifies as a vapor retarder. Three-quarters (3/4) inch tongue-and-groove exterior plywood and exterior grade OSB both meet the vapor retarder requirements. Floors with obvious gaps and holes call for a vapor retarder such as polyethylene or 15 lb. felt paper.

[502.1.6.6] **Walls.** All walls separating heated from unheated spaces must have a vapor retarder. Vapor retarders need to be installed on the inside of the wall, or the warm side in the winter.

[502.1.6.6, Exception] Wood framed walls with insulated sheathing installed outside of the framing and structural sheathing do not need a vapor barrier. R-5 insulated sheathing must be used in Climate Zone 1 and R-7.5 must be used in Climate Zone 2. The interior cavity insulation for this exception must be a maximum of R-21.

[502.1.6.3] **Ceilings.** All roof/ceiling assemblies must have an installed vapor retarder when the ventilation space between the top of the insulation and underside of the roof deck averages less than 12 inches.

[502.1.6.3, Exception] Unvented attic spaces are allowed under certain conditions. See Chapter 3 for details.

Air leakage control is an important but commonly misunderstood component of the energy efficient house. Tightening the structure with caulking and sealants has several positive impacts. A tight house will:

- Have lower heating bills due to less heat loss.
- Have fewer drafts and be more comfortable.
- Reduce the chance of mold and rot because moisture can not enter and become trapped in cavities.
- Have a better performing ventilation system.

[502.4.1] WSEC states specific locations in buildings requiring sealing. Air leakage must be controlled where outdoor ambient conditions are separated from interior spaces that are heated or mechanically cooled.

The type of sealing material used varies with the size of the gap. For example:

- Caulk and low expansion foam should be used for small holes and cracks (less than 1/8 inch).
- A combination of caulking and backer rod (foam rope) should be used for wider gaps (greater than 1/8 inch).
- Polyethylene, rubber or neoprene material should be used for large openings (greater than 1 inch).

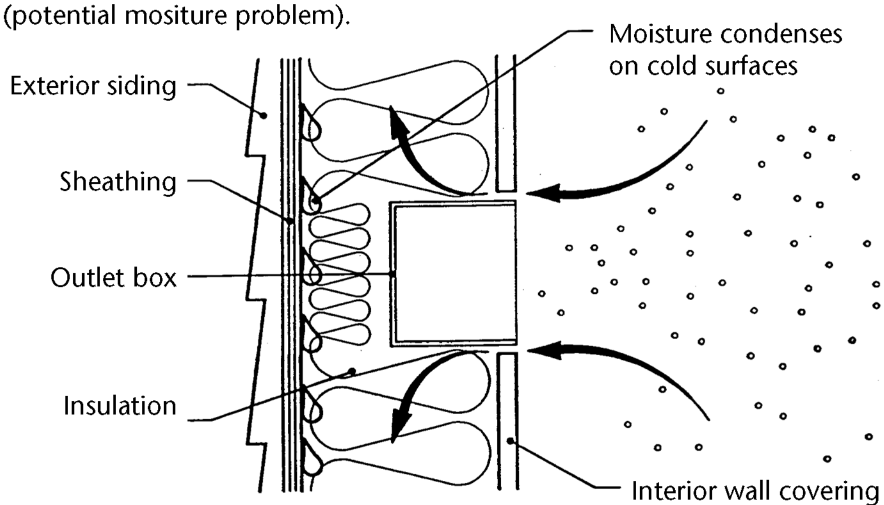
Fiberglass, loose cellulose and rockwool insulation are not suitable air sealing materials; they do not stop air movement.

[502.4.2] **Windows and Doors.** All windows and doors in exterior walls must be sealed between the frame and the rough opening framing material (see Figure 5-2).

Figure 5-1

Critical Areas for Air leakage Control

Positive Pressure:
Moist indoor air leaks into cavities
(potential mositure problem).



Negative Pressure (Exhaust Ventilation):
Dry outdoor air leaking in prevents moist indoor air
from leaking out (prevents moisture problems).

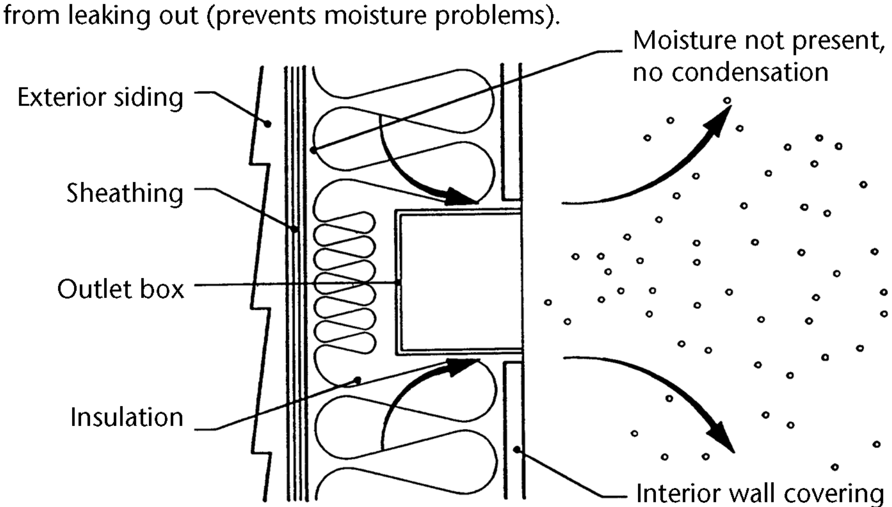
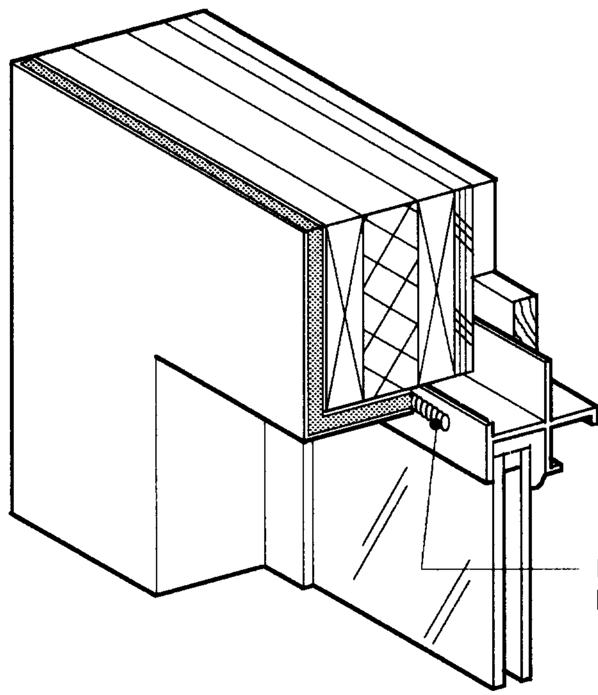


Figure 5-2

Window Sealing



[502.4.3] **Wiring and Plumbing Penetrations.** Holes drilled in top and bottom plates (between heated and unheated spaces) need to be sealed. Plumbing penetrations often leave large holes requiring sealing (see Figure 5-3).

[502.4.3] Drain traps penetrating floors over unconditioned spaces are often overlooked, but must be sealed (see Figure 5-5).

Holes drilled where interior and exterior walls intersect also need to be sealed.

Electrical boxes are considered holes in the envelope and call for sealing. A typical sealing technique is to caulk where the wire enters the box. Make sure a latex or non-petroleum based caulk is used. A silicone type caulk may corrode the insulation on the wiring and expose the wire.

Figure 5-3

Plumbing Bypass

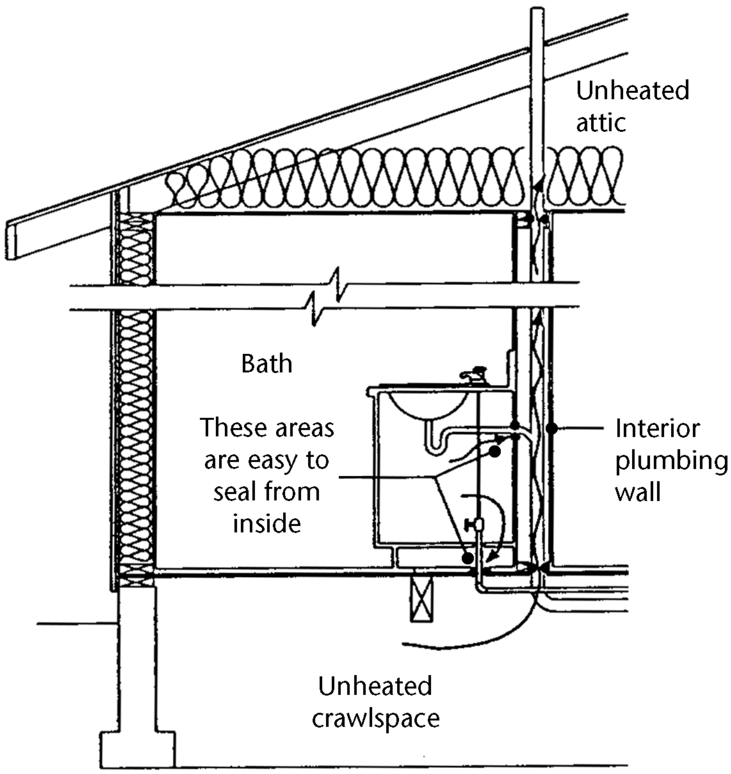
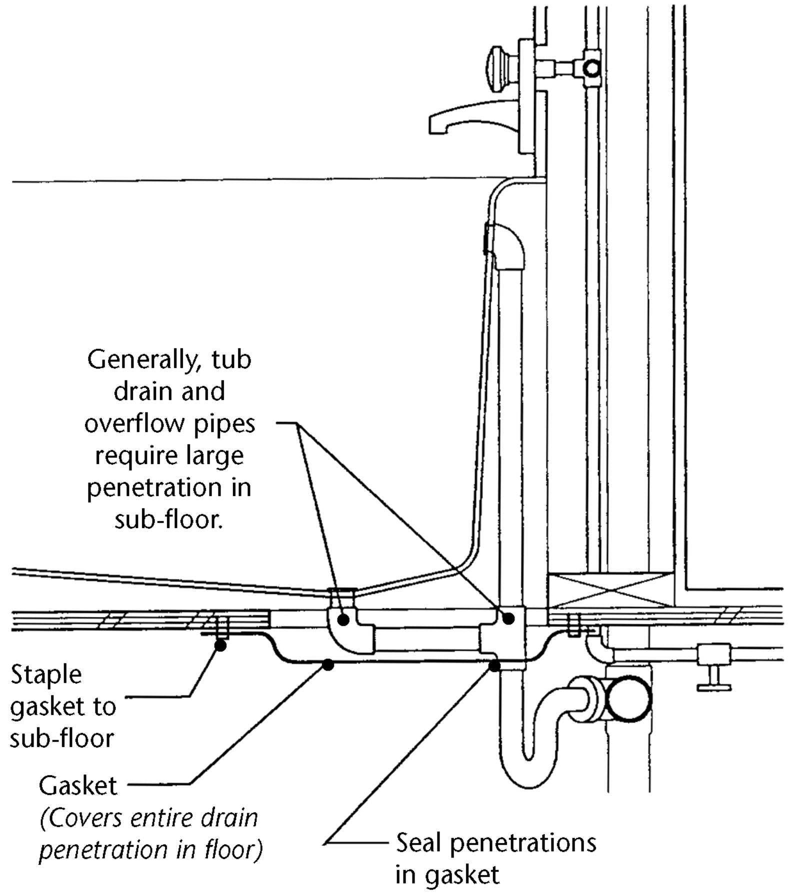


Figure 5-4

Gasket at Tub Penetration



Outlet and switchplate gaskets are recommended, but should always be installed if gaps exist between the box and wallboard.

Recessed Lighting Fixtures. Leaky recessed lighting fixtures, when installed in the building envelope, can be a major source of heat loss and moisture movement. WSEC does not limit the number of recessed lights that can be installed, but does give specific installation specifications.

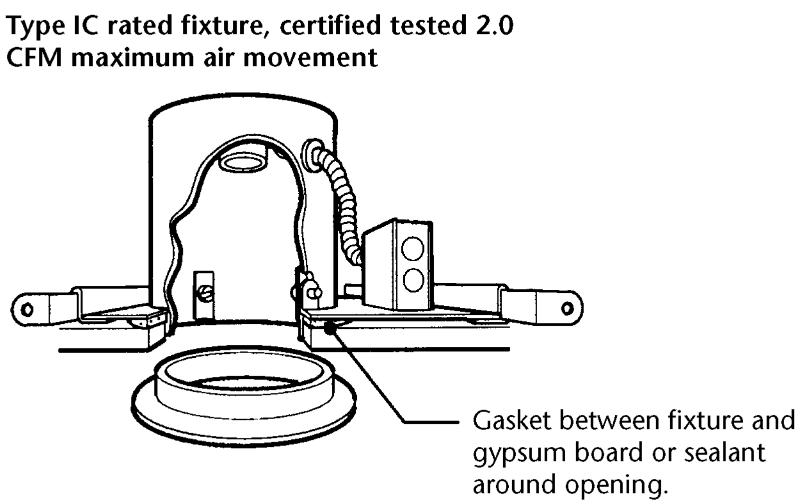
[502.4.4] To meet Code, a recessed fixture must be IC-rated (insulation cover) and installed in a way that limits air leakage (see Figure 5-6):

- Type IC-rated, tested using ASTM E283 method and was certified and labeled to meet the WSEC air leakage requirements.

> **Note:** Many recessed lighting fixtures only meet the air sealing requirement when a specific trim kit is used. Check with your supplier for details.

Figure 5-5

Recessed Lighting Fixtures



[502.4.3a] **Other Building Penetrations.** Additional areas of potential air leakage requiring sealing are:

- **Sole Plates.** Sealing sole plates to subfloors is commonly done after the house is framed and dried in. The caulking is applied at the point where the sole plate meets the subflooring. This method works well because the caulk can be applied to a clean, dry surface for a better bond and the building inspector can easily see it has been done.

  Alternative methods are to seal the sole plate on the bottom when erected or by using a plate gasket product (see Chapter 3, Figures 3-2 and 3-3).

- **Rim Joists.** Rim joists between floors can be sealed either on the interior side with caulking or on the exterior side. The exterior sealing approach requires sealing the house wrap at the rim joist to create an air barrier.

- **Mud Sills.** These are treated the same as sole plates. Mud sills are usually placed on a sill sealer that stops both air leakage and moisture wicking.

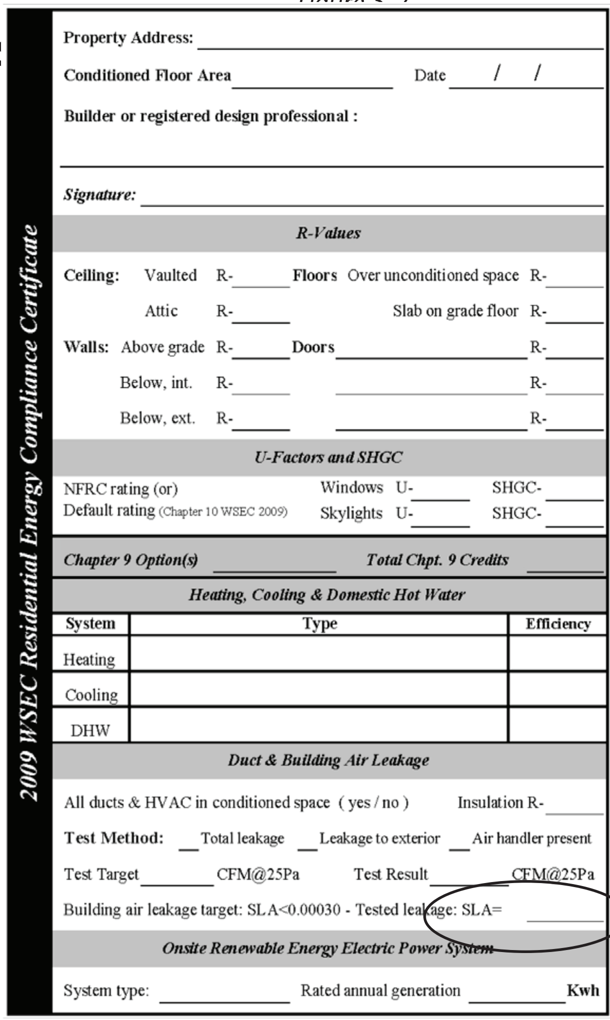
- **Flues.** Chimney penetrations are typically sealed where the support or collar meets the ceiling. Observe all fire rating restrictions.

[502.4.5] **Building Air Leakage Testing.** All new construction and additions over 750 sq.ft. need to have a blower door test done and the resulting air leakage should be less than 0.00030 Specific Leakage Area (SLA) when tested at 50 Pascals (0.2 inch w.g.) of depressurization. Testing can be done any time after rough in and after installation of penetrations of the building envelope, including penetrations for utilities, plumbing, electrical, ventilation and combustion appliances (and sealing of these penetrations) have been completed. Building officials can request that the test be conducted while building department staff is present.

The blower door test results need to be recorded on the certificate that is required in Section 105.4 (see Figure 5-7 for an example).

Figure 5-7

tures



2009 WSEC Residential Energy Compliance Certificate

Property Address: ____________________

Conditioned Floor Area __________ Date ___/___/___

Builder or registered design professional :

____

Signature: ____________________

R-Values

Ceiling: Vaulted R-____ **Floors** Over unconditioned space R-____

Attic R-____ Slab on grade floor R-____

Walls: Above grade R-____ **Doors** __________ R-____

Below, int. R-____ __________ R-____

Below, ext. R-____ __________ R-____

U-Factors and SHGC

NFRC rating (or) Windows U-____ SHGC-____

Default rating (Chapter 10 WSEC 2009) Skylights U-____ SHGC-____

Chapter 9 Option(s) __________ ***Total Chpt. 9 Credits*** ____

Heating, Cooling & Domestic Hot Water

System	Type	Efficiency
Heating		
Cooling		
DHW		

Duct & Building Air Leakage

All ducts & HVAC in conditioned space (yes / no) Insulation R-____

Test Method: __ Total leakage __ Leakage to exterior __ Air handler present

Test Target ______ CFM@25Pa Test Result ______ CFM@25Pa

Building air leakage target: SLA<0.00030 - Tested leakage: SLA= ______

Onsite Renewable Energy Electric Power System

System type: __________ Rated annual generation ________ **Kwh**

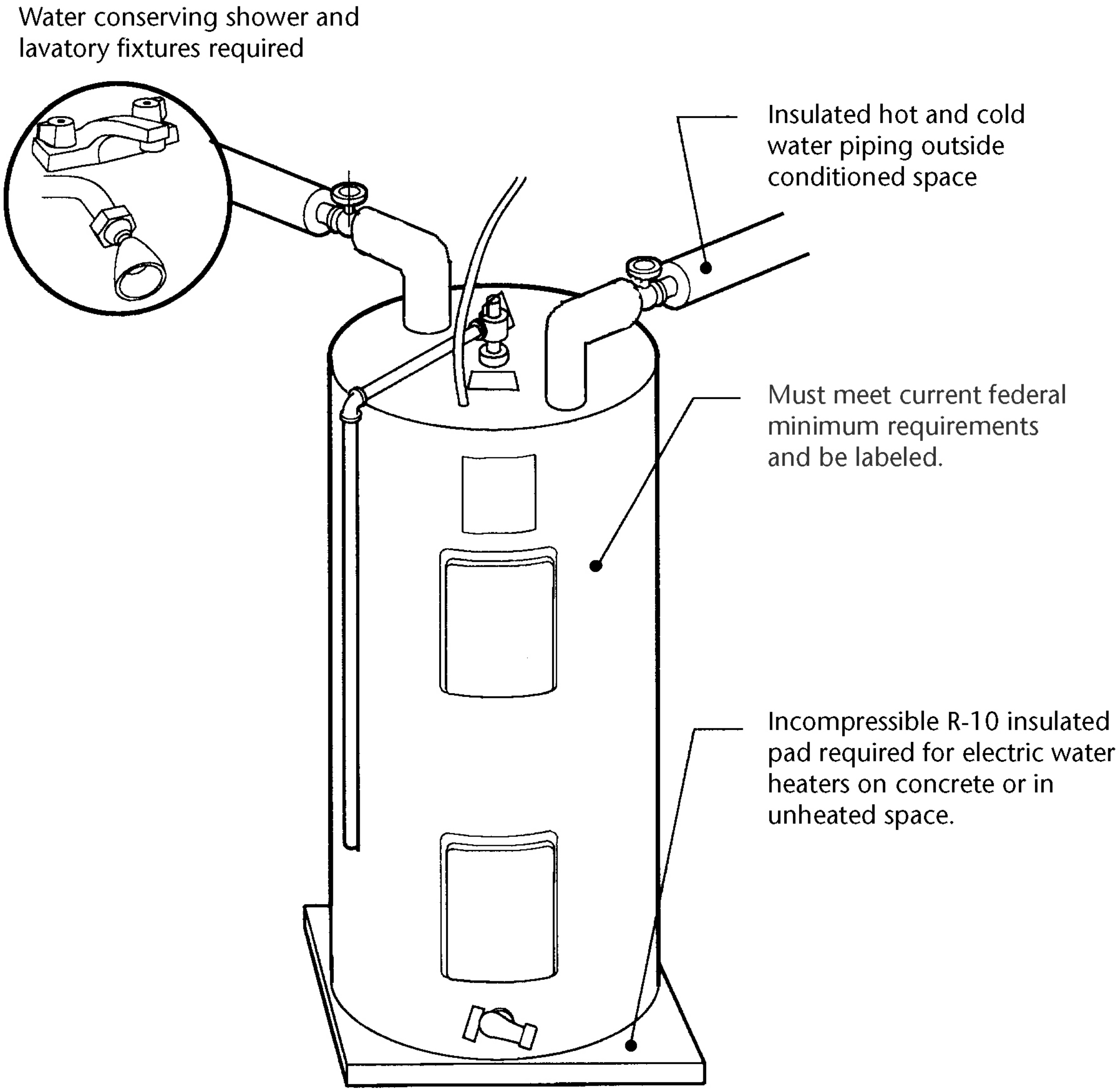
Record building air leakage results here

Chapter 6: Plumbing

The *Washington State Energy Code* (WSEC) sets standards that minimize heat loss and conserve water (see Figure 6-1).

Figure 6-1

Plumbing Requirements



[504.8.1] **Water Conservation.** Flow rates for shower heads and lavatories are limited by the Washington Administrative Code.

[504.2.1] **Water Heaters.** All water heaters must comply with current federal minimum standards and be labeled. For more information, please visit: ***www.eere.energy.gov/buildings/appliance_standards***

All electric water heaters in unheated spaces or on concrete floors must be placed on an incompressible insulated surface with minimal thermal resistance R-10.

[504.3] Residential water heaters must be set to a maximum 120°F.

[504.4] Each water heater must have a separate shut-off switch or valve.

[504.2.1] Storage water heaters used for combination space heating and water heating must meet the efficiencies listed in Section 504.2.1.

[503.11] **Pipe insulation.** Hot and cold water pipes outside the conditioned envelope of the building must be insulated to the level specified in WSEC Table 5-12 (R-3.6 for < 2-inch pipe, R-5.4 for > 2 inches).

Swimming Pools. Heated swimming pools must meet the following requirements:

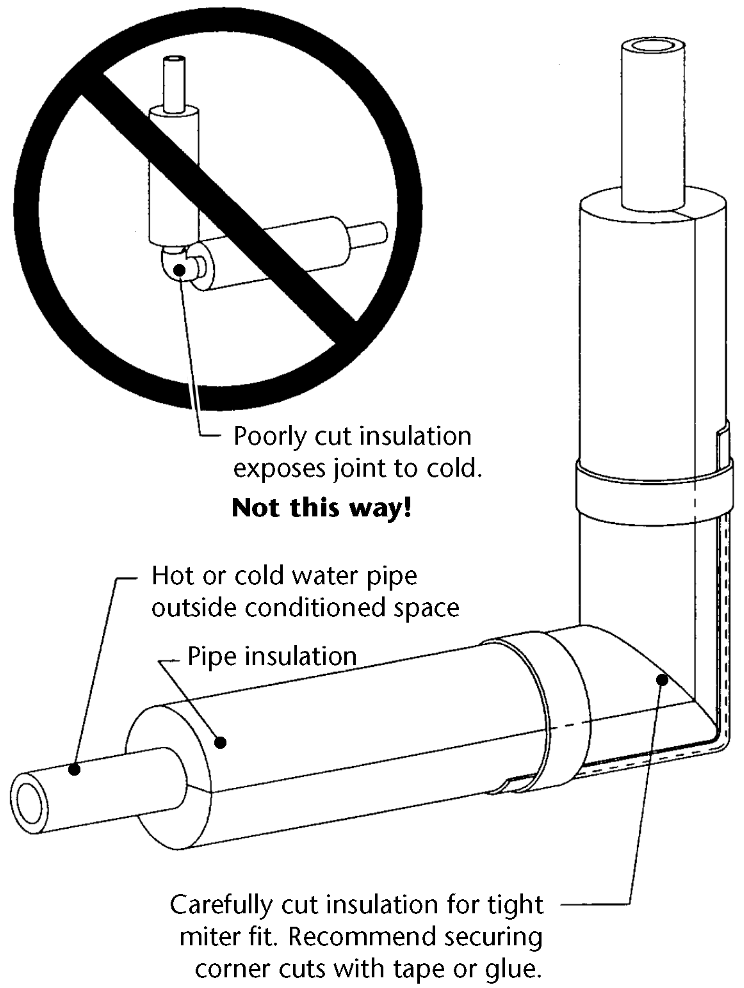
[504.5.3] Have a pool cover approved by the Building Official.

[504.5.1] All pool heaters must have an accessible ON/OFF switch to shut off the heater without adjusting the thermostat.

[504.5.1] Pool thermostats must be adjustable to a minimum 65°F setting.

Figure 6-2

Pipe Insulation



Note: Polyethylene foam will provide approximately R-3.6 per inch of thickness.

Residential Pool Pumps and Controls. Pool pump motors cannot be split phase or capacitor start induction run type.

[504.5.2.1] One horsepower (1 hp) pump motors or larger must have the capability of operating at two or more speeds. The low speed is limited to one-half (1/2) the motor's maximum rotation rate.

Pump controls must have the capability of operating the pool pump with at least two speeds. The default circulation speed is the lowest speed with the control having an override allowing the pump to operate at high speed not to exceed one normal cycle.

Chapter 7: Heating and Cooling Systems

Design Conditions

The *Washington State Energy Code* (WSEC) sets the following conditions for heating system design and equipment sizing:

[302.2.1]

- **Indoor Design Temperature:** 70°F heating - 78°F cooling.

> *EXCEPTION: Other design temperatures may be used provided they result in lower energy consumption.*

[302.1]

- **Outdoor Design Temperature:** Based on local weather data taken from Table 3-1 of the 2009 WSEC. If you cannot find a particular location listed in Table 3-1, use a site near your location with similar weather conditions.

- **Recommended Air Infiltration Rate for Equipment Sizing:** 0.6 air changes/hour (ACH). 0.6 ACH is a liberal air infiltration estimate for homes meeting code required infiltration rates of .00030 SLA. This infiltration rate is from the Air Conditioning Contractors of America (ACCA) *Manual J* Table 5A default infiltration rates during the heating season.

  .6 ACH is the assigned infiltration rate for a 1,501-2,000 sq.ft. home with average air leakage. Infiltration rates for smaller or larger houses of similar construction will vary slightly.

Design Heat Load (DHL) Calculation

[503.2.1] Heating and cooling design loads for the purpose of sizing the heating and/or cooling equipment must be calculated in accordance with accepted engineering practice, including infiltration and ventilation.

[503.2.2] **System Sizing Limit.** The Code requires that systems be sized as required in *International Residential Code* (IRC) Section M1401.3. IRC M1401.3 states that systems be sized using ACCA Manual S and Manual J or other approved calculation methods. Many jurisdictions allow the use of the heating system sizing calculators that are incorporated into the *WSU Extension Energy Program Prescriptive Compliance and Component Performance worksheets*. You should check with the governing jurisdiction to see if they accept the WSU Extension Energy Program forms.

The WSEC allows some exceptions to system sizing limitations.

- Packaged equipment that provides both heating and cooling, such as a heat pump, need only show compliance for the heating or cooling sizing limit. The unit should be sized for the larger of the two loads.

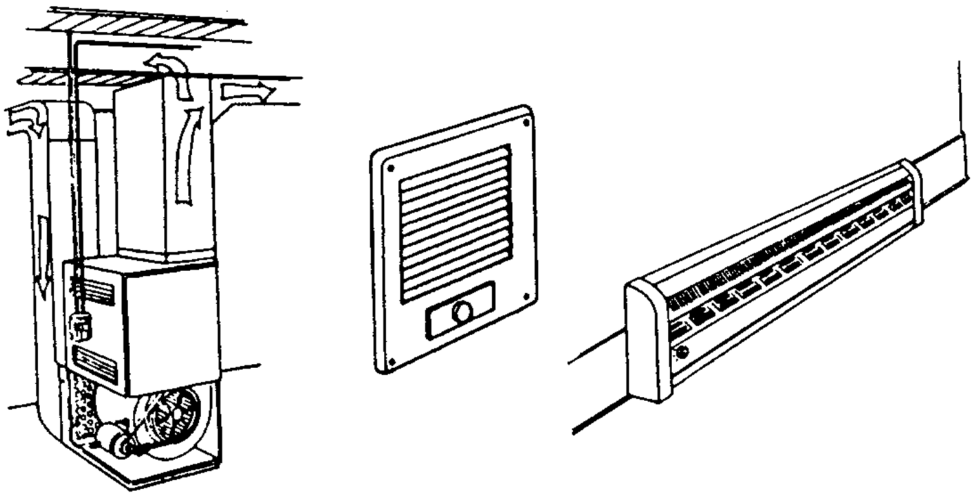
- If installing a gas or oil furnace and the system size is less than 40,000 Btu/hr, it is exempt from sizing limits.

- The WSEC allows the installation of stand by equipment if controls are installed that only allow the stand by equipment to operate when the primary system is not.

- The Code also allows the installation of electric resistance heaters less than 2 kW without sizing limitations.

Figure 7-1

Electric Resistance Heating Systems



(503.4)

HVAC Equipment Performance Requirements

Electric Resistance Heating Systems

System efficiency. No requirement. Electric resistance heating is considered 100 percent fuel efficient.

Combustion Heating Systems

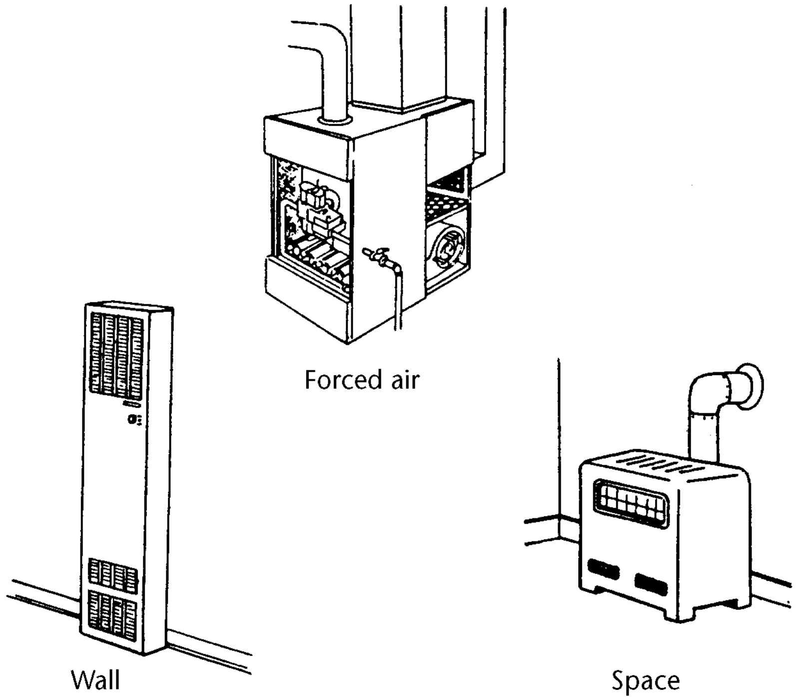
System efficiency. A minimum 78 percent AFUE is required.

- Oil, gas, or propane space heaters require an intermittent ignition device and must meet 1987 NAECA efficiency requirements.

- Chapter 9 of the 2009 WSEC gives 1.0 credit for systems installed with a 92 percent AFUE or greater.

Figure 7-2

Combustion Heating Systems



Heat Pumps

System efficiency.

Air Source:

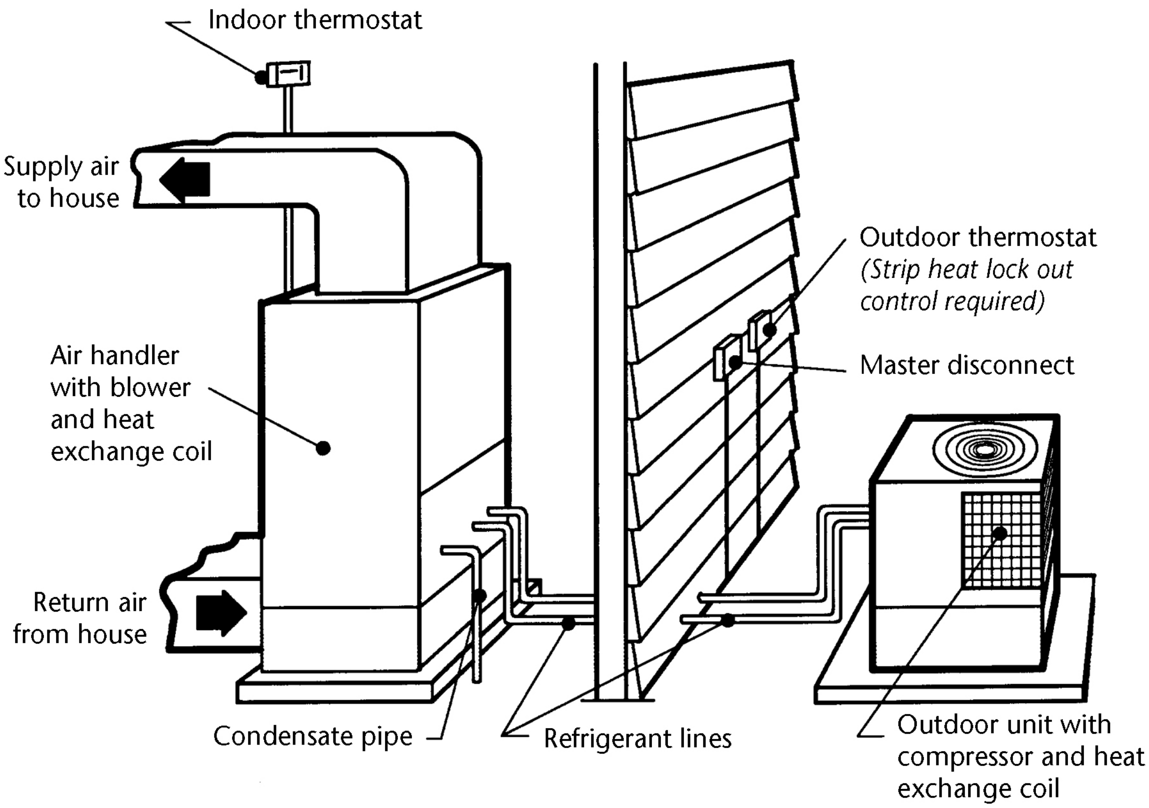
- For split and single package systems, a minimum of 7.7 Heating Seasonal Performance Factor (HSPF) for heating and 13.0 Seasonal Energy Efficiency Ratio (SEER) is required for cooling for systems under 65,000 Btu/h (see WSEC Table 14-1B).

- Chapter 9 of the 2009 WSEC gives 1.0 credit for systems installed with an HSPF of 8.5 or greater.

Figure 7-3

Split Package Heat Pump Options

Ducted



Ductless

Air handler with blower and heat exchange coil

Outdoor unit with compressor and heat exchange coil

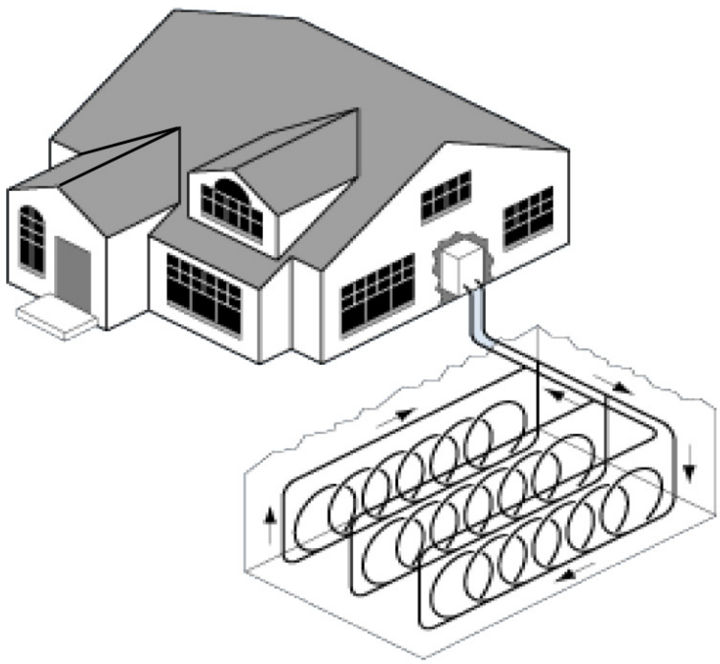
Ground Source

- Minimum Coefficient of Performance (COP) = 3.1 Chapter 9 of the 2009 WSEC gives 2.0 credits for systems installed with a COP of 3.3 or greater.

Figure 7-4

Ground Source Closed Loop System

From EERE.ENERGY.GOV



[503.8] **Controls. Applicable to all system types**

A primary space conditioning system must have a programmable thermostat as its control. At a minimum, the programmable thermostat must have the capability to program temperature settings for five weekdays and two weekend days. In addition, the thermostat must be able to be programmed for two setback periods per day.

The Code also states that each additional space conditioning system within a dwelling unit shall be provided with at least one adjustable thermostat for the regulation of temperature. An example of this may be a house with electric resistance wall heaters for its heating system. The main living area could be controlled by a programmable thermostat while the bedrooms and bathrooms would have their heaters controlled by individual and adjustable thermostats.

The WSEC allows two exceptions for space conditioning control requirements. An occupant sensor may be used instead of a programmable thermostat. The occupant sensor must shut off the system when no occupants are detected for a period of up to 30 minutes.

A timer control may be installed if the timer limits the operation of the system to two hours.

The WSEC requires that each thermostat shall be capable of being set by adjustment or selection of sensors as follows:

- When used to control heating only: 55°F to 75°F
- When used to control cooling only: 70°F to 85°F.
- When used to control both heating and cooling, the thermostat shall be capable of being set from 55°F to 85°F and shall have an adjustable deadband of not less than 10°F between hot and cold.
- If the heat pump has an electric resistance backup heating system, a control that locks out the strip heat needs to be installed. The control must prevent the backup system from operating when the heating load can be met by the heat pump alone.
- Have the capability to lock out supplementary heating based on outdoor temperature. The Code requires that the control has a maximum setting of

40°F and is set to 32°F at final inspection. If the heat pump will not meet the heating load at the 32^0, the lockout can be set higher but not above 40^0

.

- Lockout capacity may be met by external or internal components. Programmable thermostats with lockout capability or aftermarket devices that meet the temperature requirements noted above are examples of externally applied lockout mechanisms. Some heat pumps may have lockout capability built into the system.

Duct Systems

Insulation Requirements

[503.9] Ducts, plenums, and enclosures outside conditioned space such as crawl spaces, attics or garages must be insulated to R-8. Ducts and plenums on roofs and/or the exterior of buildings must have an approved weatherproof barrier. These ducts need to be insulated to R-8 in Climate Zone 1 and R-10 in Climate Zone 2. Ducts and plenums in slabs or in the ground shall be insulated to R-5 with material approved for below grade application for both climate zones. Extruded polystyrene is typically used for this requirement.

Exceptions:

Ducts do not have to be insulated when:

1. *The heat gain or loss of the ducts, without insulation, will not increase the energy requirements of the building.*
2. *Ducts are within HVAC equipment.*
3. *Exhaust air ducts. Some exhaust air ducts are required to be insulated by the Washington State Amendments to the IRC.*
4. *Supply or return air ducts installed in basements or cellars in one and two-family dwellings.*

5. The insulation required on supply air ducts may be reduced to R-4 when the ducts are located in buffer spaces not intended for human occupancy such as insulated crawl spaces and enclosed attic spaces. To use this exception, the buffer space must be air sealed and insulated to the full value of the conditioned spaces.

Duct Fasteners

Ducts must be fastened in accordance with the *International Mechanical Code* (IMC). For small sheet metal ducts, a minimum of three screws per connection equally distributed around the duct, or equivalent is required. For flex duct, and duct board, you must follow instructions developed by the SMACNA, noted in the IMC. More information can be found at: ***www.smacna.org/***

[503.10] Building cavities may not be used as ducts. You may run a duct through a building cavity but installation of these ducts in exterior walls, floors or ceilings shall not displace required envelope insulation.

Leakage Testing

Ducts shall be leak tested in accordance with RS-33 (available at ***www.energy.wsu.edu/code***), using one of the maximum duct leakage rates specified below:

- Post construction test. This test is typically done at or near completion of construction.

    – Leakage rate to outdoors shall be less than or equal to 6 percent of the conditioned floor area tested at 25 pascals pressure. This test measures duct leaks that are outside of the conditioned space. To perform this test you need a duct tester and a blower door.

Or

- Total leakage rate shall be less than or equal to 8 percent of the conditioned floor area tested at 25 pascals pressure.

- Rough-in test. This test is done immediately after the HVAC system is installed. This is the preferred time to test so the ducts are still exposed and any leakage areas are accessible.

  - Total leakage rate shall be less than or equal to 6 percent of the conditioned floor area tested at 25 pascals pressure.

    Or

  - Total leakage shall be less than or equal to 4 percent of the conditioned floor area tested at 25 pascals pressure if the air handler is not present. To accomplish this test you need to test the supply ducts and the return ducts and add the leakage rates together.

EXCEPTIONS:

1. Duct testing is not required if the air handler and all ducts are located within the conditioned space.

2. Duct testing is not required if the furnace is a nondirect vent type combustion appliance installed in an unconditioned space. This is an atmospherically vented furnace installed outside the conditioned space, usually in a garage. This exception allows a maximum of six feet of connected ductwork in the unconditioned space. All additional supply and return ducts need to be inside the conditioned space.

Duct Sealing

All duct, air handler and filter box seams and joints shall be sealed.

Primary sealants approved for ducts include welds, gaskets, mastic or mastics with embedded fabric systems. Tapes may be used if specific installation procedures provided by the manufacturer are followed.

Figure 7-5

Duct Insulation and Sealing

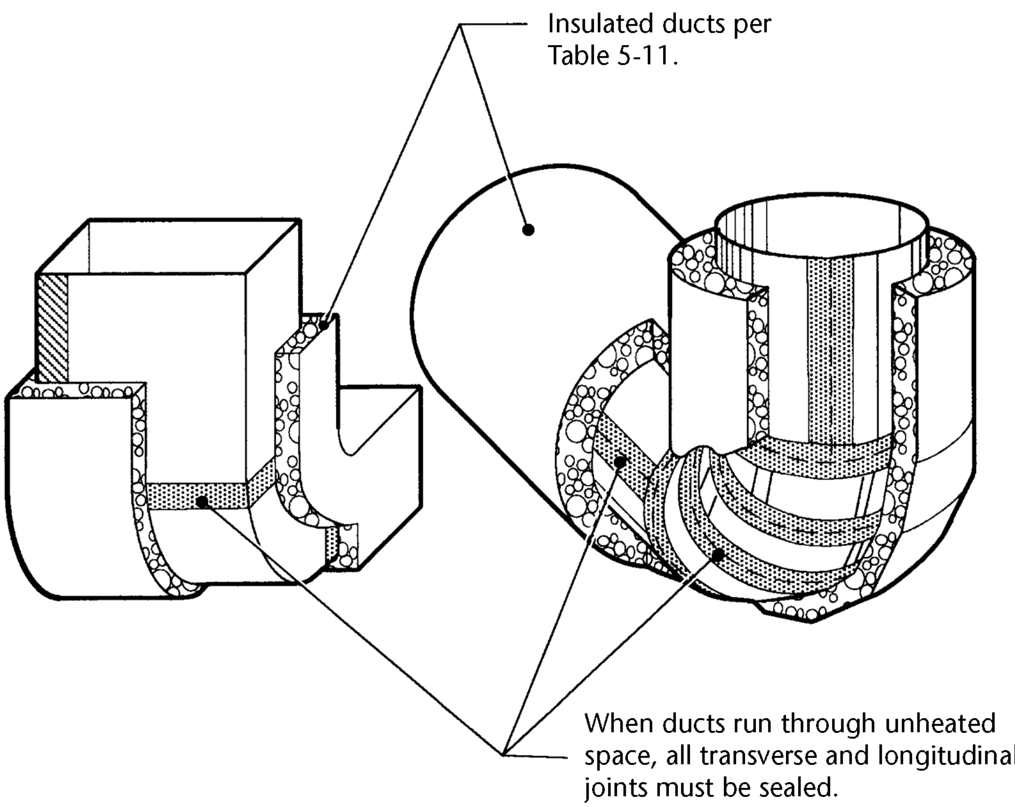
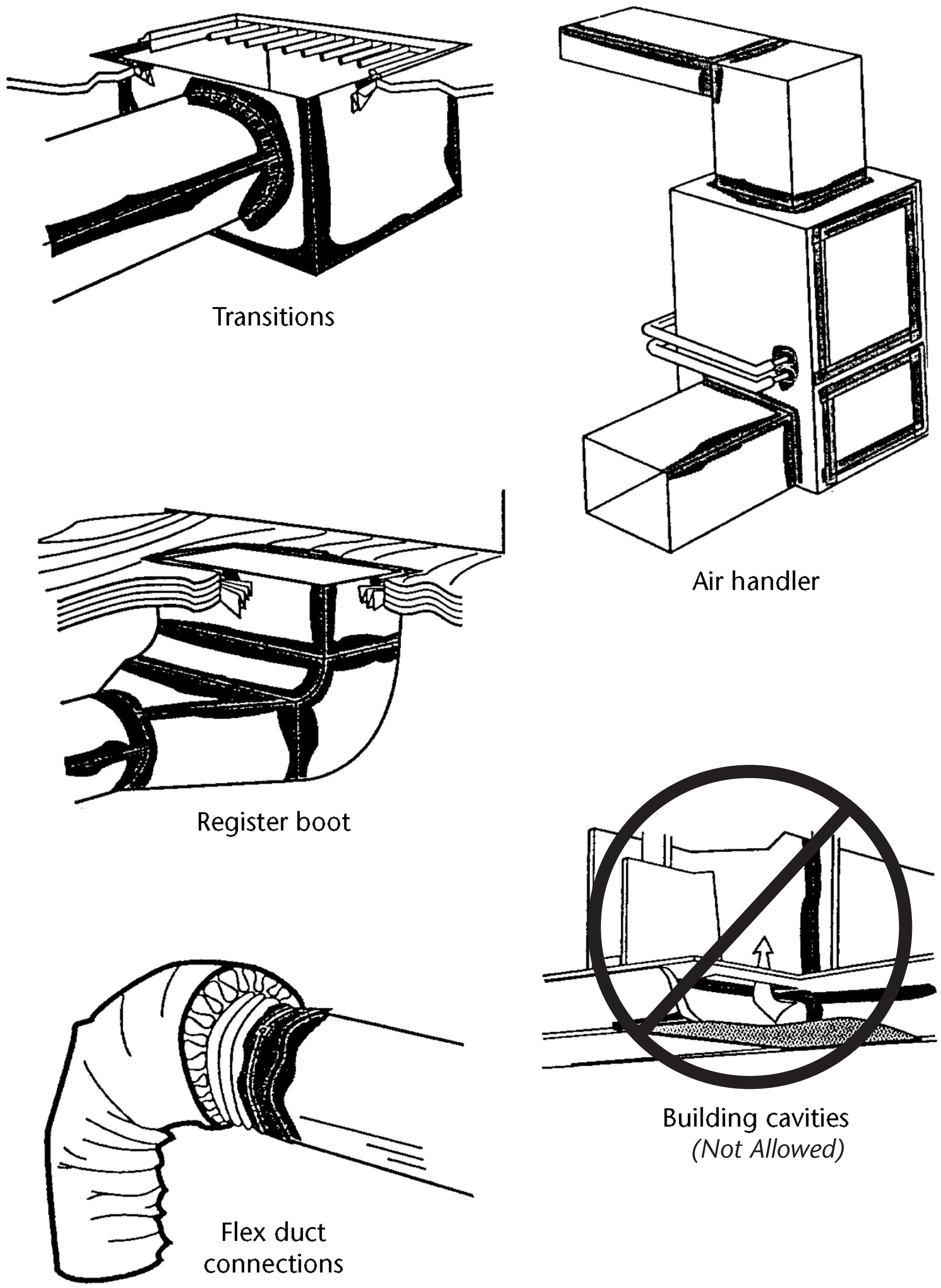


Figure 7-6

Sealing Ducts



Tapes must be installed in accordance with the manufacturer's instructions, or in the case of UL 181 sealants, in accordance with the product listing. If the product does not have instructions specific to the material or application it is being applied to, it does not meet the intent of the Code. For example, if tape is used to seal sheet metal, instructions published by the manufacturer must include notes on application to sheet metal. If the sheet metal needs to be cleaned, the manufacturer's instructions must provide specific instructions on cleaning. These instructions must be followed by the installer.

For additional information on duct sealing, see the *Builder's Field Guide's Supplement A*, "Improving Forced Air Heating Systems."

Chapter 8: Fireplaces and Wood Stoves

[51-51 WAC] To ensure indoor air quality and reduce heat loss, Washington State's amendments to the *International Residential Code* (IRC) place installation requirements on all solid fuel combustion appliances, including:

- All wood stoves, including cook stoves.
- Pellet stoves.
- Fireplaces.
- Masonry heaters (must have Washington State Department of Ecology approval).

Combustion Air

In order to prevent backdrafting, an adequate supply of combustion air must be supplied to each solid fuel combustion appliance (see Figure 8-1).

[R1006] Combustion air must:

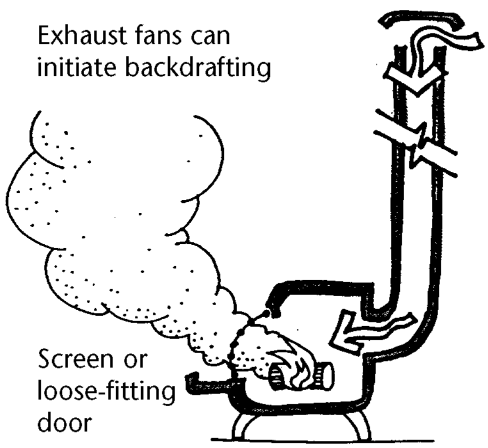
- Come from outside the building structure.
- Originate from a point below the firebox.
- Enter through a minimum 4-inch diameter duct (minimally 6 square inches for fireplaces) less than 20 feet in length.
- Be directly connected to the appliance (see Figure 8-1).

Exceptions: Combustion air may be supplied to the room in which the solid fuel combustion appliance is located rather than directly to the appliance when either:

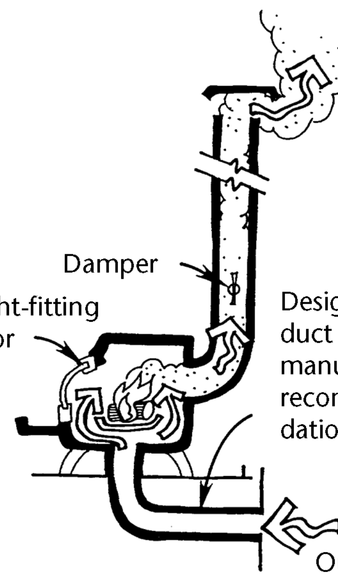
- The appliance is part of a central heating system installed in an unconditioned space in accordance with the *International Mechanical Code* (IMC).
- The appliance is installed in existing construction directly on a concrete floor or surrounded by masonry as in a fireplace.

Figure 8-1

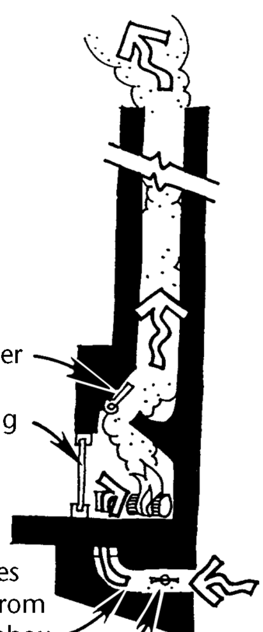
Backdrafting



Correctly Operating Stove with Outside Combustion Air



Correctly Operating Fireplace with Outside Combustion Air



Site-built fireplaces may use a flue draft induction fan instead of doors.

In addition: Alternative methods of providing combustion air (using the manufacturer's specifications) are allowed if the unit and combustion air supply have been certified. They must have passed a test specified by the IRC Section 1006.2 and the test must have been done by an independent lab.

Tight-Fitting Doors

[R1001.7.1] All solid fuel burning appliances, fireplaces and masonry heaters must have tight-fitting ceramic glass or metal doors.

Exception: Site-built fireplaces may use a flue draft induction fan instead of doors.

Note: *Although a flue draft induction fan will minimize potential backdrafting, glass doors are also recommended to prevent heat loss when the fireplace is not in use.*

Flue Dampers

[R1001.7.1] Fireplaces must have a tight-fitting flue damper.

Exception: Fireplaces with gas logs must be installed in accordance with the IMC.

Chapter 9: WSEC Chapter 9 Credits

[901]

Additional Residential Energy Efficiency Requirements

The 2009 *Washington State Energy Code* (WSEC) now requires that all *International Residental Code* (IRC) defined occupancies develop one credit from Chapter 9, Table 9-1, if complying prescriptively or when using the component performance approach. If complying with IRC Chapter 4, *Systems Analysis*, compliance is accomplished by demonstrating that the proposed building's annual energy use is 8 percent less than the target building.

Table 9-1 includes 14 options, with various measures ranging from .5 credits to 3 credits. Options must be chosen to total one credit for the project.

HVAC Equipment

There are four options for credits related to HVAC equipment efficiency and location:

- **High Efficiency HVAC Equipment: 1 credit**
  You can obtain 1 credit if you install a 92 percent or higher Annual Fuel Utilization Efficiency (AFUE) gas, propane or oil-fired furnace or boiler or an air-source heat pump with a minimum Heating Season Performance Factor (HSPF) of 8.5. There is no minimum Seasonal Energy Efficiency Ratio (SEER) requirement for heat pumps to claim this credit.

- **High Efficiency HVAC Equipment: 2 credits**
  2 credits are obtained for installing a closed loop ground source heat pump with a minimum Coefficient of Performance (COP) of 3.3 or better. Even though the WSEC calls out a ground source

heat pump for this credit, a water source heat pump with the same efficiency or higher should also be granted 2 credits.

- **High Efficiency HVAC Equipment: 1 credit**
  1 credit can be taken for installing a ductless split system heat pump with zonal control. To satisfy the requirements for this credit, it has to be installed in a house with zonal electric heat and the heat pump must supply heat to at least one zone. For example, the ductless heat pump could be installed in the main living area of the house with electric resistance heat (baseboard or wall units) in the bedrooms.

- **High Efficiency HVAC Distribution System: 1 credit**
  1 credit is obtained when all HVAC components, including both the furnace and ductwork, are installed inside the conditioned space. Combustion equipment must be direct vent or sealed combustion. This credit is not allowed if ductwork or the air handler is located in a conditioned crawl space. Also, this credit cannot be taken for a structure heated with an electric resistance system such as baseboards or electric wall heaters. Direct combustion equipment cannot be less than 80 percent AFUE to claim this credit.

Building Envelope

Three options are available for making the building envelope more efficient. Prescriptive packages can be used in Climate Zone 1 only.

- **Efficient Building Envelope 1: .5 credit**
  .5 credits are allowed if the building envelope is improved in Climate Zone 1 to:

  – Windows U-.28 (area weighted average)
  – Floor R-38
  – Slab-on-grade R-10 fully insulated
  – Below grade slab R-10 fully insulated

  Or you may use the component performance approach. If the structure has at least a 5 percent reduction in UA from the target house, .5 credits are obtained.

- **Efficient Building Envelope 2: 1 credit**
  1 credit is gained by improving the building envelope in Climate Zone 1 to:

  – Windows U-.25 (area weighted average)
  – Floor R-38
  – Slab-on-grade R-10 fully insulated
  – Below grade slab R-10 fully insulated
  – R-21+R-5 below grade basement walls. This measure requires R-21 cavity insulation with R-5 foam sheathing on the exterior of the below grade wall.

  Or you may use the component performance approach. If the structure has at least a 15 percent reduction in UA from the target house, 1 credit is obtained.

- **Super-Efficient Building Envelope 3: 2 credits**
  2 credits are allowed for improving the building envelope in Climate Zone 1 to:

  - Windows U-.22.
  - Walls R-21+R-12. This measure requires R-21 cavity insulation and R-12 exterior foam sheathing.
  - Floor R-38.
  - Slab-on-grade R-10 fully insulated.
  - Below grade slab R-10 fully insulated.
  - R-21+R-12 below grade basement walls. This measure requires R-21 cavity insulation with R-12 foam sheathing on the exterior of the below grade wall.

  Or you may use the component performance approach. If the structure has at least a 30 percent reduction in UA from the target house, 2 credits are obtained.

Air Leakage Control

There are two options for tightening the building envelope and reducing air leakage. Because the leakage rate of the house is being reduced, the whole house ventilation system must be provided by a heat recovery ventilator (HRV) to take either of these credits.

- **Air Leakage Control and Efficient Ventilation: .5 credit**
  If the specific leakage area (SLA) of the house is reduced to .00020 from the standard code maximum SLA of .00030, .5 credits are obtained.

Documentation of the test results are recorded on the certificate posted at the house (See Figure 5-7 in Chapter 5). An HRV must also be installed to claim this credit.

- **Additional Air Leakage Control and Efficient Ventilation: 1 credit**

  1 credit is allowed if the SLA of the house is further reduced to .00015. As with the previous credit, documentation of the test results are recorded on the certificate posted at the house. An HRV must also be installed to claim this credit.

Water Heating Equipment

Two options are available for water heating equipment and/or components.

- **Efficient Water Heating: .5 credit**

  .5 credits are given when installing a minimum .62 Energy Factor (EF) gas, propane or oil water heating equipment. If installing an electric water heater, a minimum EF of .93 or higher is required for this credit. In addition, all showerheads and kitchen sink faucets need to be rated for 1.75 gallons per minute (GPM) or less. All other lavatory faucets need to be rated at 1.0 GPM or less.

- **High Efficiency Water Heating: 1.5 credits**

  1.5 credits are given if ***one*** of the following is met:

  – The water heating system includes a minimum of .82 EF gas, propane or oil water heater. This is likely going to be an on-demand or 'tankless' type of system.

– Solar water heating can be installed to supplement a standard water heater. It must provide a rated minimum savings of at least 85 therms or 2,000 kWh. Savings are based on the Solar Rating Certification Corporation (SRCC) Annual Performance of OG-300 Certified Solar Water Heating Systems. Their website is: ***www.solarrating.org/ratings/ratings.htm*** Credits for an electric heat pump water heater are allowed if the unit has a minimum EF of 2.0.

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House Size

House size credits and debits are given based on the size of the house.

- **Small Dwelling Unit: 1 credit**
  1 credit is given to houses less than 1,500 square feet. and with a maximum window and door area of 300 square feet. This credit also applies to additions less than 750 square feet.

- **Large Dwelling Unit: -1 credit**
  Minus (-) 1 credit is assessed as a deficit for houses exceeding 5,000 square feet. This means that houses over 5,000 square feet need to get two credits from Chapter 9 to satisfy Chapter 9 requirements.

Renewable Electric Energy Production

Up to 3 credits are available for renewable electric energy production.

- **Renewable Electric Energy: .5 credit**
  .5 to 3 credits are allowed for every 1,200 kWh of annual electrical generation for on-site solar or wind. A documentation method is outlined in Chapter 9 of the WSEC, see Option 8 in Table 9-1.

Chapter 10: Default Heat Loss Coefficients

Building component heat loss coefficients are used extensively when complying with either the **Component Performance** or **System Analysis Approach**. The **Prescriptive Approach** only utilizes heat loss coefficients for doors, windows and skylights.

The *Washington State Energy Code* (WSEC) Chapter 10 lists default heat loss coefficients for hundreds of building assemblies. Heat loss coefficients are listed as default **F-factors** for slabs and default **U-factors** for most other components.

The WSEC Chapter 10 default heat loss coefficients for **windows**, **skylights** and **doors** should only be used when the product manufacturer or dealer cannot provide you with National Fenestration Rating Council (NFRC) tested U-factors. In most cases it will be to your advantage to contact the manufacturer to obtain NFRC tested U-factors before submitting your application for a building permit.

Component Descriptions

To assure you select the correct heat loss coefficient, it is important to read the description of the component that precedes each table. The heat loss coefficient will vary based on the construction method. Examples of construction details that will change the heat loss coefficient include framing style, siding type, slope of attic, insulation type and insulation location. The illustrations used in earlier chapters of this guide will help you visualize the written descriptions.

What to Do If a Building System is Not Listed in WSEC Chapter 10

[104] WSEC requires that plans and specifications be submitted to the building official with all the needed supporting data.

This could include detailed U-factor calculation for building systems not detailed in the Chapter 10 default heat loss coefficients. Heat loss coefficients should be calculated using the methods detailed in the *ASHRAE Handbook of Fundamentals*.

Manufacturers of pre-fabricated building assemblies may have engineering staff available that will provide the required calculations.

Links to WSEC Chapter 10 Default Heat Loss Coefficients

Table 10-1: Default Wall U-Factors and Slab F-Factors for Basements

Table 10-2: Default F-Factors for On-Grade Slabs

Table 10-3: Default U-Factors for Floors Over Vented Crawlspace or Unheated Basement

Table 10-4: Default U-Factors for Floors Over Heated Plenum Crawlspaces

Table 10-4A: Default U-Factors for Exposed Floors

Table 10-5: Default U-Factors for Above-Grade Walls

- 2 x 4 Single Wood Stud: R-11 Batt
- 2 x 4 Single Wood Stud: R-13 Batt
- 2 x 4 Single Wood Stud: R-15 Batt
- 2 x 6 Single Wood Stud: R-19 Batt
- 2 x 6 Single Wood Stud: R-21 Batt
- 2 x 6 Single Wood Stud: R-22 Batt
- 2 x 6 Single Wood Stud: Two R-11 Batts
- 2 x 8 Single Stud: R-25 Batt
- 2 x 6: Strap Wall
- 2 x 6 + 2 x 4: Double Wood Stud
- 2 x 4 + 2 x 4: Double Wood Stud
- Log Walls
- Stress Skin Panel

Table 10-5A: Default U-Factors for Overall Assembly Metal Stud Walls

Table 10-5B: Default U-Factors for Concrete and Masonry Walls

- 12-inch Concrete Masonry
- 8-inch Clay Brick
- 6-inch Concrete Poured Or Precast

Table 10-6: Other Than Group R Occupancy: Default U-Factors for Vertical Glazing, Overhead Glazing and Opaque Doors

- Vertical Glazing
- Overhead Glazing
- Opaque Doors

Table 10-6A: Group R Occupancy: Default U-Factors for Vertical Glazing

Table 10-6B: Group R Occupancy: Default U-Factors for Vertical Glazing for Small Businesses

Table 10-6C: Group R Occupancy: Default U-Factors for Doors

- Revolving Doors (Rough Opening: 82 in. x 84 in.)
- Sectional Overhead Doors (Nominal: 10 ft. x 10 ft.)

Table 10-6D: Group R Occupancy: Default U-Factors for Glazed Doors

Table 10-6E: Group R Occupancy: Default U-Factors for Overhead Glazing

Table 10-7: Default U-Factors for Ceilings

Table 10-8: Assumed Effective Air Changes Per Hour

Table 10-8A: Default Heat Capacity/Density Product for Air

Table 10-9: Heat Capacity

Table 10-10: Default Mass Values

Chapter 11: Lighting

Interior Lighting

[505.1] Fifty percent of all interior lighting luminaires (fixtures) are required to be high efficacy luminaires. To determine what a high efficacy luminaire is, you need to refer to the definition located in Chapter 2 of the *Washington State Energy Code* (WSEC). The efficiency of light bulbs is referred to as efficacy, which is the measure of light output (lumens) compared to the energy (watts) needed to power the bulb. A high efficacy luminaire is defined as a lighting fixture that does not contain a medium screw base socket and whose lamps or other light sources have a minimum efficiency of:

- 60 lumens per watt for lamps over 40 watts;
- 50 lumens per watt for lamps over 15 watts to 40 watts;
- 40 lumens per watt for lamps 15 watts or less.

[1521] The WSEC allows two exceptions to this requirement. Lighting compliance can be met by using the *Prescriptive Lighting Option* in Section 1520 or the *Lighting Power Allowance* in Section 1530. The *Prescriptive Lighting Option* allows unlimited use of certain types of fluorescent lighting fixtures. This option is used predominantly in commercial buildings and although it is allowed to be used in residential, it probably will not be used often.

[1530 Table 15-1] The *Lighting Power Allowance* allows a maximum of 1.0 watt per square foot of floor area of installed lighting. Keep in mind this applies to hard wired luminaires and not to plug-in lights such as table lamps. This means the average size house in Washington (2,200 sq.ft.) is allowed to have 2,200 watts of installed luminaires of any type.

Note: The Washington State Building Code Council provided an interpretation of this code section. They stated that screw in lamps can be substituted for luminaires if it is demonstrated that the application meets or exceeds the provisions of the WSEC. To view this interpretation go to: ***https://fortress.wa.gov/ga/apps/sbcc/Page.aspx?nid=71***

Exterior Lighting

[505.2] Luminaires permanently attached to residential buildings or other buildings on the same lot are required to be high efficacy luminaires as described previously.

The WSEC allows two exceptions to this requirement. Any type of outdoor luminaire may be installed if it is controlled by both a motion control and an integral photocontrol photosensor.

Also, permanently installed luminaires in or around swimming pools and water features are exempt.

Linear Fluorescent Fixtures

[505.3] Any fluorescent lighting fixtures must have T-8 or smaller lamps. T-10 or T-12 lamps are not allowed.

Supplement A

Improving Forced Air Heating Systems

The Challenge

Recent research and testing of new homes in the Pacific Northwest and across the United States shows the importance of a properly installed HVAC system. Interactions between system components, the house envelope, and other equipment can seriously affect:

- Occupant health and safety;
- Occupant comfort;
- Equipment and structural durability; and
- Energy efficiency.

The *Washington State Energy Code* (WSEC) provides specifications for duct sealing, duct insulation, equipment sizing, equipment efficiency, and controls that provide a basis for a safe, efficient system. In forced air heating and cooling systems, attention to detail in duct installation is very important. Ductwork that is undersized, unbalanced or leaky can cause serious problems. Understanding these problems helps you build a better, safer home for your client that meets the intent, as well as the letter, of the Code.

Health and Safety

Leaky ducts can compromise health and safety. Because the air handler fan drives air into the ductwork, even small leaks can have a large impact. When duct leaks are connected to areas outside of the conditioned space, the leakage induces pressure changes across the envelope of the house. Supply leaks depressurize the house. Return leaks pressurize the house (see Figure A-1). Depressurization can cause combustion appliances to backdraft. Backdrafting allows flue gases to enter the living space and can

Figure A-1

Supply and Return Leakage

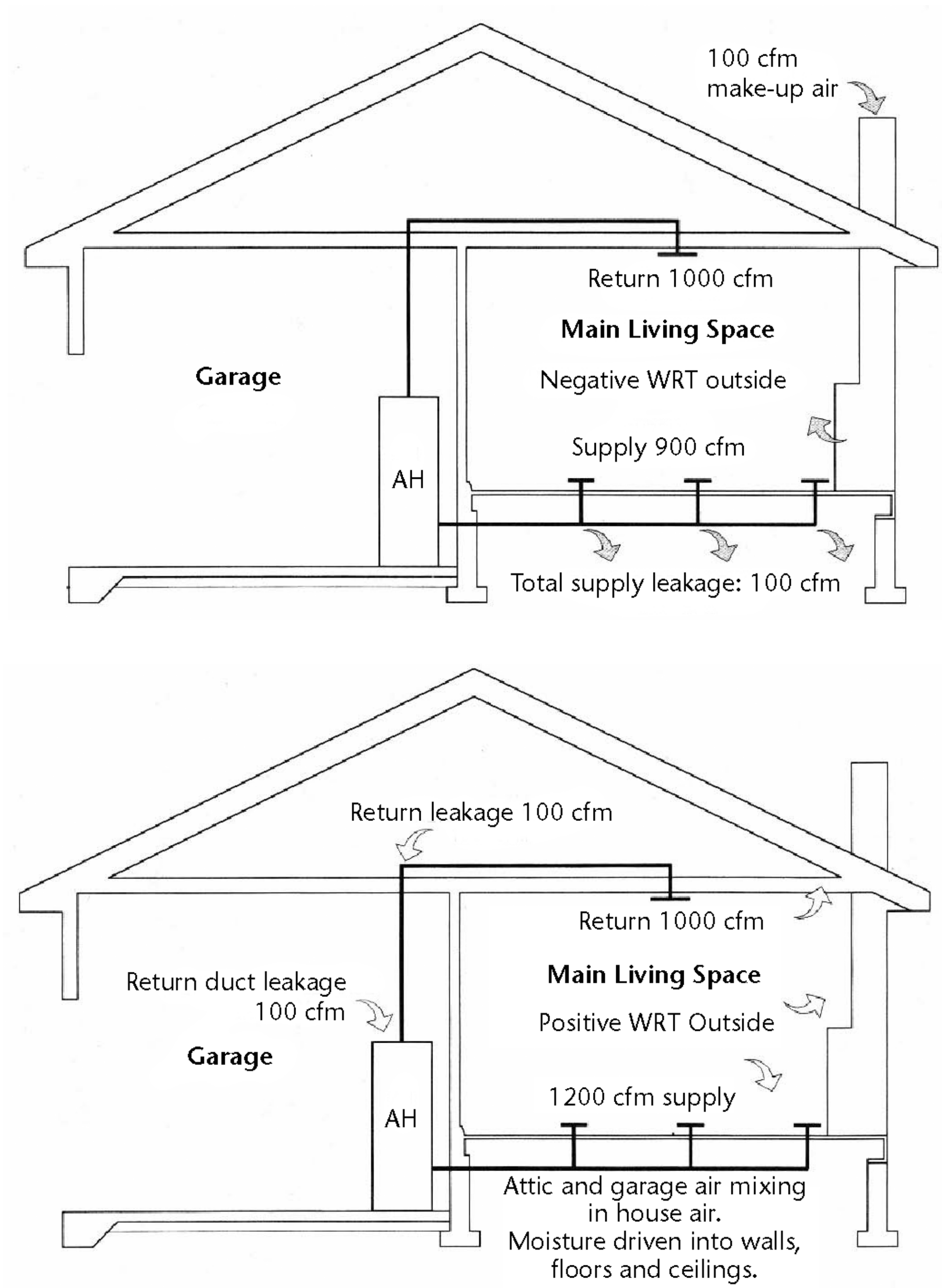
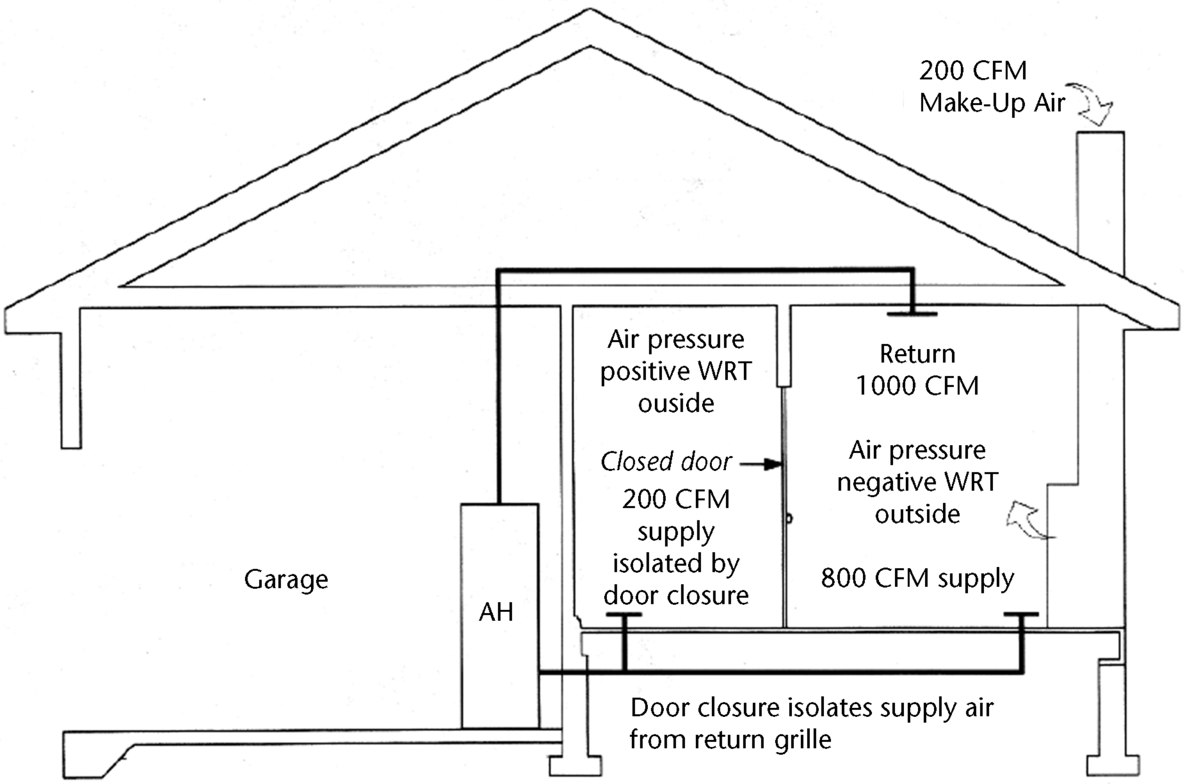


Figure A-2

Unbalanced Duct System



be very serious, potentially leading to death from carbon monoxide exposure. Return leaks in a confined area such as a utility room or basement can also induce depressurization. This can backdraft an adjacent gas-fired water heater, or suck soil gases (such as radon) into a basement. Return leaks in a garage, crawlspace, or attic can potentially introduce pollutants into a house, adversely affecting indoor air quality.

Unbalanced duct systems also cause pressure problems. In systems with central returns (very common in newer homes) supply registers and return grilles are often isolated when bedroom doors are closed. With the door closed, the zone with the return depressurizes, again creating potential backdrafts (see Figure A-2).

Testing in new homes shows that approximately 1 square inch of unobstructed return air pathway is required for each CFM of supply air delivered to a zone. This may be accomplished with ducted returns in each zone, undercut doors, transfer grilles or some combination of the above (see Figure A-3).

Figure A-3

Unobstructed Return Air Options

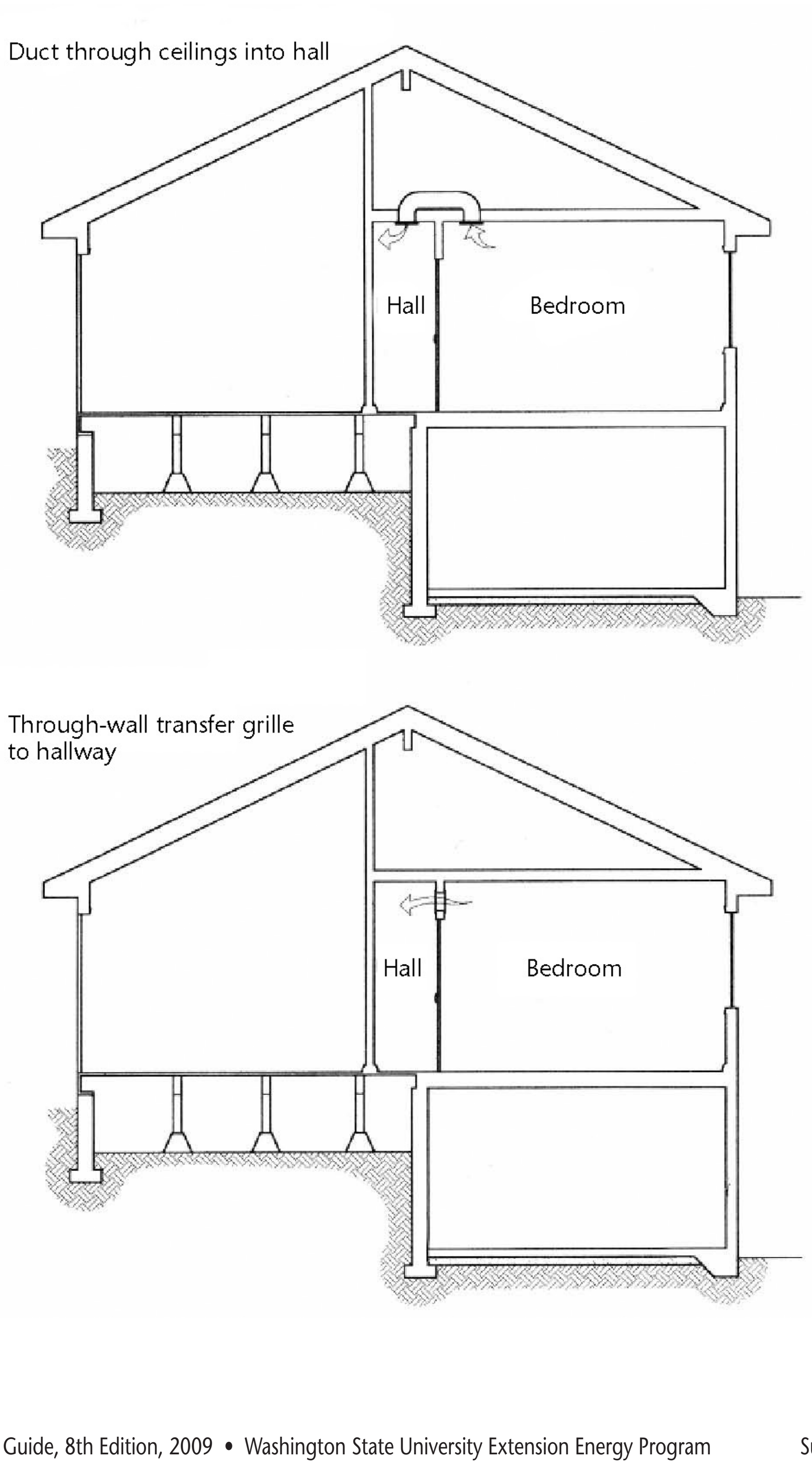


Figure A-4

Moisture Damage Resulting from Return Duct Leakage

Improper duct design and sizing can cause heating and cooling equipment to operate out of the manufacturer's specifications for temperature rise, pressure drop or air flow. This impacts efficiency and equipment lifetime. Airflow through the system is especially important for air conditioning and heat pump equipment. Inadequate airflow is a major cause of premature compressor failure. Follow the manufacturer's specifications, but generally look for 400-425 cfm of airflow per ton of installed capacity.

Comfort

Leaky ducts can also cause comfort problems. When supply ducts leak, the air delivery to different parts of the home may not match heating and cooling loads. If the ducts are well sealed, the register dampers can be adjusted to distribute conditioned air where it is needed. If the ducts leak, this control option is lost.

Return leaks connected to the outside can change the return air temperature, adversely impacting system performance.

Example: A large return leak in an attic in the summer time may draw 150°F air into the system rather than 75-80°F house air. The higher return temperature can overwhelm the system capacity and make it impossible to cool the home.

Duct leakage may also change the air infiltration rate of the home leading to excessive dryness during the heating season and high humidity levels during the cooling season. Both are common comfort complaints.

Improperly sized ductwork and poor register placement often contribute to comfort problems. Inadequate or excessive airflow may result from poor design. Heat pump systems with lower delivery temperatures are especially vulnerable to comfort complaints because of the higher volumes of air that must be moved.

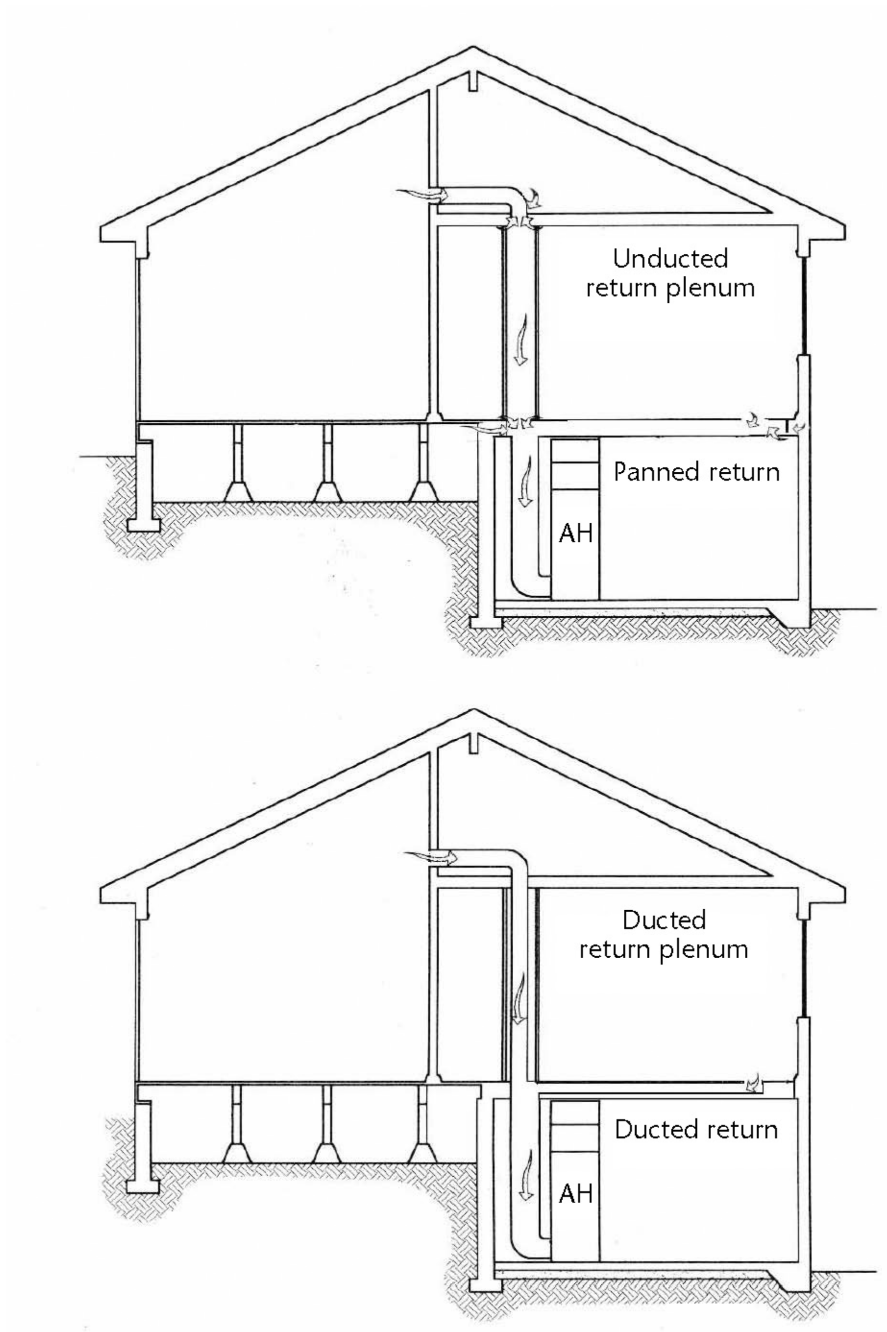
Durability

Leaky return ducts connected to the outside pressurize a home. Unbalanced systems also induce pressurization in zones where supply air does not have an adequate return pathway (see Figure A-1). Pressurized zones in homes in heating climates may adversely affect structural durability. During the heating season, positive pressure in the home causes warm moist air to flow into building cavities. As the air reaches colder exterior surfaces, the moisture condenses and wets the building materials.

Example: The photograph in Figure A-4 shows moisture damage to the exterior siding on a new home caused by a

Figure A-5

System with Fully Ducted Returns



return duct leak, which pressurized the house and drove moisture into the exterior wall. The area of most severe damage is the exterior wall for an upstairs bathroom. The use of air cleaning systems with continuous run times exaggerates this problem, making proper sealing and balancing even more important.

Energy Efficiency

The problems that impact health and safety, comfort and durability can also adversely affect energy efficiency. Leaky ducts can deliver conditioned air to unconditioned spaces. Pressure differentials created by leaky ducts or unbalanced systems increase whole house air leakage rates. To put this in perspective, studies have shown that, even in new homes, many systems perform below their expected efficiency (losses of 20-30 percent are not uncommon).

Ductwork and its interaction with the house has a significant impact on overall system effectiveness. When system components operate outside of the manufacturer's specifications for temperature rise, pressure drop, or air flow, efficiency is often lost.

The Solutions

Duct Sealing

To achieve optimum duct sealing performance, the following practices are recommended:

- Do not use building cavities as ductwork. Testing in Northwest homes has shown that return ducts leak far more often than supply ducts. This is associated with the use of panned floor joists and building cavities used as part of the return system. Making a tight well-sealed duct out of a building cavity is often very difficult. For a quality system, it may be less expensive (in the long run) to install a fully ducted return (see Figure A-5).

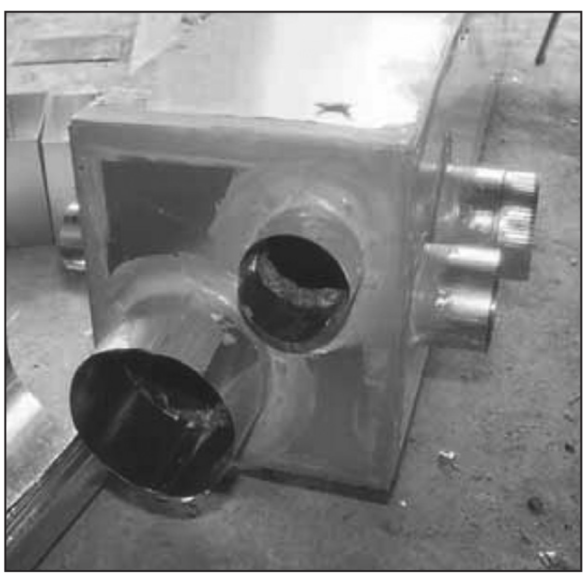
Figure A-6

Poor Duct Fittings Can Not be Well Sealed

Tight fittings and assembly are required to control duct leaks over the long term.

Figure A-7

Tight fittings and Mastic Make the Best Seal



- Select fittings that do not leave large gaps in the system. Many ducts are assembled with large gaps between fittings. Even if they are well sealed when first installed, this practice will eventually lead to sealing failure. Duct sealing materials simply are not designed to seal large holes for long periods of time. Tight fittings and assembly are required to control duct leaks over the long term (see Figure A-6).

- Do not use “duct tape” – instead, use durable sealing materials. Advanced aging tests conducted on commonly used duct sealing materials by Lawrence Berkeley National Laboratory concluded that duct tape is a poor performer. Cloth or vinyl backed duct tapes with rubber adhesives failed very quickly and are not recommended for duct sealing. The metal-backed tapes with acrylic adhesive worked better. Mastics were by far the most durable (see Figure A-7).

- Select sealing materials that are compatible with duct system components. Duct sealing materials need to be installed according to the manufacturer's instructions. Many tapes require that the ducts be clean and oil free before installation. Using sealants rated under the UL 181 standard assures compatibility with duct board and flexible duct systems.

- Use performance testing methods to assure a tight seal. Contractors should consider duct tightness testing. While this may not be practical on every job, it is a valuable learning experience. Duct tightness testing will provide feedback on problem areas and sharpen a crew’s ability to provide quality installations. Testing can also alert contractors to potential liabilities associated with combustion appliance back-drafting, as well as durability issues. Tests are required to obtain Energy Efficient Mortgages and the Energy Star® Homes five star rating. Make sure the ducts are fully insulated. The code requires R-8 insulation for ducts outside the conditioned space (R-5 in slabs or the ground). The Super Good Cents® energy efficiency standard suggests that insulating ducts up to R-11 is cost-effective in electrically heated homes. See Chapter 7 of the *Builder's Field Guide* for more detail.

Move the Ductwork Inside

Rather than placing the air handler and duct work in the garage, crawlspace or attic, consider moving it inside. By bringing the components inside the insulation and air barrier of the home, significant energy savings can be achieved. By keeping the system completely indoors, the chance of bringing poor quality air in from the garage or attic space is eliminated. An additional benefit is that ducts installed in the heated space do not require insulation.

Studies conducted in the Northwest indicate that forced air heating systems located completely indoors will reduce energy use by about 30 percent. This can be accomplished at no additional cost. When the builder provides a space indoors for the equipment and ducts, it reduces the HVAC contractor's cost. The HVAC contractor will use less duct-work, will not need to insulate the ducts and will be able to work in better conditions. The HVAC contractor will also be able to specify smaller equipment, reducing cost further. The builder will need to provide an indoor space for the ducts. This may add to the cost of framing and drywall. Per project, the HVAC contractor and builder cost will usually offset each other.

Moving the heating system indoors is most easily accomplished in two-story homes. The duct work can be placed in the space between the floors. Much of the system can be placed in existing floor cavities (see Figure A-8).

Where transitions must be made between floor cavities,

Figure A-8

Ducts Placed Within the Floor Joists

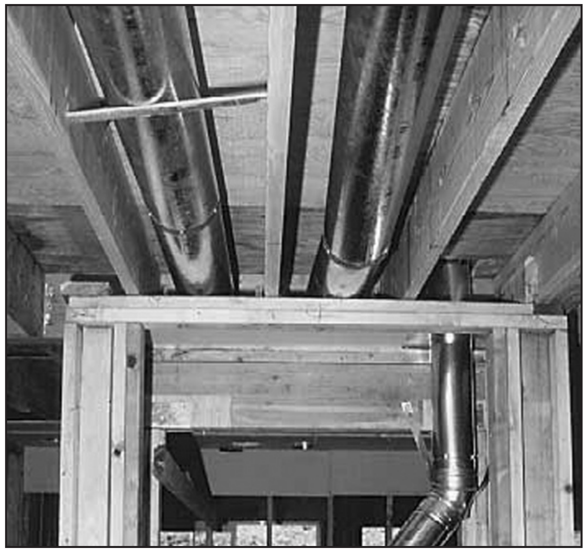


Figure A-9

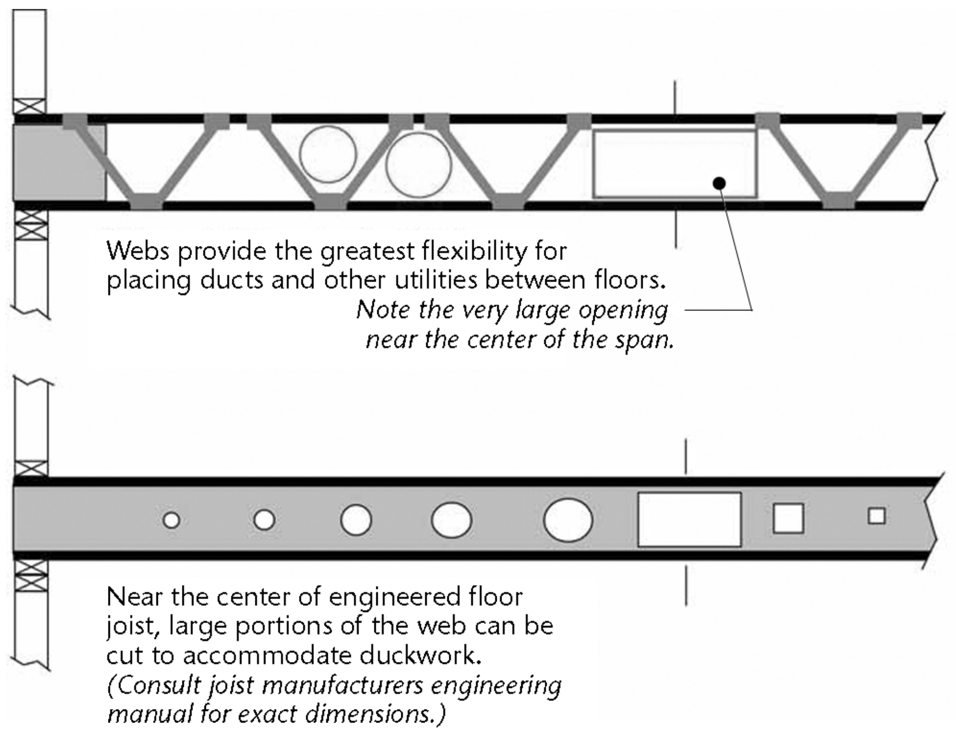
Drop Soffit Conceals Ducts

drop soffits are traditionally used (see Figure A-9).

The increasing use of engineered floor trusses provide additional opportunities for moving ducts easily between floors. Most composite wood trusses can be cut to accommodate large transitions across the floor joist. Web trusses provide the greatest opportunity. Steel webs with wood cords provide areas large enough to incorporate substantial

Figure A-10

Engineers Trusses Provide Space for Ducts Between Floors



duct systems (see Figure A-10).

Bringing combustion furnaces inside the envelope requires care in meeting combustion air and venting requirements. Direct vent and sealed vent equipment are likely the best solutions.

Heating System Design and Installation

Heating systems do not perform to promised specifications when the ducts are not the correct size. Ducts supplying air to individual rooms need to be sized to provide air flow that matches the heating requirement of the room. The entire system must be designed so that it allows the correct air flow through the heating and cooling equipment. In many cases, these two criteria are not met. This leads to comfort problems, and loss of equipment efficiency.

To correctly size duct systems, use recognized engineering principles and calculated loads. The most widely used methods are *ACCA* * *Manual J* heat loss method and *ACCA Manual D* duct sizing method.

The home designer needs to provide space for the ductwork. Forced air heating systems need to be included in the home planning process. Too often systems fail because the home designer has not provided space for equipment and ductwork. Home designers should consult the HVAC contractor early in the design process.

* Air Conditioning Contractors of America Association, Inc.

Recommended Practice

Follow these suggestions to build quality HVAC systems:

- Meet or exceed Code requirements. Codes affecting HVAC installations are set up to establish minimum safety and efficiency standards. It is a good place to start.
- Size and design duct systems using recognized engineering principles and calculated loads. **Examples:** *ACCA Manual D* and *ACCA Manual J*.
- Install equipment according to the manufacturer's instructions.
- Test and adjust the equipment and the distribution system.
- When combustion appliances are present, provide for combustion safety. Vent properly, provide combustion air, minimize negative pressures, test for CO (carbon monoxide) production and backdrafting, install CO alarms and educate the homeowner about combustion safety.
- Where possible, install ducts in the heated space.
- Seal ducts.
- Insulate ducts not installed in the heated space.
- Use a systems approach to assure health, safety, comfort, durability and energy efficiency.

Supplement B

Taking Credit for Reduced Air Leakage in Residential Buildings

In recent years, a growing number of *Washington State Energy Code* (WSEC) submittals have attempted to take credit for energy savings that result from air sealing of homes. In many cases these submittals do not include accurate energy simulations and are not performing tests to confirm that they meet the proposed infiltration levels. This supplement will discuss the Code language, documentation, and field inspection as it applies to air leakage control in residential buildings.

Chapter 4 of the WSEC allows applicants to take credit for building practices that reduce energy using the systems analysis approach. This approach allows applicants to take credit for improved heating system efficiency, impacts of glazing type and orientation, and other features not covered by the component trade off or prescriptive compliance methods. Software capable of evaluating building performance is used to demonstrate compliance with the Code.

Systems analysis is by far the most complex code compliance approach, and both the applicant and code official need to know how to handle these complexities. When evaluating a systems analysis submittal, code enforcement personnel need to establish early on if the software is capable of performing needed calculations and whether the proposed measures can be verified during inspection.

What Does the Code Say About Air Leakage Control Credits?

WSEC language is very specific when it comes to the air leakage rate to be used in systems analysis calculations:

[402.1.5] Infiltration levels used shall be set at 0.35 air changes per hour for thermal calculation purposes only.

As written, the Code does not implement a method for taking credit for reduced air leakage in homes with the exception of Chapter 9 credits for improved air leakage control. For further details on Chapter 9 of the Code, please see Chapter 9 of the *Builders Field Guide.* The Code requires that 0.35 ACH be used for both the proposed and target building calculations. In addition, the Code does not specify how to calculate the energy impacts of required mechanical ventilation.

The history of this code language dates back to the original adoption of the WSEC in 1990. The code enforcement community did not want to administer additional inspections needed to verify reduced air leakage in homes.

Because of the limitations placed in the Code, credit for reduced infiltration must be submitted as an alternative method. The applicant must submit documentation that includes the proper methodology for calculating and inspecting a home with reduced air leakage. Because this is an alternative method, the building department has the latitude to accept or reject the proposed alternative for technical or administrated reasons as stated in WSEC Section 103.

What About Mechanical Ventilation?

In a home with average air leakage area, mechanical ventilation will add about 50 percent of the fan flow to the natural air change rate. In a home with very little air leakage area, mechanical ventilation will add nearly 100 percent of the fan flow to the natural air change rate. This occurs because it is more difficult for the fan to overcome the natural stack effect in homes with more air leakage area. Balanced mechanical ventilation systems with equivalent supply and exhaust flows will always add 100 percent of the fan flow to the natural air change rate. Given the

Code requirements for mechanical ventilation, the net annual air change rate in homes will rarely drop below 0.25 per hour.[1]

Also at issue is the size of the ventilation fan. Some heat recovery ventilators have a much higher capacity than the minimum ventilation rate specified in the Code. If the Code requires a 100 CFM exhaust fan and the builder installs a 300 CFM HRV, there will not be any energy savings. As noted below, the software chosen to document savings from reduced air leakage needs to include the capability of analyzing the impacts of the mechanical ventilation system.

What are the Software Capabilities?

The two most popular programs used for energy analysis in Washington have been *WATTSUN* and *SUNDAY*. Both are capable of documenting the energy savings achieved through reduced air leakage in homes. However, they do not account for required mechanical ventilation. Without including mechanical ventilation in the analysis, the simulation will overestimate the savings of reduced air leakage.

DOE-2 based programs called *Energy Gauge*, DOE 2.1E and DOE 2.2 (EQUEST) do an acceptable job of analyzing this variable.

What are the Recommended Inspections and Tests?

Systems analysis is a whole building approach. Air leakage involves all of the systems in the building. A builder might do a fine job of air sealing the building envelope, but if the back-draft dampers are not in place on the kitchen exhaust, the building will no perform to the levels promised in the submittal. A blower door test is needed to confirm that the proposed air leakage rate has been achieved as part of the inspection process. There are a number of methods for testing and calculating the results. For simplicity, we recommend a single point blower door test (see next page for details).

[1] John Heller, *Residential Construction Demonstration Project: Cycle III. Analysis of Innovative Ventilation Systems in Multifamily Buildings,* Bonneville Power Administration, Portland, 1998, p. 4.

What are the qualifications for blower door test professionals? Should Code enforcement personnel observe the test? This has not been established in the Code until now. A builder can choose to test their own homes or they can hire a third party tester. Building department staff can request to be on site when the test is conducted. See Chapter 5 of the *Builders Field Guide* for more information.

What Happens if the Applicant Fails the Blower Door Test?

Due to the test occurring at or near the completion of the home, failure puts both the applicant and code enforcement personnel in a difficult position. If there is one large hole in the building, it is fairly easy to identify the air leakage path and plug it. In most cases, the additional leakage is the result of a series of very small failures in air sealing. Finding and fixing these failures can be difficult – particularly in very tight homes.

The best approach is to avoid failure during submittal by limiting proposed air leakage rates to reasonable levels. For example, if compliance requires passing a blower door test with results of 0.25 ACH, don't submit documentation that places the target at 0.10 ACH.

Summary

1. WSEC Chapter 4 does not allow credit for reduced air leakage in the home. Proposals must be submitted as an alternative method. The code officials can reject proposals for technical or administrative reasons.
2. The target value for home air leakage in the WSEC is 0.35 ACH.
3. The software selected needs to be capable of performing the needed calculations to account for building air sealing and mechanical ventilation.
4. Blower door tests should be used to document compliance.

Figure B-1

Single Point Blower Door Test

To determine the air leakage rate of a home, a blower door test is performed. A specialized fan is placed in an exterior door of the home. The fan exhausts air from the home, creating a negative pressure in the home with respect to outdoors. The target test pressure used for single point test is 50 Pascals (0.205 inches of water). The blower door fan speed is adjusted until the target test pressure is achieved; then the flow through the fan is recorded. The fan flow is noted on the report as CFM50 (cubic feet per minute at 50 Pascals pressure difference). Set-up for the test is important. The following notes should be used:

- Testing shall occur after everything is roughed-in/ installed that will penetrate the building envelope (plumbing, electrical, HVAC, ventilation, combustion appliances, etc.) and the air barrier has been installed. Testing should NOT be conducted when wind gusts exceed 15 mph.
- All windows and doors shall be properly closed, including pass-through wood-box doors and pet doors. All interior doors shall be left open.
- All exhaust fan openings, vent openings, and intake-air vents with backdraft dampers (e.g., dryer vents and kitchen, bathroom, utility room, whole-house, range vents, etc.) shall ***NOT*** be sealed. Exterior vent openings without backdraft dampers (e.g., some continuous ventilation systems) shall be temporarily

sealed for the test. Heat recovery ventilator supply openings shall be sealed. Heat recovery ventilator exhaust openings should have backdraft dampers and shall not be sealed.

The blower door test does not measure air leakage. (It is a measurement of the size of all the holes in the home.) This is converted to an estimate of average annual air leakage by applying math to the blower door test results. The final result is called *ACH Natural*.

Single Point Blower Door Test Math

Step 1:
Convert the blower door test value from CFM50 to ACH50 (air change per hour at 50 Pascals pressure difference)

ACH50 = CFM50 x 60/ Building Volume (cubic feet)

Step 2:
Convert the ACH50 to ACH Natural
ACH natural = ACH50/20

Example:
House Volume = 15,000 cubic feet
Blower door test results = 1,600 CFM50

Step 1: ACH50 = (1,600 x 60) / 15,000 = 6.4

Step 2: ACH natural = 6.4 / 20 = 0.32 ACH

Supplement C

Thermal Performance of Common Insulation Materials

Below are listed nominal R-values for typical insulation materials. In some cases a range of R-values are listed to indicate variation in the materials. This will get you started. Specific insulation R-values should be obtained from the product manufacturer.

Use only nominal steady state R-values obtained using test methods approved by the Federal Trade Commission. Nominal R-value labeling is required for all insulation materials. At a minimum this is required to be on the packaging.[1]

Batt, board and blanket insulation is labeled with the R-value. The *Washington State Energy Code* (WSEC) requires that these labels be visible for inspection.

Loose or spray-applied insulation must be applied at the manufacturer's specified thickness and density to provide the tested R-value. This is documented by providing calculations of the volume of insulation installed per square foot of component area. For example, a count of the number of bags of cellulose insulation installed in a 1,200 square foot attic can be used to determine the density of the product. An inspection of the depth of the insulation is also required.

The following list has been compiled from a number of sources. This includes the latest edition of the *ASHRAE Handbook of Fundamentals*.[2] Data obtained by other sources is referenced in the footnotes. For some assemblies, the following tables provide insulation values for a filled cavity as they would apply to the prescriptive application of the WSEC.

[1] *Title 16 – Commercial Practices Chapter I – Federal Trade Commission Part 460 – Labeling and Advertising of Home Insulation*

[2] *2005 ASHRAE Handbook Fundamentals, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.*

Table C-1

Thermal Performance of Common Insulation Materials

Fiberglass

Type	Density	R /inch	2X4	2X6	2X10	2X12/Flat Ceiling
Batts LD	0.4-2.0	3.0-3.2	11	19		30 (10.0 inches)
Batts MD	0.4-2.0	3.3-3.6	13			
Batts HD	1.2-1.6	3.6	15	21	30	38 (10.25 inches)
BIBs HD	2.0	4.2	15	23	40	38 (9.0 inches)
Loose fill	0.5-1.0	2.2-2.7				38 (17.0 inches)

Cellulose *R-values obtained from the Cellulose Insulation Manufacturers Association*

Type	Density	R /inch	2X4	2X6	2X10	2X12/Flat Ceiling
Loose fill	1.5 – 2.0	3.2 – 3.8				38 (12 inches)
Wet Spray	3.5 - 4.0	2.94 – 3.0	10	17	28	36(12 inches)
Dense Pack	5.5 – 6.0	3.3-3.45	12	19	33	41(12 inches)

Rigid Board

Type	Density	R /inch
Extruded Polystyrene (XPS)	1.8 – 3.5	5.0
Expanded Polystyrene (EPS)	1.0 – 2.0	3.85 – 4.36
Polyisocyanurate	1.5 – 2.0	5.56 – 7.04
Fiberglass, cellular glass	8.0	3.03

Spray Applied Foam

Type	Density	R /inch
Polyurethane, closed cell	1.5 – 2.5	5.6 – 7.3
Polyurethane, open cell	.5	3.7

Duct Board & Duct liner

Type	Density	R /inch
Glass Duct Board	4.0 – 9.0	4.0
Duct liner	1.75 – 3.0	3.7 - 4.2

Supplement D

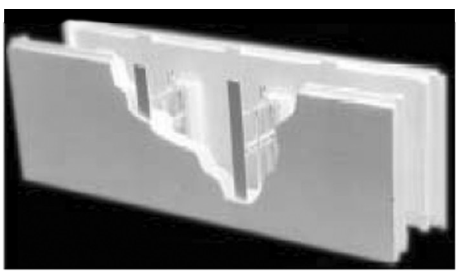
Insulated Concrete Form Systems

Thermal Characteristics

Insulated Concrete Form (ICF) systems use a prefabricated form made of foam insulation that is assembled into walls at the building site and filled with concrete. Systems vary, but generally they are composed of a layer of foam insulation, either expanded polystyrene (EPS) or extruded polystyrene (XPS), on the outside, a concrete layer in the middle and a layer of EPS or XPS foam on the inside.

Figure D-1

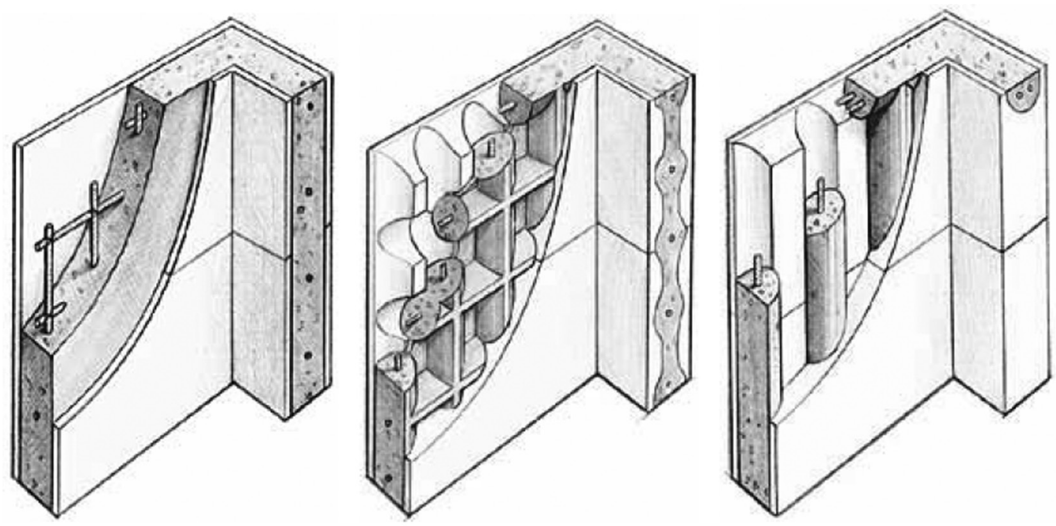
Examples of Foam Forms



Conventional finishes are applied to suit the building. ICF systems are differentiated by the type of insulation, the shape of the cavity and the method of connecting the insulation layers. The basic cavity shapes of the concrete blocks are flat, grid and post-and-beam. Many, but not all, ICF systems meet the thermal requirements of the *Washington State Energy Code* (WSEC), see WSEC Tables 6-1 and 6-2.

Figure D-2

Examples of Various Conventional Finishes



Flat Wall *Grid Wall* *Post & Beam Wall*

Why Do Some ICF Perform Better Than Others?

Not all ICF systems are constructed the same. The primary variables are the type of material used for the form, the ratio of concrete to form materials, and the type of ties. For example, an ICF with steel cross ties will have greater heat loss than one with plastic ties. Forms with more insulation and less concrete will have less heat loss than forms with high ratios of concrete to insulation.

Prescriptive Application of U-Factors

Strictly speaking, the prescriptive requirements in the WSEC do not allow the use of wall U-factors. But the use of U-factors as a demonstration of compliance with prescriptive values is an acceptable alternative method. For above grade and below grade walls, the following prescriptive U-factors may be utilized (see Tables 6-1 and 6-2).

Table 6-1

Zone 1 Presecriptive Requirements

	R-Value Required	Acceptable U-Factor
Above Grade Wall, all options	21 Int.	0.054
Below Grade, exterior, continuous	10	0.056
Below Grade, interior, in stud cavity	21	0.037

Table 6-2

Zone 2 Presecriptive Requirements

	R-Value Required	Acceptable U-Factor
Above Grade Wall, option I	21 Int.	0.054
Above Grade Wall, options II, III	19 + 5	0.044
Below Grade, exterior, continuous	12	0.050
Below Grade, interior, in stud cavity	21	0.037

Thermal Storage (Mass Value)

Thermal storage may improve overall building performance. Adding mass in ICF systems has been shown to improve annual performance of a building in certain conditions. Although thermal mass may have a benefit in its ability to store heat, prescriptive path R-values do not take thermal mass into account. R-values used to demonstrate code compliance is the tested "steady state" R-value without any increases for the potential benefit from thermal mass. "Effective" R-values commonly provided by manufacturers or vendors may not be used to demonstrate code compliance.

Moisture Control

The WSEC requires a one-perm or less vapor retarder in all walls. Although extruded polystyrene products typically meet this requirement, ICF construction does not guarantee compliance. Check manufacturer or vendor information to see if applying a one-perm vapor retarder, on the warm side (in winter), is needed.

How to Handle Non-Compliant Walls

If a building cannot meet the prescriptive requirements of the WSEC, the Component Performance approach may allow one element of the structure to be less efficient than what the code requires if the deficiency is compensated for in another area of the building. A home that has ICF walls with U-factors greater than allowed by the Prescriptive Path may comply with code using the Component Performance Approach worksheets. This web site link lets the user download the worksheets:

www.energy.wsu.edu/code/

Default U-Values

The following table (see Figure B-3) lists tested U-factors for common ICF products. Use "Total U-factor" values when using the Component Performance Approach for qualifying an ICF house. Total U-factor values include the effect of air films, wood exterior siding and half inch drywall sheathing.

Figure D-3

Common ICF Products*

Brand Name	Manufacturer	Wall Thickness	Insulation Type[1]	R-Value[2]	U-Factor[3]
Blue Maxx	AFM Building Corp.	11.25″	EPS	R-21	.043
Diamond SnapForm	AFM Corp.	8″	EPS	R-19	.048
Durisol	Durisol Bldg Systems	12″	No foam inserts	R-9.13	.109
Durisol	Durisol Bldg Systems	12″	3.5″ foam inserts	R-21	.048
Feather Lite	Feather Lite, Inc.	Varies	--	R-22	.042
Fold-Form	Lite Form, Inc.	8″	EPS	R-19	.048
GreenBlock	Greenblock Worldwide	9.87″	EPS	R-18	.049
Ice Block	Foam Block	9.25″	EPS	R-12	.070
Lite Form	Lite Form, Inc.	8″	XPS	R-21	.043
Polysteel Form	American Polysteel Forms	9.25″	EPS	R-12	.070
Quad-Lock	Quad Lock Bldg Systems	8.125″	EPS	R-21	.044
R-Forms	R-Forms	8″	XPS	R-21	.043
Rastra	Rastra	8″	EXP	R-8	.1134
Rastra	Rastra	12″	EPS	R-15	.0654
Rastra	Rastra	14″	EXP	R-18	.0524
Reddi-Form	Reddi-Form	9.625″	EPS	R-21	.047
Reward Wall	Reward Wall	9.25″	EPS	R-19	.048
ThermoFormed	ThermoFormed Block Corp.	8″	EPS	R-16	.055
Therm-O-Wall	Therm-O-Wall	9.125″	EPS	R-15	.058

**This list may not include all ICF products available. Refer to manufacturers tested R-values and U-factors for compliance with code requirements. Information courtesy Oregon Department of Energy Pamphlet #20.*

[1] *EPS Expanded Polystyrene; XPS Extruded Polystyrene.*

[2] *R-values are for ICF only – not total wall assembly.*

[3] *U-factors are for total wall assembly.*

[4] *Assumes stucco finish exterior and interior.*

Supplement E

Table E-1

Permeance Values for Common Building Materials*

Materials	Permeance
Polyethylene (4 mil)	0.08
Latex Primer/Sealer	6.28 (1 coat = 0.0012 inches)
Vapor Retarder Paint	0.45 (1 coat = 0.0031 inches)
Polyvinyl Acetate Latex (PVA)	5.5 (3 coatings – 4 oz/sq.ft.)
Vinyl Acrylic Primer Latex	8.62 (1 coat = 0.0016 inches)
Kraft Paper (Asphalt Impregnated)	0.03
15 lb Asphalt Felt Paper	1.0
Gypsum Wall Board (3/8-inch)	50
Plywood (1/4-inch with exterior glue)	0.7

The *Washington State Energy Code* requires vapor retarders have a permeance rating (dry cup) of 1.0 or less. See Section 502.1.6.1

*2005 ASHRAE Fundamentals Handbook. See Section 25.17, Table 9 for more details.

Materials must be applied in accordance with manufacturer's instructions to achieve specified permeance ratings.

This table permits comparisons of materials: but in the selection of vapor retarder materials, exact values for permeance or permeability should be obtained from the manufacturer or from laboratory tests.

Supplement F

Common Duct Insulation Materials

The *Washington State Energy Code* (WSEC) *Hotline* has received questions about different types and thicknesses of duct insulation. There appears to be some confusion about Table 5-11 of the WSEC which lists the minimum densities, out-of-packages thickness and R-values for different types of duct insulation. Table F-1 shows what the R-values are for varying thicknesses and types of duct insulation in a better layout than Table 5-11. This table also lists the ASTM and UL.

Table F-1

R-Values for Common Duct Insulation Materials

Installed R-Value[1] (h.°F sq.ft.)/Btu	**Typical Material meeting or exceeding the given R-value**[2]
1.9	1/2-inch Mineral fiber duct liner per ASTM C 1071, Type I
	1-inch Mineral fiber duct wrap per ASTM C 1290
3.5	1-inch Mineral fiber duct liner per ASTM C 1071, Types I & II
	1-inch Mineral fiber board per ASTM C 612, Types I & IB
	1-inch Mineral fiber duct board per UL 181
	1-1/2-inch Mineral fiber duct wrap per ASTM C 1290
	1-inch Insulated flex duct per UL 181
6.0	1-1/2-inch Mineral fiber duct liner per ASTM C 1071
	1-1/2-inch Mineral fiber duct board per UL 181
	1-1/2-inch Mineral fiber board per ASTM C 612, Types IA & IB
	2-inch, 2 lb/cu.ft. Mineral fiber duct wrap per ASTM C 1290
	2-1/2-inch, .6 to 1 lb/cu.ft. Mineral fiber duct wrap per ASTM C 1290
	2-1/2-inch Insulated flex duct per UL 181
8.0	2-inch Mineral fiber duct liner per ASTM C 1071, Types I & II
	2-inch Mineral fiber Duct board per UL 181
	2-inch Mineral fiber board per ASTM C 612, Types 612, Types I! & IB
	3-inch 3/4 lb/cu.ft. Mineral fiber duct wrap insulation per ASTM C 1290
	3-inch Insulated flex duct per UL 181
10.0	2-1/2-inch Mineral fiber board per ASTM C 612, Types IA & IB

[1] Listed R-values are for the insulation only as determined in accordance with ASTM C 518 at a mean temperature of 75°F at the installed thickness and do not include air film resistance.

[2] Consult with manufacturers for other materials or combinations of insulation thickness or density meeting the required R-value1.

• This table is from the User's Manual for ANSI/ASHRAE/IESNA Standard 90.1-2004, p 6-29.2

Duct Insulation Requirements

The WSEC requires residential ducts be insulated per Table 5-11 in Chapter 5.

Table F-2

Duct Insulation
(Table 5-11, WSEC Chapter 5)

Duct Location	Climate Zone	Group R Occupancy Heating or Cooling Ducts
On roof or on exterior of building	1	E and W
	2	D and W
Attic, garage, crawl space, in walls[1], in floor/ceiling[1]	1	E
	2	E
Within the conditioned space or in heated basements		None Required
In cement slab or in ground		B

Note: Where ducts are used for both heating and cooling, the minimum insulation shall be as required for the most restrictive condition.

[1] Insulation may be omitted on that portion of a duct which is located within a wall or floor/ceiling space where both sides of this space are exposed to conditioned air and where this space is not ventilated or otherwise exposed to unconditioned air.
[2] Vapor barriers shall be installed on conditioned air supply ducts in geographic areas where the average of the July, August and September mean dewpoint temperature exceeds 60°F.

INSULATION TYPES: Minimum densities and out-of-package thickness.

A. 0.5-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket or equivalent to provide an installed total thermal resistance of at least R-2.
B. 2-inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 1.5-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 1.5-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-5.
C. 3-inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 2-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 2-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-7.
D. 4-inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 3-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 3-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-10.
E. 3.5-inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 2.5-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-8.
V. Vapor barrier, with perm rating not greater than 0.5 perm, all joints sealed.
W. Approved weatherproof barrier.

Supplement G

Inspecting Attic Insulation

There are several factors to consider when inspecting loose fill, blown-in attic insulation. These include the type, depth and density of the insulation.

Types of blown-in insulation

The two commonly used types of blown-in attic insulation are cellulose and fiberglass. Blown-in rock wool insulation is also available but its use in the Pacific Northwest is not common.

Cellulose is a natural wood product and is made primarily from recycled newspaper.

A fire retardant chemical is added to meet flame-spread and smoke-development requirements of today's building codes. Fiberglass insulation is the same type of material that is in batts or rolls of fiberglass insulation except it is chopped or cubed so it can be installed with an insulation blowing machine. Fiber glass insulation typically contains 20 to 30 percent recycled glass[1].

The R-value of loose fill cellulose is R-3.2 to 3.8 per inch[2]. Loose fill fiberglass has an R-value of R-2.2 to 2.7 per inch[3]. Achieving the desired R-value depends on both the depth of the insulation and its density.

Insulation depth

Depending on your climate, energy codes require varying R-values for ceiling insulation. Code requirements may also vary for attics and single rafter or joist vaulted roof assemblies. The *Washington State Energy Code* (WSEC) requires all attics be insulated to R-38 advanced framed construction or R-49 standard framed construction in both Climate Zones 1 and 2. Using the known R-values per inch

[1] Percentages of recycled content from USDOE, EERE
[2] R-values obtained from Cellulose Insulation Manufacturers Association
[3] Loose fill fiberglass R-values from USDOE, EERE

of each type of insulation, we know that to install R-38 you need from 10 to 12 inches of cellulose and 14 to 17 inches of fiberglass. For an accurate depth for a given type of insulation there is a chart on the insulation bag noting the required depths for various R-values.

To assist an inspector and the installer in verifying the depth of the insulation, the WSEC requires that depth markers (see Figure G-1) be placed in the attic space. The depth markers must be installed for every three hundred square feet of attic area and must face toward the attic access.

Figure G-1
Insulation depth marker

Insulation Density

Checking the depth of the insulation is essential but the density of the insulation is equally important. Blown-in insulation can be "fluffed up" when installed so that it appears to meet the depth requirement without achieving the desired R-value. Over time the insulation may settle, resulting in a lower R-value.

The easiest way to document the amount and R-value of installed blown-in insulation is to install an attic card. These are usually stapled to the truss or rafter near the attic access and show the depth of installed insulation. There should be one marker installed for every 300 square feet of attic or ceiling space. For more information, see the *Code of Federal Regulations* (CFR) Part 460, Labeling and Advertising of Home Insulation.

If you are an installer, you must give your customers a contract or receipt for the insulation you install. For loose-fill, the receipt must show the coverage area, initial installed thickness, minimum settled thickness, R-value and the number of bags used.[4]

[4] Code of Federal Regulations (CFR) 460.17

The following table (Table G-1) is a chart for Owens Corning ThermaCube Plus® blown-in fiberglass insulation.

Table G-1

Attic/Ceiling Guidelines

R-Value	**Minimum Bags/1,000 Sq.Ft.**	**Maximum coverage/Bag** (Net Sq.Ft.)	**Minimum Weight/Sq.Ft.** (lbs)	**Minimum thickness** (inches)
R-49	25.0	40	0.878	19.50
R-44	22.2	45	0.786	17.75
R-38	19.2	52	0.676	15.50
R-30	15.2	66	0.531	12.25
R-26	13.2	76	0.459	10.75
R-22	11.1	90	0.388	9.25
R-19	9.5	105	0.334	8.00
R-11	5.5	182	0.193	4.75

Manufacturers provide similar charts on their insulation bags. The chart states the minimum number of bags that need to be installed per 1,000 square feet of area to obtain a specific R-value. For example, to install R-38 in an attic with 3,200 square feet of area use the following formula:

3,200 sq.ft. ÷ 1,000 = 3.2

19.2 (bags per 1,000 sq.ft. for R-38) x 3.2 = 61.4 bags

Building inspectors typically check the insulation depth to verify compliance with local codes. Making sure the correct amount of insulation is installed requires a bag count, or a comparison with the recommendations on an attic card.