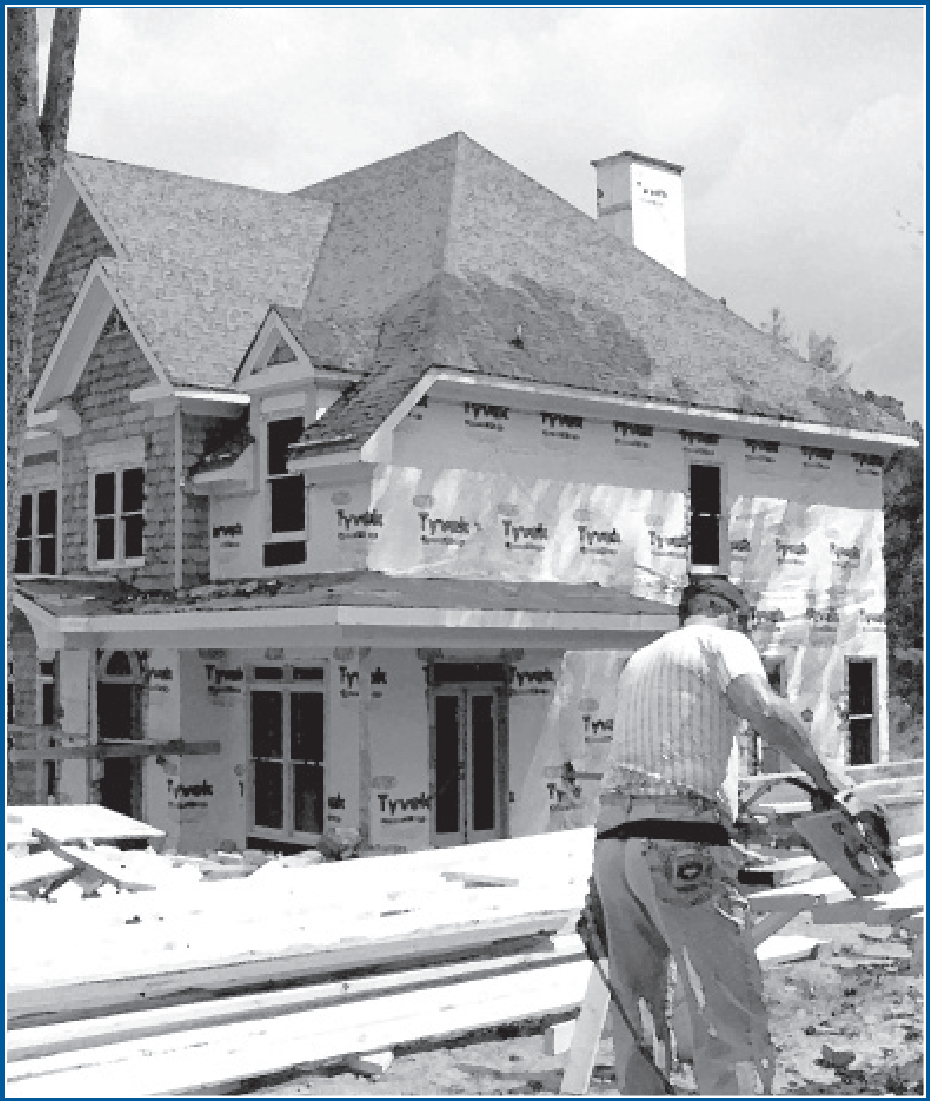
Alabama Builder's Field Guide

Energy Efficient Building Envelope



ADECA
www.adeca.alabama.gov

Alabama Department of Economic and Community Affairs
Science, Technology and Energy Division

Alabama
Builder's Field Guide
Energy Efficient
Building Envelope

ADECA
www.adeca.alabama.gov

Alabama Department of Economic and
Community Affairs

Science, Technology and Energy Division

Montgomery, Alabama
September 2004

First Edition—September 2004

Principal Authors
Jeffrey S. Tiller, PE
Dennis B. Creech

Technical Review
Mike Barcik, Brett Dillon

Graphics and Desktop Composition
Greg Brough

Technical Editors
Laura Burch, Greg Brough

For additional copies of this publication or other energy information, please contact:
Alabama Department of Economic and Community Affairs
401 Adams Avenue
Montgomery, AL 36103-5690
(334)242-5290
www.adeca.alabama.gov

This publication was prepared under contract to the
Alabama Department of Economic and Community Affairs
by Southface Energy Institute, Inc. Southface may be reached at:
Southface Energy Institute, Inc.
241 Pine Street, NE
Atlanta, GA 30308
404-872-3549
FAX 404-872-5009
www.southface.org

DISCLAIMER
This publication was prepared with the suppoprt of the U.S. Department of Energy (DOE) Grant No. DE-FG44-OOR410758. However, any opinions, findings, conclusions, or recommendations express herein are those of the authors and do not necessarily reflect the views of DOE.

TABLE OF CONTENTS

1: Step-by-Step Energy Efficient Construction 1

2: Why Build Efficiently? 13

3: The House as a System 19

4: Air Leakage—Materials and Techniques 31

5: Insulation Materials and Techniques 43

6: Windows and Doors 69

Appendix 1: Mortgage Rate Tables 83

Appendix 2: Fingertip Facts 87

Appendix 3: Resources 89

Chapter 1
Step-by-Step Energy Efficient Construction

When properly used in home construction, energy features save money, improve indoor air quality, enhance comfort, prevent moisture problems, and increase the long term durability of the building.

Key Features of an Energy Efficient Building Envelope

An important objective of creating an energy efficient building envelope is to treat the house as a system, with every building and system component designed and installed in consideration of other components. The building envelope is defined as the perimeter of the structure between the interior conditioned/insulated living space and unconditioned/uninsulated space in the home. Building components to consider are:

Moisture barrier system—keeps water out of the structure. Bulk water infiltration, such as rain and dampness that naturally occurs in crawl spaces and basements, needs to be reduced to preserve the structure, reduce humidity, decrease the chance for mold to develop and deter insect infestation.

- Drain water away from foundation.
- Install polyethylene ground cover under slabs or on the floor of crawl spaces.
- Install termite shields on top of foundation walls to hinder insect infestations and serve as a capillary break.
- Make interior finish airtight.
- Carefully flash roofing details, around windows and doors, and other roof and wall penetrations through which wind-driven rain may leak.

Continuous air barrier system—seal all leaks between conditioned and unconditioned spaces with durable materials. Achieving success can be difficult without diligent efforts, particularly in homes with multiple stories and changing roof lines.

Air barriers may also help a home meet local fire codes. One aspect of controlling fires is preventing oxygen from entering a burning area. Most energy codes and fire codes have requirements to seal air leakage sites.

- Eliminate leakage between conditioned and unconditioned spaces, particularly between living areas and crawl spaces, unheated basements, and attics.
- Caulk all seams and joints before drywall is installed.
- Use drywall, plywood, or other fire-resistant sheet material to seal the tops and bottoms of chases for ductwork or flues. Use the same materials to seal between the attic and dropped soffits above cabinets and shower-tub enclosures.

Continuous insulation barrier—for an effective insulation system. In an attic, poorly installed R-30 insulation may provide less savings and comfort than R-19 installed properly. Make certain to design a complete insulation system—specify R-values for all walls, ceilings, and floors and other surfaces between conditioned and unconditioned areas.

- Install insulation as continuously as possible between conditioned and unconditioned spaces.
  - Exterior walls, floors over unconditioned or exterior spaces, ceilings below unconditioned or exterior spaces (including attic access covers).

- Wall areas adjacent to attic spaces or basement spaces—such as knee walls, attic stairways, and high walls between areas with cathedral ceilings and flat attics, and basement stairways.
- Wall areas between conditioned and unconditioned spaces—such as band joists, garage walls, and mechanical room walls.

Energy efficient windows—can be a good investment that will provide interior comfort and reduce air infiltration. Remodelers may want to weigh the cost of refurbishing older, single-pane windows versus the benefit of a new efficient window.

- Design home with minimal east and west glass area, locate additional glass area on south side for passive heating in winter months.
- Use double-glazed windows with U-values under 0.60 (R-values of at least 1.65).
- Consider low-emissivity coatings and other high performance features in the purchase of windows.
- Shade windows in summertime with overhangs or glazing treatments.

Additional Components to Consider

Although not covered in this publication you should consider these additional features. These features directly affect the building envelope and are integral to the house as a system.

Heating and cooling system designed for efficiency

- Select high efficiency equipment designed for local climatic conditions.
- Size and install equipment properly.
- Eliminate potential for backdrafting of combustion appliances.
- Install fresh air ventilation systems to bring in outside air when needed.

Ductwork sealed

- Install ductwork in conditioned space where possible.
- Size and lay out ductwork to supply proper airflow; measure airflow to guarantee comfort.
- Seal all duct seams and joints with mastic or mastic plus fiber mesh.
- Seal joints around removable components (ie. filter door) with duct tape.

Intentional ventilation—a well-sealed building envelope needs fresh air to maintain good indoor air quality. Design with the intention of replacing air that is vented out of the structure.

- Provide spot ventilation in bathrooms and the kitchen combined with a source of outside air.
- Consider upgrading to a whole house ventilation system using a central blower or a heat recovery ventilation system.

Water heating and plumbing appliances—choose for efficiency. For water heaters, install to minimize heat loss and to reduce venting flue gases to the living space (on fuel-fired models).

- Select an efficient water heater. Look for the EnergyGuide label and comparatively shop.
- Install heat traps and insulate plumbing lines. Retrofit water heater wraps on older units.
- Use water conserving fixtures and appliances. Consider a hot water recirculating system that pumps hot water for instant access at the point of use.
- Fuel-fired water heaters should be located in a sealed combustion closet, or choose a direct-vented model where a combustion closet would be impractical.

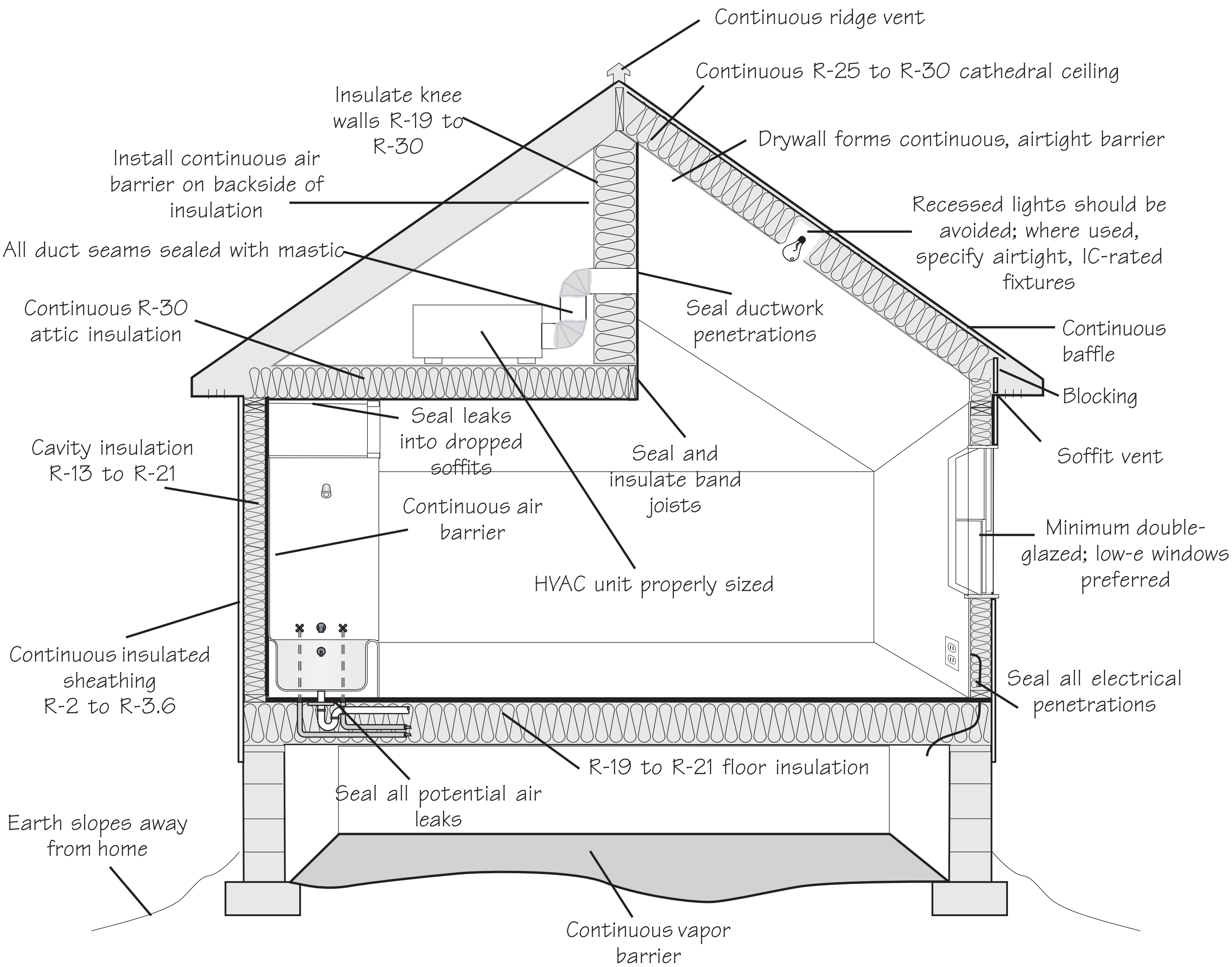
Energy efficient appliances and lighting

- Install fluorescent or compact fluorescent fixtures if the light would be on over 4 hours per day.
- Use recessed lights selectively and choose only air-tight IC-rated fixtures (IC = insulation contact).
- Use high-pressure sodium or metal halide lamps for exterior lighting with daylight sensors if used for security lighting.
- Look for the EnergyGuide and ENERGY STAR® labels and comparatively shop for appliances and fixtures.

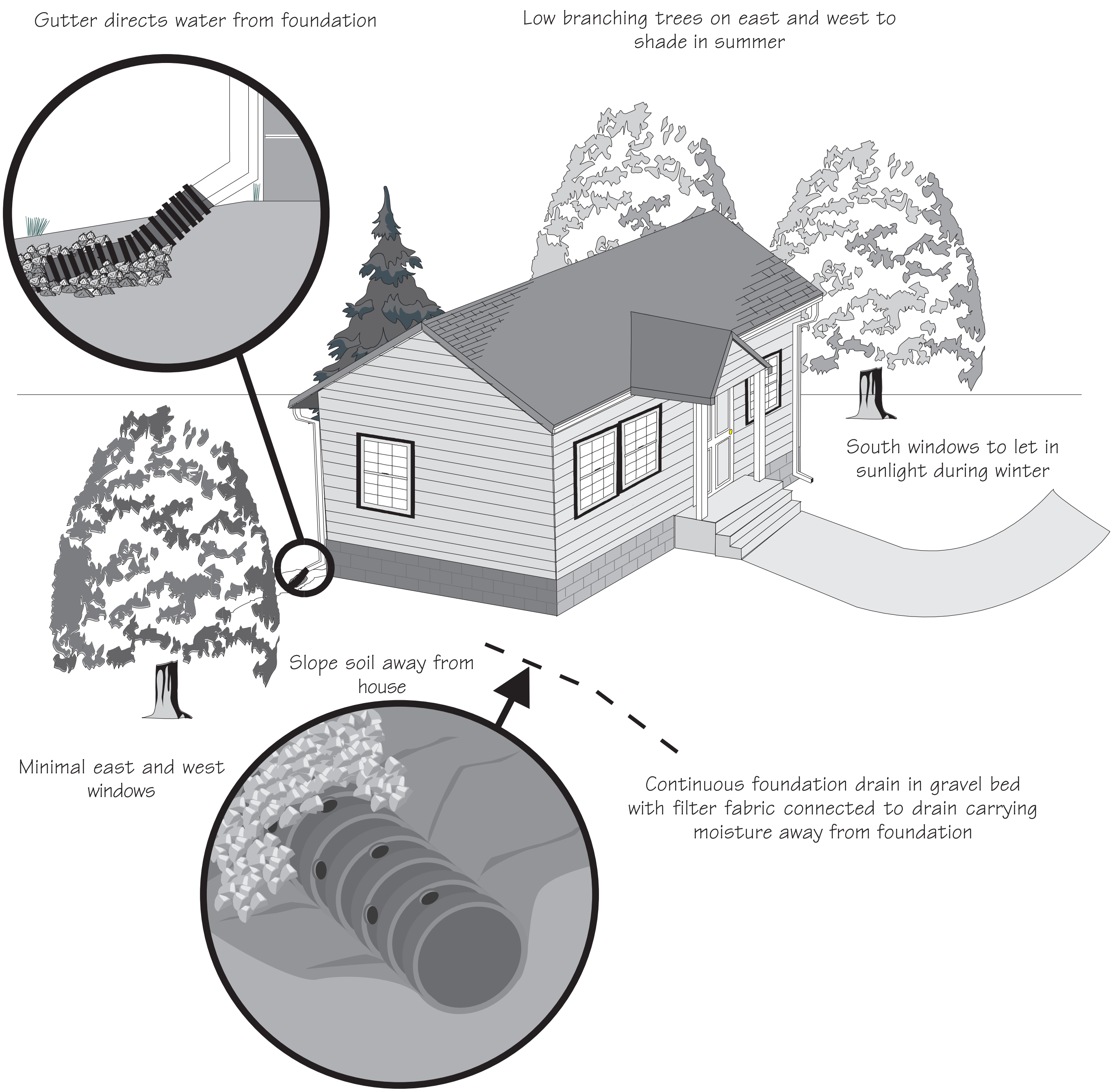
Passive solar design—to further reduce winter heating and summer cooling needs. Most design concepts can be incorporated with little additional cost.

- Consider site orientation, window choices and placement, roof overhangs and materials choices in the initial design process.

Building Section

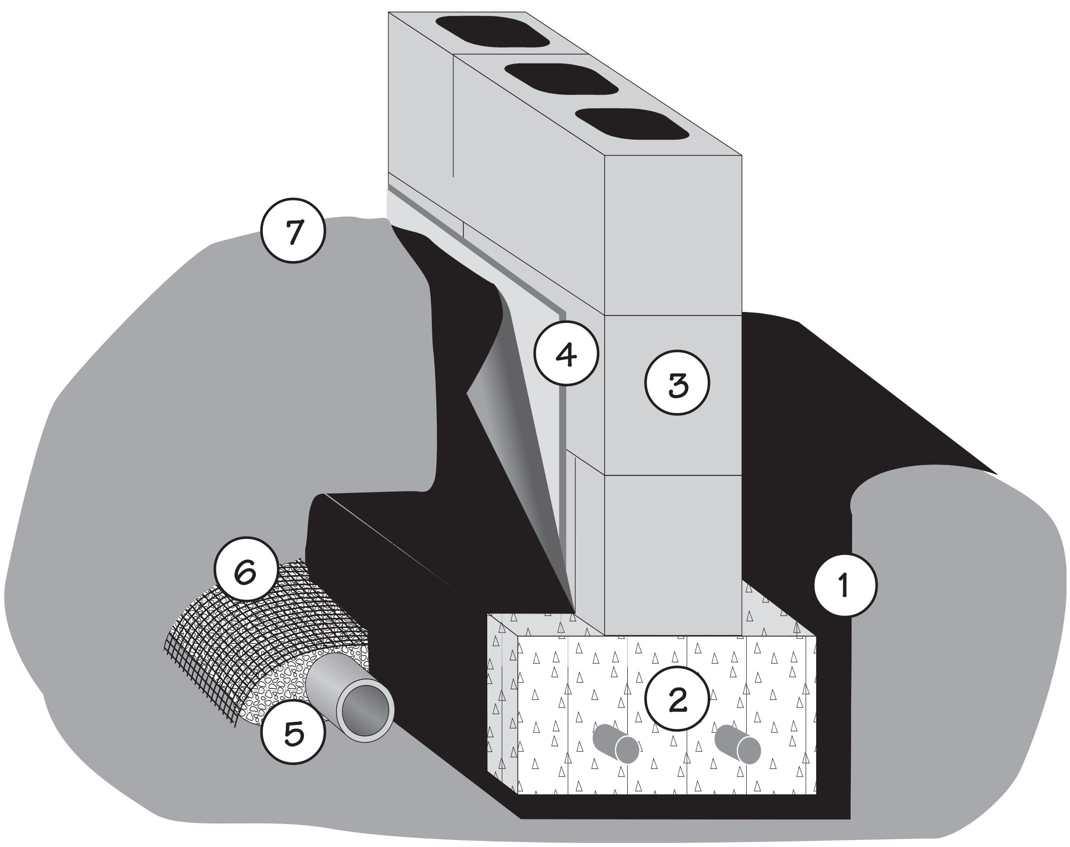


Site Planning

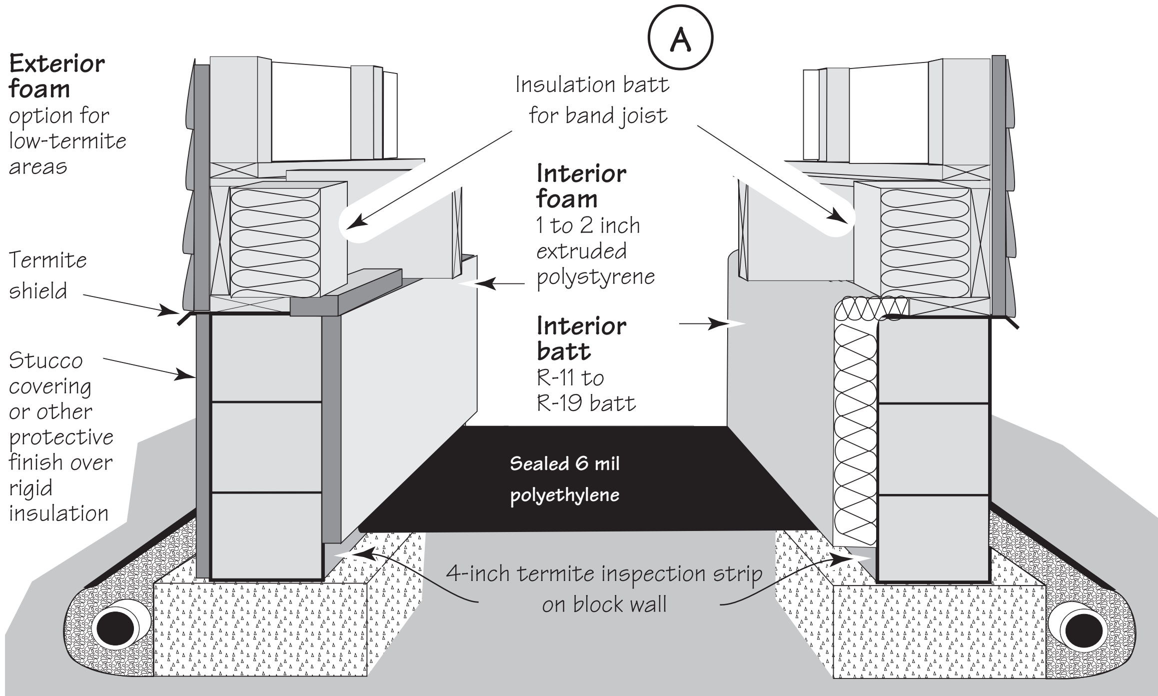


Footing and Foundation Wall

1. Install layer of polyethylene as a capillary break.
2. Set rebar as required and pour concrete.
3. Build foundation wall.
4. Waterproof below-grade portion of foundation wall and install drainage plane material if conditioned spaces are on other side of wall.
5. Cover perforated drain pipe with gravel.
6. Install filter fabric over drainage pipe and gravel.
7. When back filling foundation wall, slope earth away from house at a 5% grade on all sides.



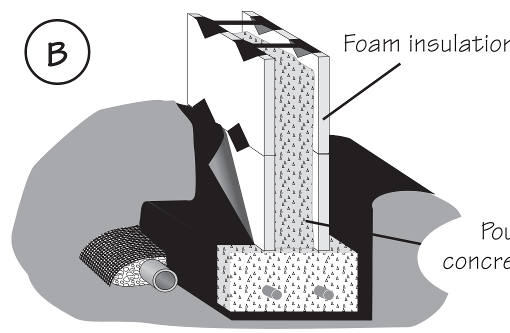
Foundation Alternatives

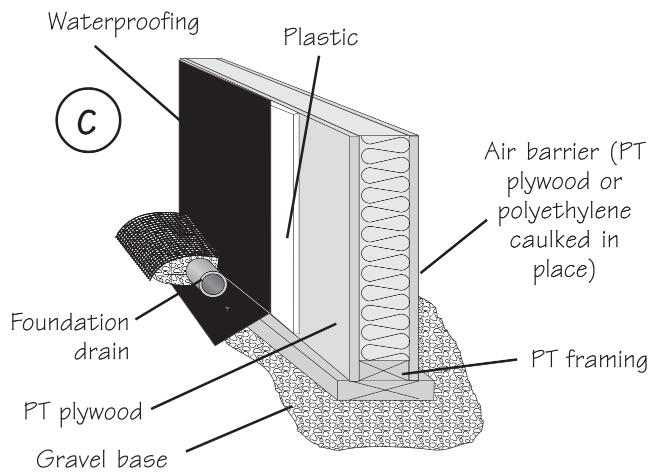


A) In unvented crawl spaces you can install rigid foam board inside and out (left) to insulate the crawl space wall. Confirm acceptance by local code official. Batt insulation can be used for interior crawl wall insulation (right). In both approaches allow for a termite inspection gap.

B) Investigate insulated concrete foundation systems and insulated foam blocks—check with manufacturer carefully for recommended water proofing, type of termite treatments, concrete specifications, reinforcing requirements, and other stipulations. Confirm acceptance by local code official.

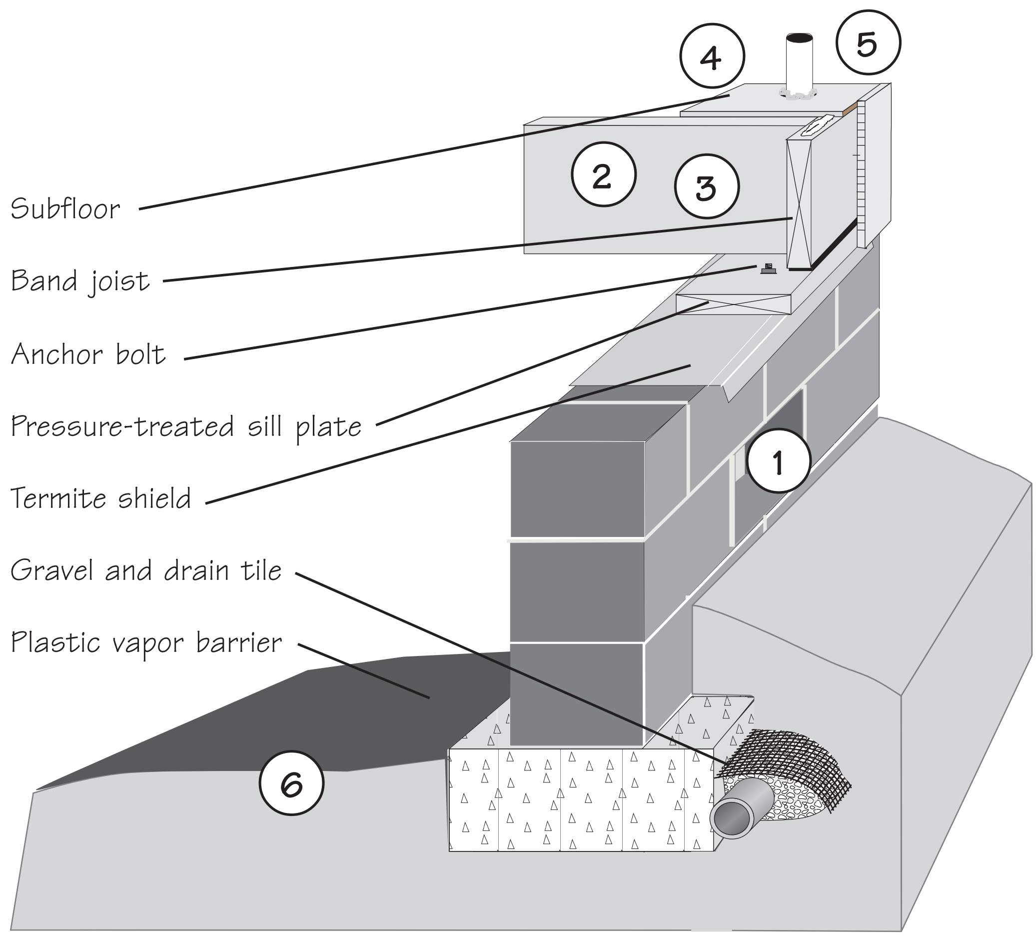
C) Permanent wood foundation—use pressure treated (PT) plywood and framing lumber; waterproof outside, cover with polyethylene plastic, and insulate. Install drainage system and back fill carefully.





Crawl Space or Unconditioned Basement

1. Install operable foundation vents and close in winter, as allowable under local codes.*
2. Consider manufactured joists in place of dimensional lumber, such as 2x10s or 2x12s. Manufactured joists, in most instances, can make longer spans without additional pier supports.
3. Set band joists and floor joists.
4. Glue subfloor in place, except use caulking:
   - between band joist and subfloor,
   - around other openings and subfloor.
5. Seal all holes through floor as home is constructed.
6. Lay plastic moisture barrier on 100% of crawl space floor.



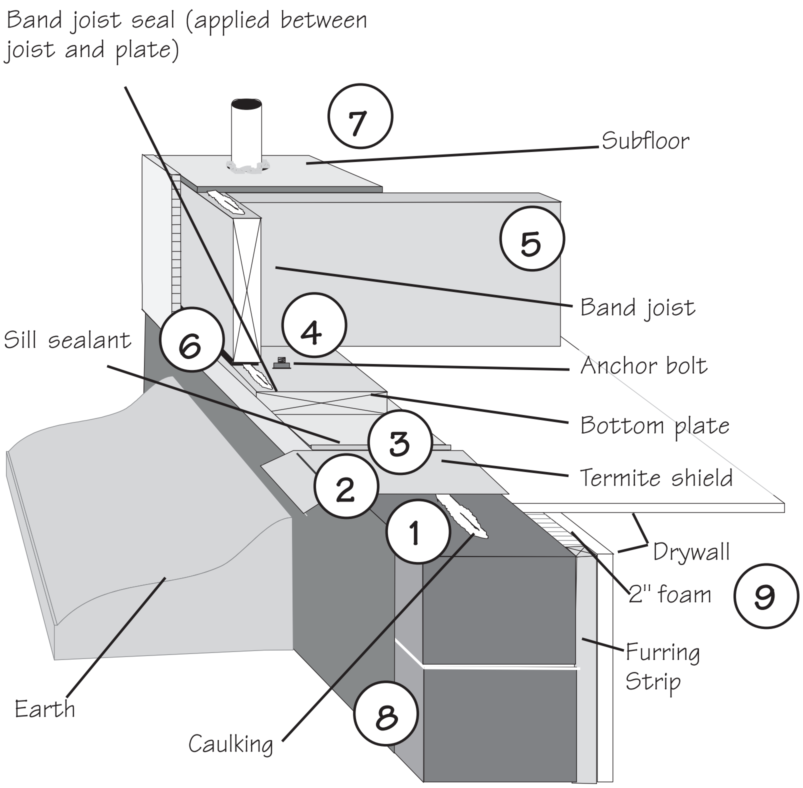
* See sidebar on foundation vents, page 57.

Floor — Conditioned Basement

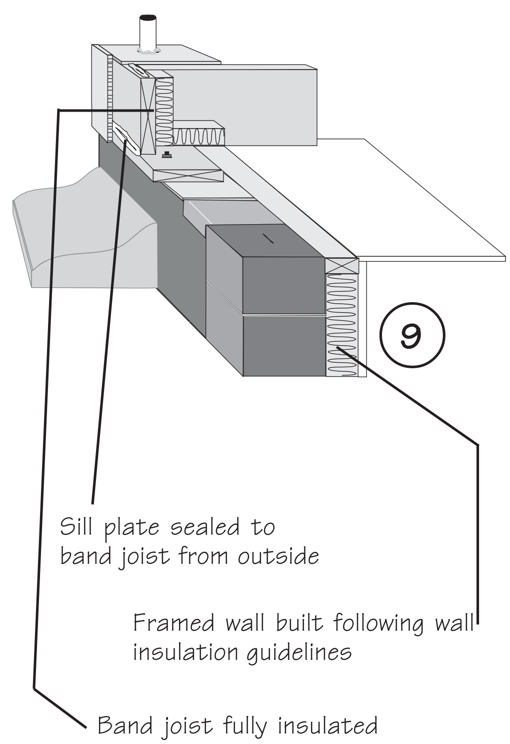
See details for crawl space floors, plus:

1. Caulk under termite shield.
2. Set termite shield on top of foundation wall.
3. Lay sill sealant material.
4. Predrill pressure-treated sill plate—bolt in place.
5. Set band joists and floor joists.
6. Seal seam between band joist and sill plate with durable caulking—either between joists and plates or from outside after floor framing is completed. Insulate band joist area.
7. Caulk subfloor to band joist and floor joists.
8. Waterproof wall and install drainage plane material plus drain tile adjacent to footing.
9. Install interior foam insulation or interior framed, insulated wall.

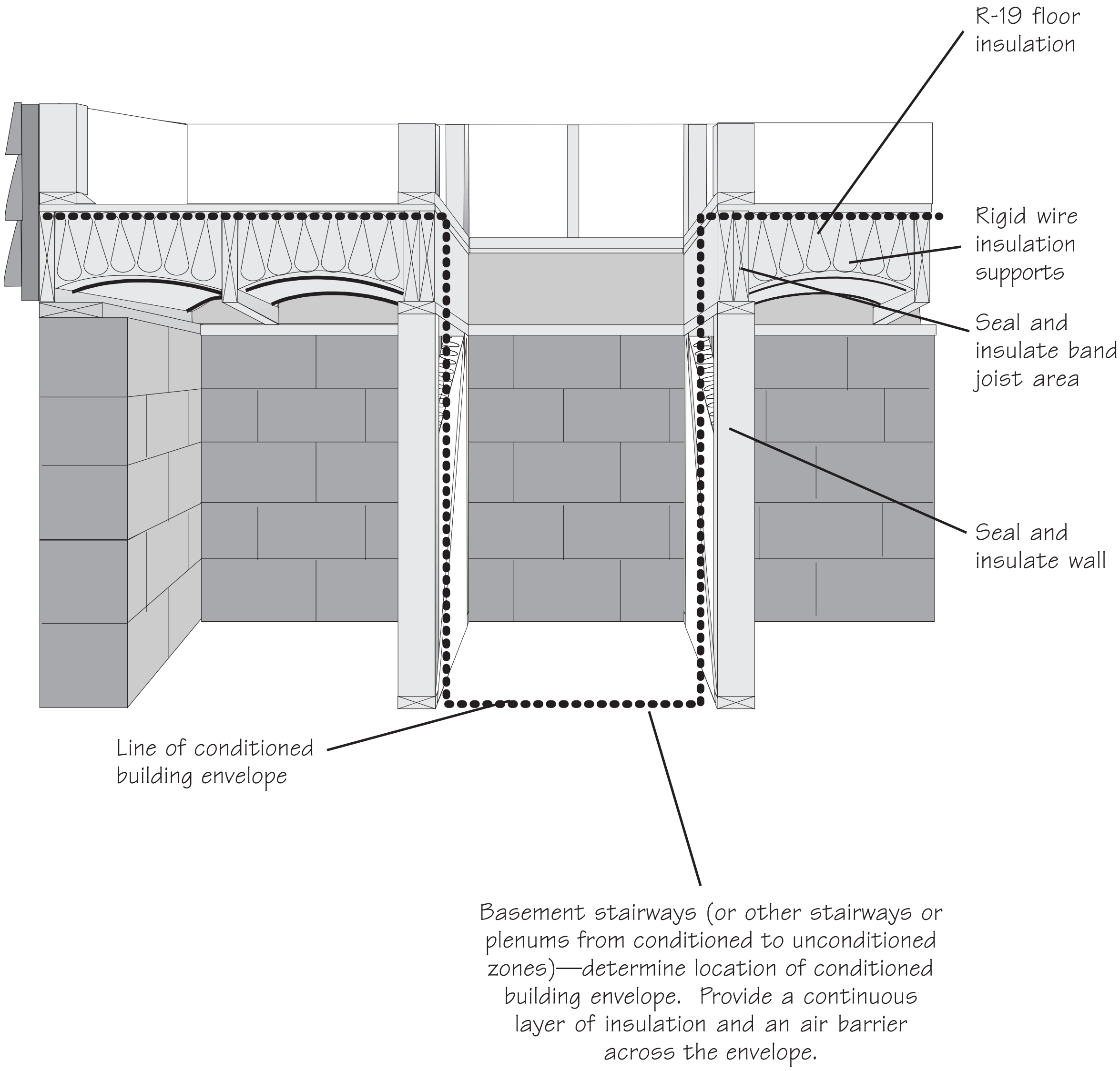
Interior Foam Insulation



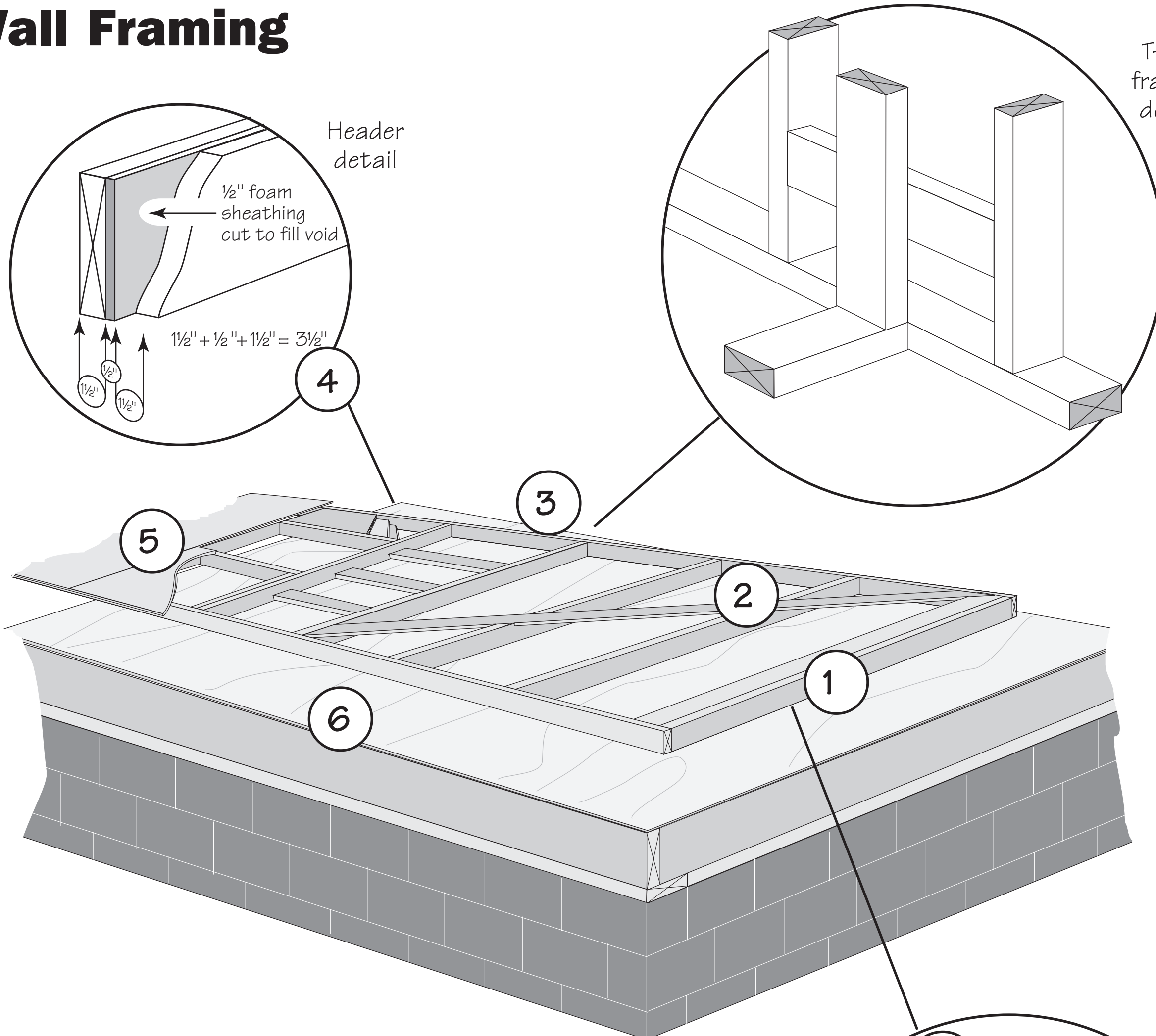
Interior Framed, Insulated Wall



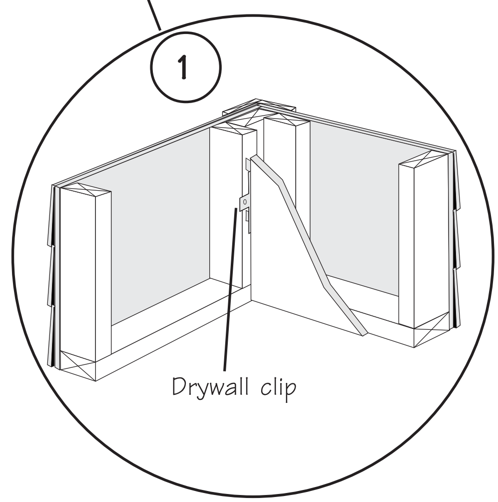
Insulated Floor



Wall Framing

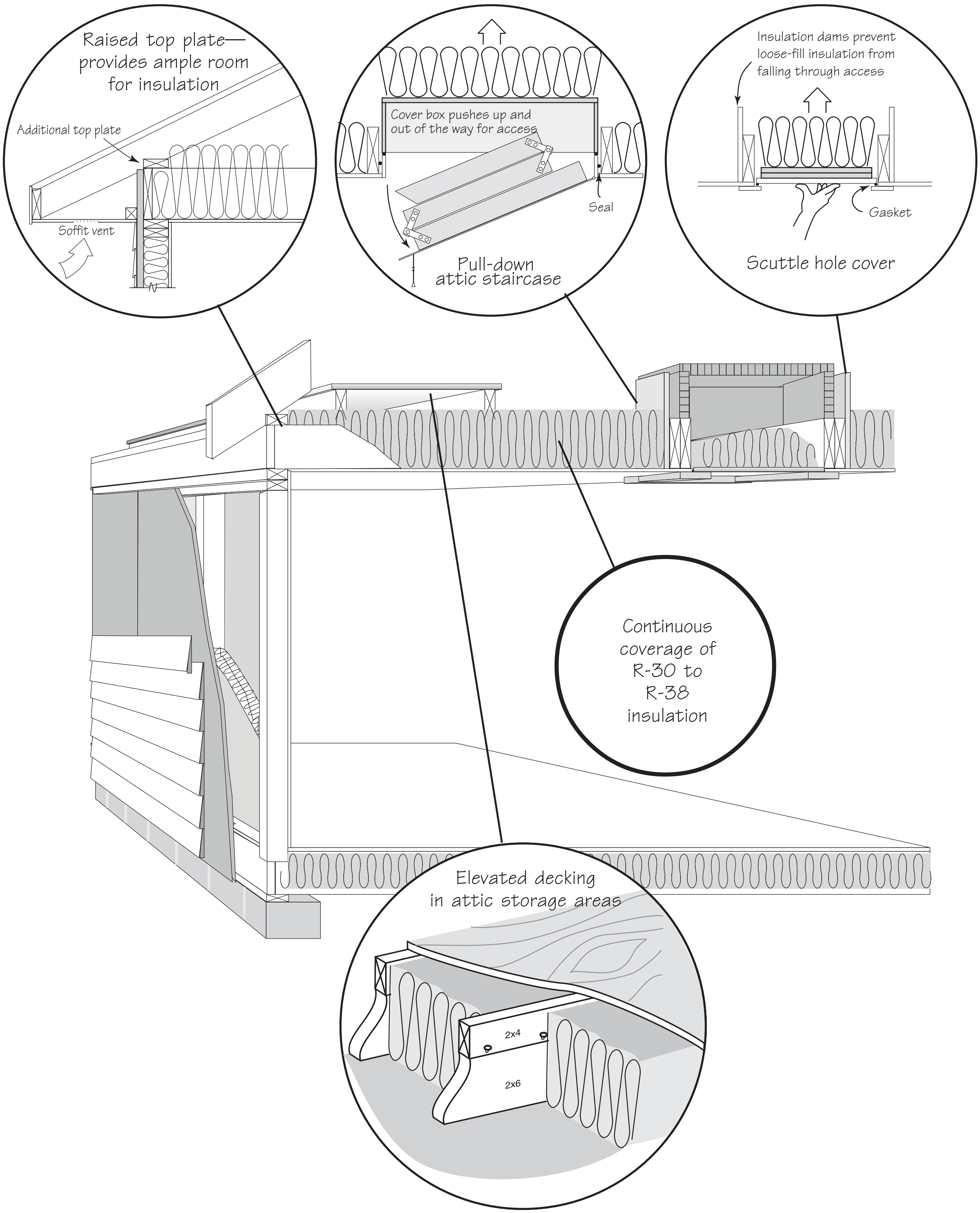


1. In corners, use single stud corner or double stud corner when using wood siding with vertical cornerboard trim.
2. Use 1x4 or metal T-brace near corners.
3. At partition wall (T-wall) intersection, eliminate additional studs for nailing drywall; use "ladder" instead.
4. Add ½" foam to structural headers.
5. Cover entire wall with ½" foam sheathing, including band joists and second top plates.
6. Before lifting wall in place, install sill sealant material between wall and subfloor.



Corner framing detail with vertical corner board and wood siding permits installation of corner insulation

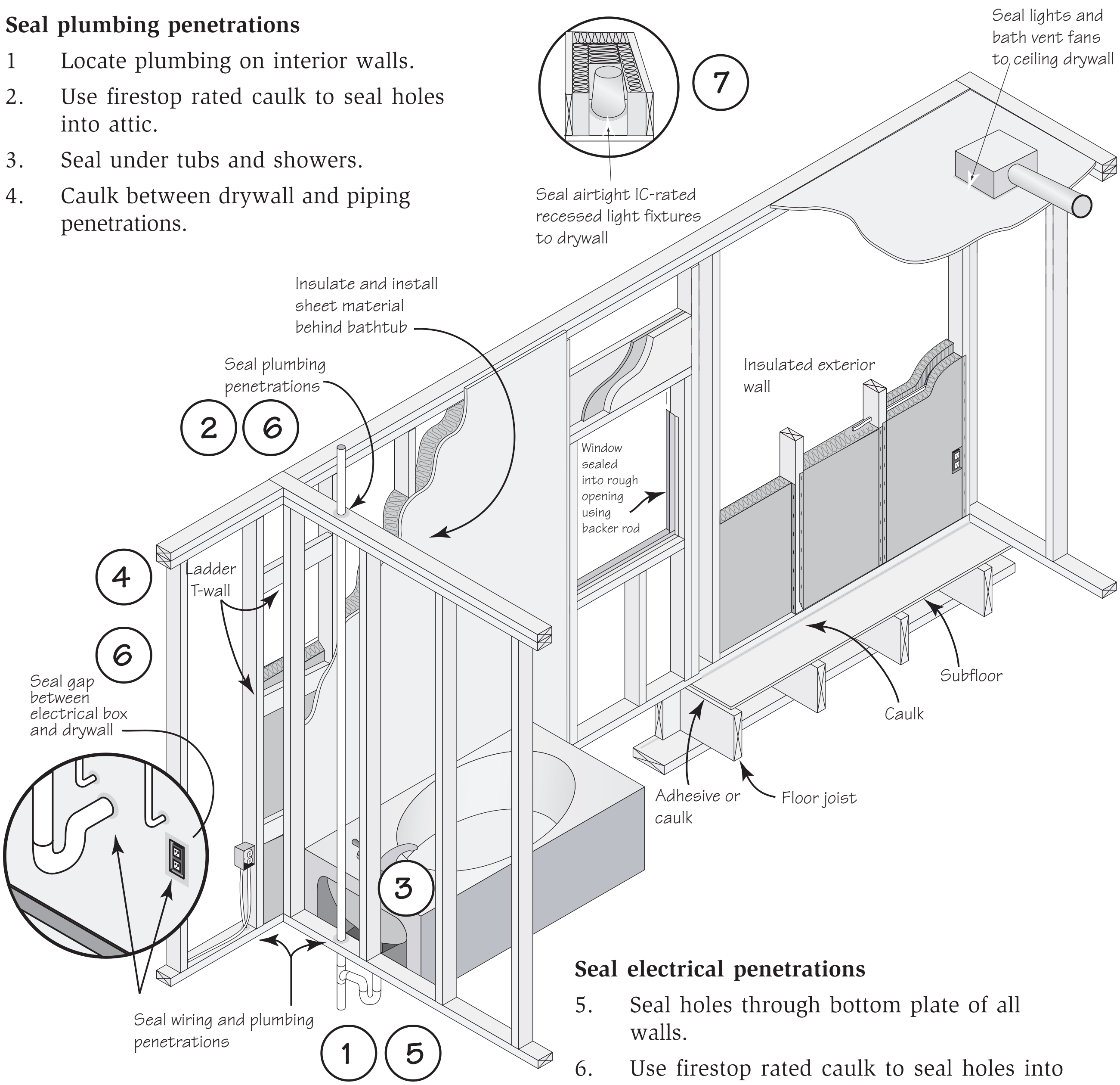
Ceiling Details



Seal Holes and Penetrations

Seal plumbing penetrations

1 Locate plumbing on interior walls.
2. Use firestop rated caulk to seal holes into attic.
3. Seal under tubs and showers.
4. Caulk between drywall and piping penetrations.



Seal electrical penetrations

5. Seal holes through bottom plate of all walls.
6. Use firestop rated caulk to seal holes into attic.
7. Caulk between drywall and all electrical boxes, including receptacles, switches and lights.
8. Minimize use of recessed lights; where used choose IC (insulated cover) fixtures that also have airtight ratings.

Chapter 2

Why Build Efficiently?

Investments in energy efficient features in new construction are remarkable because everyone wins:

- Homeowners receive a positive cash flow within 1 to 3 years.
- Homeowners benefit additionally from improved comfort, better indoor air quality, reduced moisture problems, and fewer health problems.
- Builders have fewer call-backs to make corrections and earn additional profit from the added value.
- Heating and cooling contractors have fewer call-backs.
- Realtors benefit from the value added features and enhance their reputation by selling higher quality homes that consumers appreciate.
- Bankers generate higher mortgage payments for homes with lower annual costs of ownership due to the reduced energy bills.
- National lending agencies, such as the Federal Housing Authority (FHA), the Veteran's Administration (VA), and Fannie Mae offer preferred financing options to owners of energy efficient homes.
- The local economy benefits as more money stays within the community and local subcontractors and product suppliers make additional income by selling improved energy efficient features.
- Everyone enjoys reduced pollution from fossil-fueled power plants and increases in national security from decreased demand for non-renewable energy sources.

Achieving Efficiency

Energy efficient homes are no accident. Too often, measures that may be easier to market are installed, but key ingredients—such as sealing air leaks and duct leaks—are left undone. The results are homes that fall far short of the goals of a truly energy efficient home—energy bills higher than necessary, comfort and moisture problems, and homeowners who are thoroughly dissatisfied.

Designing and building a home that uses energy wisely does not mean sacrificing a home's aesthetics or amenities. Homes of any architectural style can meet the requirements of this book. Any good home design considers the characteristics of a particular site: the local climate, the availability and cost of energy sources, and the lifestyle of the occupants.

Building an energy efficient home requires no special materials or construction skills. However, the quality of basic construction has a major influence on building comfort and energy costs, especially:

- Quality of framing and installation of insulation and windows.
- Attention to detail in sealing air leaks.
- Design and installation of the heating and cooling equipment.
- Effectiveness of sealing duct leaks.

Table 2-1 shows the savings available for a "typical energy efficient home." The cumulative net savings are about $8,000 over a 30-year period. The investment begins providing a positive cash flow in the second year, once the additional downpayment for the energy feature, added into the first year's extra mortgage has been paid.

Table 2-2 shows the rate of return for energy investments with different payback periods.

Independent Home Energy Rating

Because most of the energy efficiency of a home is dependent on the quality of installation, purchasing a home energy rating provides the assurance of third party verification of your home's quality and savings. The Home Energy Rating System (HERS) is a national effort to train and certify home energy raters to evaluate the energy performance of homes.

Home energy ratings involve an on-site inspection of a home by a residential energy efficiency professional, a home energy rater. Home energy raters are trained and certified by the operating home energy rating system. As a rule, home energy raters come from either the housing or energy fields. Their backgrounds include experience as home inspectors, appraisers, energy auditors, low-income weatherization contractors, and energy efficient home builders and designers.

The home energy rater inspects the home and measures its energy characteristics, such as insulation levels, window efficiency, window-to-wall ratios, the heating and cooling system efficiency, the solar orientation of the home, and the water heating system. Diagnostic testing, such as air leakage and duct leakage testing, is often part of the rating.

Table 2-1
Savings from an Energy Efficient Home

Standard		Energy Efficient			
Year	Annual Energy Cost	Extra Mortgage Cost	Annual Energy Cost	Total Cost	Cumu-lative Savings
1	$1,200	$526*	$850	$1,376	$(176)
2	1,218	166	863	1,029	13
3	1,236	166	876	1,042	208
4	1,255	166	889	1,055	407
5	1,274	166	902	1,068	613
6	1,293	166	916	1,082	824
7	1,312	166	929	1,096	1,040
8	1,332	166	943	1,124	1,491
9	1,352	166	958	1,138	1,725
10	1,372	166	972	1,138	1,725
11	1,393	166	986	1,153	1,965
12	1,414	166	1,001	1,167	2,211
13	1,435	166	1,016	1,182	2,464
14	1,456	166	1,032	1,198	2,722
15	1,478	166	1,047	1,213	2,987
16	1,500	166	1,063	1,229	3,259
17	1,523	166	1,079	1,245	3,537
18	1,546	166	1,095	1,261	3,622
19	1,569	166	1,111	1,277	4,113
20	1,592	166	1,128	1,294	4,412
21	1,616	166	1,145	1,311	4,717
22	1,640	166	1,162	1,328	5,029
23	1,665	166	1,179	1,346	5,349
24	1,690	166	1,197	1,363	5,676
25	1,715	166	1,215	1,381	6,010
26	1,741	166	1,233	1,399	6,352
27	1,767	166	1,252	1,418	6,701
28	1,794	166	1,271	1,437	7,058
29	1,821	166	1,290	1,456	7,423
30	1,848	166	1,309	1,475	7,796

*The extra mortgage costs are for financing energy efficient features. The first year costs are higher because they include the additional downpayment.

Table 2-2
Rate of Return for Energy Investments (%)

Payback (Years)	Lifetime of Energy Investments (Years) 5	7	10	12	15	17	20
1.5	67	73	73	75	75	75	75
2	47	53	57	57	57	57	57
3	25	22	37	39	39	39	39
4	13	21	27	29	29	31	31
5	5	14	20	22	25	25	25
6	0	9	15	18	20	20	21
7	0	5	12	14	16	17	18
8	0	1	9	12	14	15	16
9	0	0	7	9	12	13	14
10	0	0	5	8	10	11	13
11	0	0	3	6	9	10	11
12	0	0	1	4	8	9	10
13	0	0	0	3	6	8	9
14	0	0	0	2	5	7	8
15	0	0	0	1	5	6	8
16	0	0	0	0	4	5	7
17	0	0	0	0	3	4	6
18	0	0	0	0	2	4	6
19	0	0	0	0	2	3	5
20	0	0	0	0	1	3	4

Note: A zero indicates the rate of return is either negligible or negative. The table assumes energy prices escalate 4% per year.

The data gathered by the home energy rater is entered into a computer program and translated into points. The home receives a score from 1 to 100, depending on its relative efficiency. An estimate of the home's energy costs is also provided. The home's energy rating is then given a star rating ranging from one star for a very inefficient home to five stars for a highly efficient home. Along with the rating sheet, a home owner receives a report listing cost-effective options for improving the home's energy rating.

Home energy rating is also a major component in most green builder programs. In addition to energy efficiency, these programs address other environmental concerns regarding home building, such as materials conservation, water efficiency, land preservation, waste management, and indoor air quality.

Home energy rating offers many benefits including:

- Verification of home quality
- Estimate of annual energy costs
- Design process tool to choose energy features
- Nationally-approved scoring system that allows home buyers to compare energy efficiency of homes
- Added value that increases the appraised value
- Compliance tool for the Model Energy Code adopted by Alabama
- Home certification for marketing programs such as ENERGY STAR® and others
- Home certification for energy efficient mortgages (see below)

For more information on home energy ratings and a list of certified raters in Alabama, see Appendix 3.

Financing Energy Efficiency

A useful tool is now available in Alabama to help finance energy efficiency features and solar technologies—energy efficient mortgages. With energy efficient mortgages, different finance options are available depending on the lender. These mortgages make it easier for homebuyers to qualify for energy efficient homes or to afford a more costly home at a given income.

For example, preferred terms for homebuyers purchasing ENERGY STAR® Homes through an ENERGY STAR® Mortgage can include:

- Cash back at closing
- Increased debt-to-income ratio
- Assured appraisal values
- Free interest lock
- Reduced loan origination fees
- Discounted interest rates

Lenders of energy efficient mortgages usually require a home energy rating.

For more information on energy efficient mortgages and programs that currently operate in Alabama, please see Appendix 3.

The Residential Energy Code of Alabama

The Residential Energy Code of Alabama (RECA) is a voluntary state developed code equivalent to the IECC 2000 (International Energy Conservation Code) with the exception that windows have a SHGC of .4. The RECA specifies the amount of insulation required for walls, ceilings and floors in relation to the amount installed in each one of those individual components and takes in to account the climatic zone where the dwelling is located.

Alabama has four distinct climatic zones, see figure 2-1. In general, the northern section of the state is a "Mixed Climate" moving to a "Warm Climate" in the southern portion of the state. The RECA provides guidelines for glazing, insulation and heating/cooling equipment efficiencies and where trade-offs can occur. This strategy, referred to as a *prescriptive approach,* increases efficiency in one area in exchange for reduced efficiency in another area. Along with the zone specific information provided by the RECA, there are basic guidelines for all climatic zones.

Summary of Basic Requirements

- *Air Leakage*. Joints, penetrations, and all other such openings in the building envelope that are sources of air leakage must be caulked, gasketed, weatherstripped, or otherwise sealed. The maximum leakage rate for manufactured windows is 0.34 cfm/ft of operable sash crack. The maximum leakage rate for manufactured doors is 0.5 cfm/ft of door area.
- *Vapor Retarder*. Vapor retarders must be installed on the warm-in-winter side of all non-vented framed ceilings, walls, and floors.

- *Materials and Insulation Information*. Materials and equipment must be identified so that compliance can be determined. Manufacturer manuals for all installed heating and cooling equipment and service water heating equipment must be provided.
- *Duct Insulation*. Supply and return ducts for heating and cooling systems located in unconditioned spaces must be insulated.
- *Duct Construction*. All transverse joints must be sealed with mastic. The HVAC system must provide a means for balancing air systems.
- *Temperature Controls*. Thermostats are required for each separate HVAC system in single-family buildings and each dwelling unit in multifamily buildings (non-dwelling portions of multifamily buildings must have one thermostat for each system or zone). Thermostats must have the following ranges:

  Heating Only – 55°F - 75°F

  Cooling Only – 60°F - 85°F

  Heating and Cooling – 55°F - 85°F

  A manual or automatic means to partially restrict or shut off the heating and/or cooling input to each zone or floor must be provided for single-family homes and to each room for multifamily buildings.
- *HVAC Piping Insulation*. HVAC piping in unconditioned spaces conveying fluids at temperatures above 120°F or chilled fluids at less than 55°F must be insulated.
- *Circulating Hot Water*. Circulating hot water systems must have automatic or manual controls and pipes must be insulated.
- *Electric Systems*. Each multifamily dwelling unit must be equipped with separate electric meters.

Notes on the State's Residential Code:

The Residential Energy Code of Alabama (RECA), a voluntary state developed code equivalent to the IECC 2000 (International Energy Conservation Code) without SHGC 0.40 (solar heat gain low-e window) requirements. SHGC 0.40 is contingent upon local adoption.

The state has made available the RECA 2004 based on the IECC 2000. Residential designers are able to comply with RECA 2004 by following the prescriptive standards of RECA 2004 or by complying with the IECC 2000.

For more information on Energy Code resources, see Appendix 3.

Figure 2-1

EVALUATING ENERGY EFFICIENT PRODUCTS

The energy efficient builder seeks to minimize the lifetime costs of a home rather than the first costs. Making such calculations is often time-consuming and confusing. One of the best ways to determine whether an investment is sound is to compare the annual energy savings with the additional annual mortgage costs to find the Net Annual Savings.

For example, suppose you are wondering whether it is worthwhile for a home to have high efficiency, low-e windows, which use special coatings to reduce heat loss and gain. A builder had planned to install double-glazed units, but is now considering an upgrade to low-e units. He receives the following information from a window dealer:

- Additional Window Cost = $500
- First Year Energy Savings = $75

He can easily calculate that the payback period on the above investment is just under 7 years. However, he is unsure whether the payback is acceptable. To find the Net Annual Savings, first, he finds the extra mortgage costs for the windows:

- Mortgage Interest Rate = 8.5%
- Term of Mortgage = 30 years
- Monthly Payment per $1,000 (from Appendix 1) = $7.69
- Annual Payment per $1 (multiply the above by 12 and divide by 1,000) = $.092
- Extra Annual Payment (multiply the additional cost of the windows by the above factor) = $500 x $.092 = $46
- Net Annual Energy Savings (subtract the annual payment from annual energy savings) = $75 - $46 = $29

Since the Net Annual Energy Savings is positive, the investment is sound, especially when considering that energy costs will increase over time, while mortgage costs will remain relatively constant.

It is often useful to calculate the Rate of Return (ROR) for an energy investment. Homeowners can compare the annual percentage return for an energy measure to that earned by their financial investment. The steps for finding the ROR, using the above example, are as follows:

1. Find the payback period (divide the total cost by the annual savings) = 500/75 = about 7 years
2. Determine the life of the energy measure = over 20 years
3. For the payback period and lifetime, find the ROR in Table 2-2 = 18% (and it's tax free)

Notes:

Chapter 3

The House As A System

We sometimes think of our homes as independent structures, placed on an attractive lot, and lived in without regard to the world around. Yet, most homes have problems—some minor nuisances, others more serious:

- Mold on walls, ceilings, and furnishings
- Mysterious odors
- Excessive heating and cooling bills
- High humidity
- Rooms that are never comfortable
- Decayed structural wood and other materials
- Termite or other pest infestations
- Fireplaces that do not draft properly
- High levels of formaldehyde, radon or carbon monoxide

These problems occur because of the failure of the home to properly react to the outdoor or indoor environment. The house should be designed to function well amid fluctuating temperatures, moisture levels, and air pressures.

Health and Comfort Factors

The following factors define the quality of the living environment. If kept at desirable levels, the house will provide comfort and healthy air quality.

- *Moisture levels*—often measured as the relative humidity (RH). High humidity causes discomfort and can promote growth of mold and organisms such as dust mites.
- *Temperature*—both dry bulb (that measured by a regular thermometer) and wet bulb, which indicates the amount of moisture in the air. The dry bulb and wet bulb temperatures can be used to find the relative humidity of the air.
- *Air quality*—the level of pollutants in the air, such as formaldehyde, radon, carbon monoxide, and other detrimental chemicals, as well as organisms such as mold, pollen, and dust mites. The key determinant of air quality problems is the strength of the source of pollution.
- *Air movement*—the velocity at which air flows in specific areas of the home. Higher velocities make occupants more comfortable in summer, but less comfortable in winter.
- *Structural integrity*—the ability of the materials that make up the home to create a long-term barrier between the exterior and interior.

Concepts

Heat Flows in Homes

The health and comfort factors are affected considerably by how readily heat moves through a home and its exterior envelope. The sidebar explains the three primary modes of heat transfer.

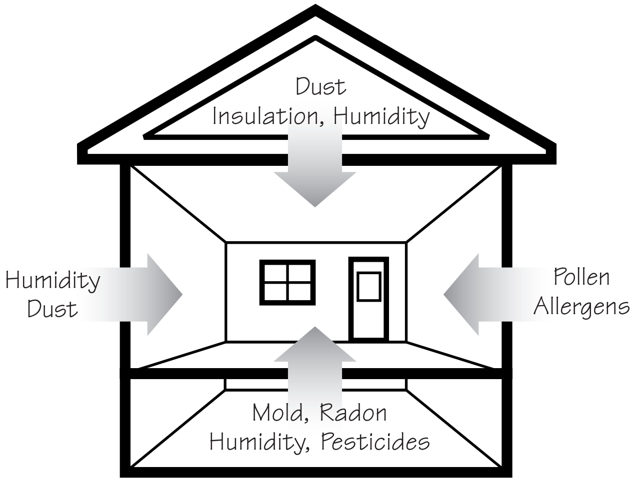
In summer, the cooling needs are driven by the location and shading of windows. Also, the percentage of the cooling load that is for *latent cooling* (humidity removal) can increase substantially in homes with a well insulated thermal envelope. The major sources of moisture, some of which can be controlled, include cooking activities, human respiration and perspiration, and infiltration of hot, humid, exterior air.

Air Leaks and Indoor Air Quality

The relationship between indoor air quality and the air tightness of a home are a concern to both building professional and homeowners alike. The major factor affecting indoor air quality is the level of the pollutant causing the problem. Thus, most experts feel that the solution to poor indoor air quality is removing the source of the pollution.

Building a leakier home may or may not help lessen the intensity of the problem, but it will not eliminate it, nor necessarily create a healthy living situation.

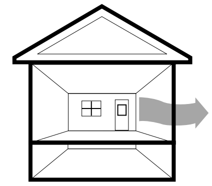
Figure 3-1:
Air Quality Problems from "Fresh" Air
in a Leaky House



HOW HEAT MOVES

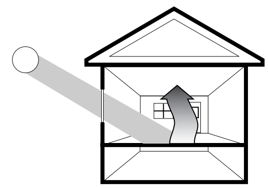
Conduction

- The transfer of heat through solid objects, such as the ceiling, walls, and floor of a home.
- Insulation (and multiple layers of glass in windows) reduce conduction losses.

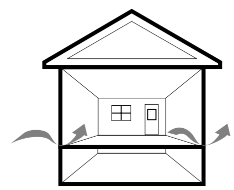


Convection

- The flow of heat by currents of air.
- As air becomes heated it rises; as it cools, it becomes heavier and sinks.

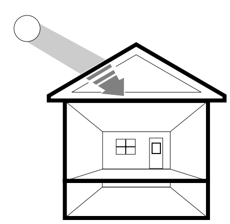


- The convective flow of air into a home is known as *infiltration*; the outward flow is called *exfiltration*. In this book, this air flow is known generally as *air leakage*.



Radiation

- The movement of energy in waves from warm to cooler objects across empty spaces.
- Examples include radiant heat traveling from:
  - inner panes of glass to outer panes in double-glazed windows in winter
  - roof deck to attic insulation during hot, sunny days
- Can be minimized by installing reflective barriers; examples include radiant heat barriers in attics and low-emissivity coatings for windows.



Air leaks often bring in air quality problems from outside, such as:

- Mold from crawl spaces and outdoors
- Radon from crawl spaces and under-slab areas
- Humidity from crawl spaces and outdoor air
- Pollen and other allergens from outdoor air
- Dust and other particles from crawl spaces and attics

The best solution to air quality problems is to build a home as tightly as possible and install an effective ventilation system that can bring in fresh outside air (not crawl space or attic air).

Radon Resistant Construction

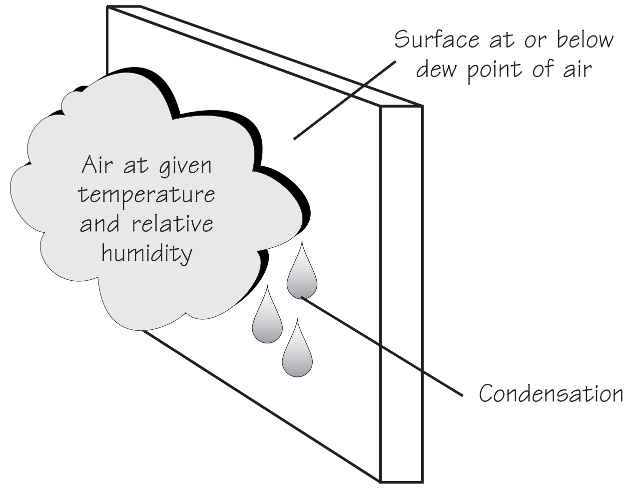
Radon is an invisible, odorless gas that is radioactive. It occurs in some rock formations and migrates upward through the soil. If a home is located over a source of radon, the gas may accumulate in high concentrations under the slab or in the crawl space. It may find its way into the living area, where its health impact is of grave concern.

Solving radon problems is easiest in new construction. For homes with slab floors, install a ventilation system below the slab — at least 4 inches of clean gravel and a series of interconnected, perforated pipes. Connect the horizontal piping system to a vertical pipe that goes up to the attic. Once the house is ready for occupancy, test the lowest living area for radon, such as a basement room, using widely available radon test kits. If radon exists in concentrations over 4 pico-curies per liter in homes with slab floors, install a blower on the vertical ventilation pipe in the attic that connects to the ventilation system under the slab. Homes with crawl spaces usually have less concern about radon, but if high concentrations exist, install a blower in the crawl space that exhausts air to the outdoors. For more information on radon, see Appendix 3.

How Condensation Occurs

Air is made up of gases such as oxygen, nitrogen, and water vapor. The amount of water vapor that air can hold is determined by its temperature. Warm air can hold more vapor than cold air. The amount of water vapor in the air is measured by its relative humidity. At 100% RH, water vapor condenses into a liquid. The temperature at which water vapor condenses is its dewpoint.

Figure 3-2:
Conditions for Condensation



The dew point of air depends on its temperature and relative humidity. A convenient tool for examining how air, temperature and moisture interact is the Psychrometric Chart, explained in the sidebar *Understanding Relative Humidity.* Preventing condensation involves reducing the RH of the air or increasing the temperatures of surfaces exposed to the air.

Effect of Relative Humidity

Humans respond dramatically to changes in relative humidity (RH):

- At lower RH, we feel cooler as moisture evaporates more readily from our skin.
- At higher levels, we may feel uncomfortable, especially at temperatures above 78 degrees F.
- Dry air can often aggravate respiratory problems.
- Molds grows in air over 70% RH.
- Dust mites prosper at over 50% RH.
- Wood decays when the RH is near or at 100%.
- Ideal health and comfort for humans occurs at 30% to 50% RH.

$$\text{RH} = \frac{\text{the amount of water vapor in the air at a given temperature}}{\text{the maximum amount of water vapor that air can hold at that temperature}}$$

MOISTURE AND RELATIVE HUMIDITY

A psychrometric chart aids in understanding the dynamics of moisture control. A simplified chart shown in Figure 3-3 relates temperature and moisture. Note that at a single temperature, as the amount of moisture increases (moves up the vertical axis), the relative humidity of the air also increases. At the top curve of the chart, the relative humidity reaches 100%—air can hold no additional water vapor at that temperature, called the dew point, so condensation can occur.

Winter Condensation in Walls

In a well built wall, the temperature of the inside surface of the sheathing will depend on the insulating value of the sheathing, and the indoor and outdoor temperatures. When it is 35°F outside and 70°F at 40% relative humidity inside:

- The interior surface of plywood sheathing will be around 39°F
- The interior surface of insulated sheathing would be 47°F

The psychrometric chart can help predict whether condensation will occur:

1. In Figure 3-4, find the point representing the indoor air conditions
2. Draw a horizontal line to the 100% RH line
3. Next, draw a vertical line down from where the horizontal line intersects the 100% RH line

In the example, condensation would occur if the temperature of the inside surface of the sheathing were at 44°F. Thus, under the temperature conditions in this example, water droplets may form on the plywood sheathing, but not on the insulated sheathing.

Summer Condensation in Walls

Figure 3-5 depicts a similar case in summer. If the interior air is 75°F, and outside air at 95°F and 40% relative humidity enters the wall cavity, will condensation occur? Using the psychrometric chart we find that the dew point of the outside air leaking into the wall cavity would be about 67°F. Since the drywall temperature is greater than the dew point, condensation should not form.

Figure 3-3
Psychrometric Chart

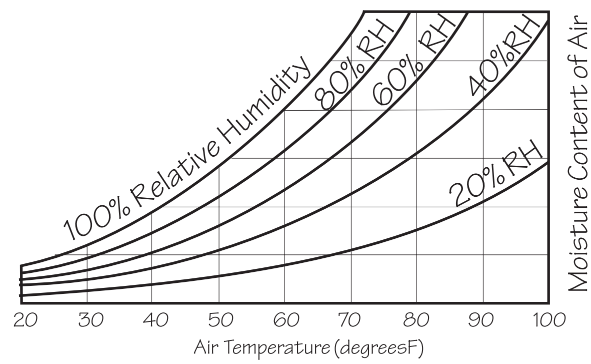


Figure 3-4
Winter Dewpoint Temperature Inside Walls

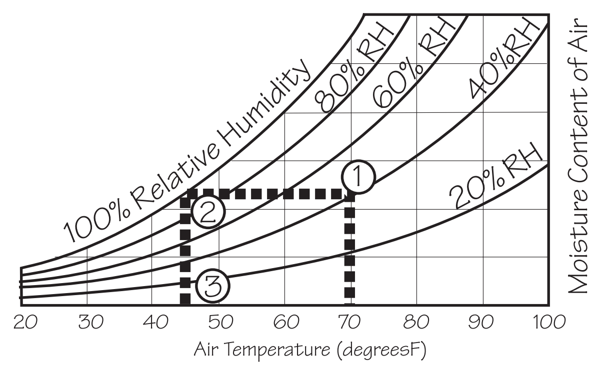
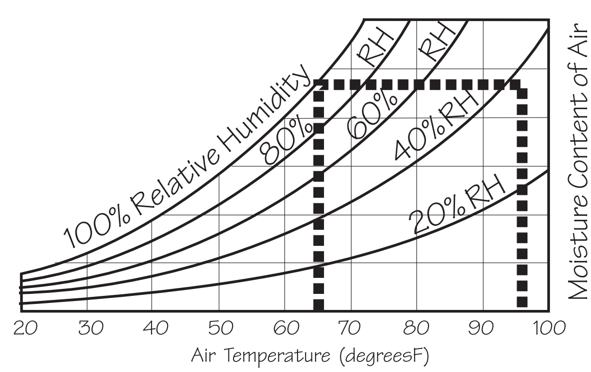


Figure 3-5
Summer Dewpoint Temperature Inside Walls



Systems in a Home

Whether the health and comfort factors of temperature, humidity, and air quality remain at comfortable and healthy levels depends on how well the home works as a system. Every home has systems that are intended to provide indoor health and comfort:

- Structural system
- Moisture control system
- Air barrier system
- Thermal insulation system
- Comfort control system

Structural System

The purpose of this book is not to show how to design and build the structural components of a home, but rather to describe how to maintain the integrity of these components. Key problems that can affect the structural integrity of a home include:

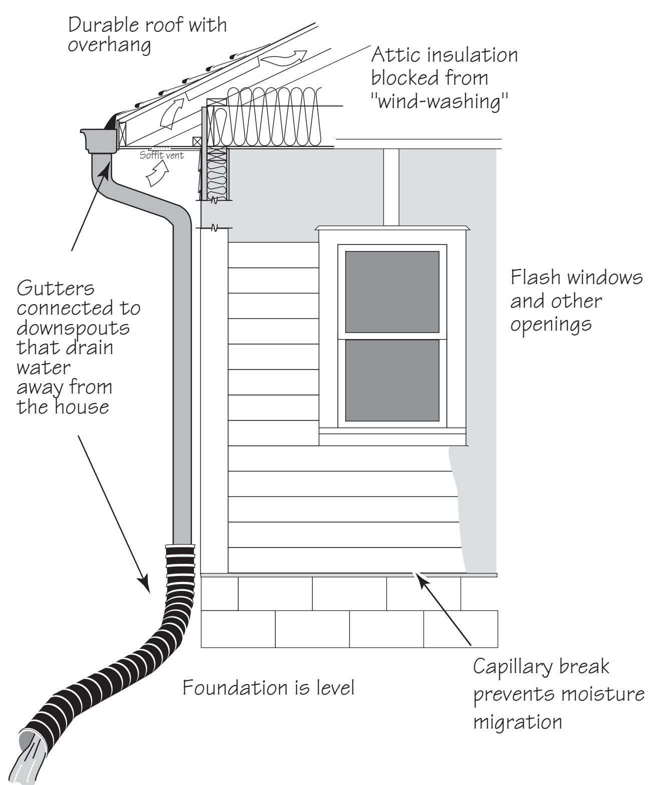
- Frost heaving
- Erosion
- Roof leaks
- Water absorption into building systems
- Excessive relative humidity levels
- Fire
- Summer heat build-up

Structural recommendations

To prevent these structural problems, the home designer and builder should:

- Ensure that the footer is installed level and below the frost line. Install adequate reinforcing and make sure the concrete has the proper slump and strength.
- Divert ground water away from the building through a properly designed and installed foundation drainage system and install effective gutters, downspouts, and rain water drains. Specifications are shown in Chapter 1 and are described as well in the later discussion of moisture control systems.
- Ensure the roof is watertight to prevent rainwater intrusion. The homeowner should clean gutters and drainage piping regularly.
- Seal penetrations that allow moisture to enter the building envelope via air leakage. Use firestopping sealants to close penetrations that are potential sources of "draft" during a fire.
- Prevent air from washing over attic insulation.
- Install a series of capillary breaks that keep moisture from migrating through foundation systems into wall and attic framing.

Figure 3-6
Structural recommendations



MOISTURE PROBLEM EXAMPLE

The owner of a residence in Alabama complains that her ceilings are dotted with mildew. On closer examination, an energy inspector finds that the spots are primarily around recessed lamps located close to the exterior walls of the building.

What type of moisture problem may be causing the mildew growth, which requires relative humidities over 70%? In reality, any of the forms of moisture transport could cause the problem:

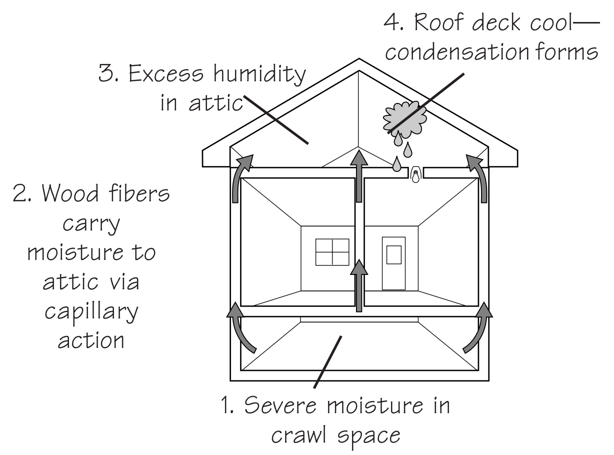
Bulk moisture transport—the home may have roof leaks above the recessed lamps.

Capillary action—the home may have a severe moisture problem in its crawl space or under a slab. Via capillary action, moisture travels up the slab, into the framing lumber, and all the way into the attic. If the attic air becomes sufficiently moist, it may condense on the surface of the cool roof deck and drip onto the insulation and drywall below.

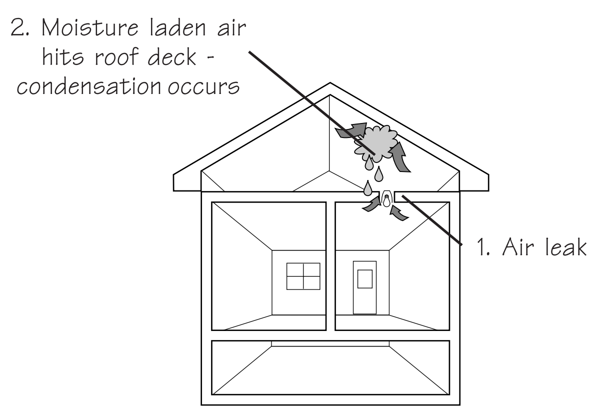
Air transport—most recessed lamps are quite leaky; if the air leaking into the attic is relatively warm and moist, and the roof deck is cool, the water vapor in the air may condense and drip onto the drywall. *This is the most likely explanation.*

Vapor diffusion—the home's ceiling may not have an adequate vapor retarder in the vicinity of the recessed lamps, causing excessive vapor flow into the attic. *This is the least likely explanation.*

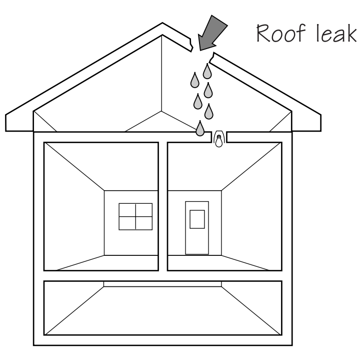
Capillary Action



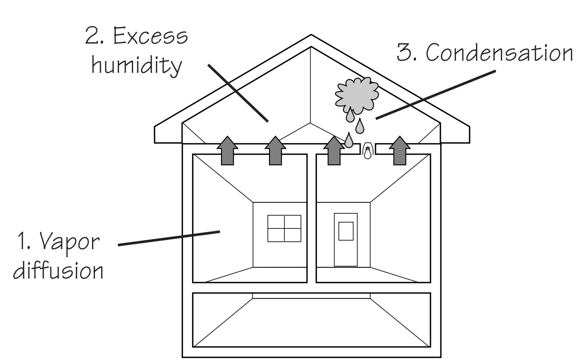
Air Transport



Bulk Moisture Transport



Vapor Diffusion



Moisture Control System

Homes should be designed and built to provide comfortable and healthy levels of relative humidity. They should also prevent both liquid water and water vapor from migrating through building components.

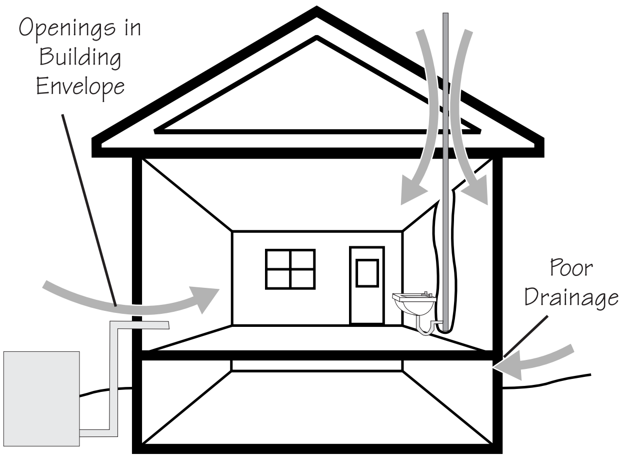
The moisture control system includes quality construction to shed water from the home and its foundation, vapor and air barrier systems that hinder the flow of water vapor, and heating and cooling systems designed to provide comfort throughout the year.

There are four primary modes of moisture migration into homes. Each of these must be controlled to preserve comfort, health, and building durability.

Bulk moisture transport

- The flow of moisture through holes, cracks, or gaps
- Primary source is rain
- Causes include:
  - poor flashing
  - inadequate drainage
  - poor quality weatherstripping or caulking around joints in building exterior (such as windows, doors, and bottom plates)
- Solved through quality construction with durable materials
- Most important of the four modes of moisture migration

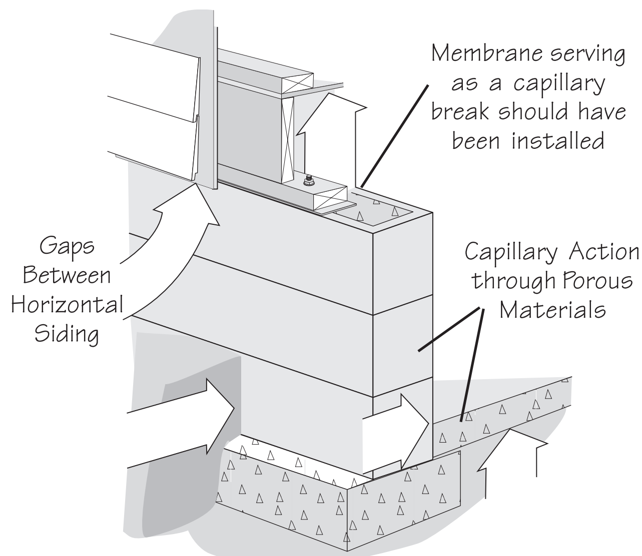
Figure 3-7
Bulk Moisture Transport



Capillary action

- Wicking of water through porous materials or between small cracks
- Primary sources are from rain or ground water
- Causes include:
  - water seeping between overlapping pieces of exterior siding
  - water drawn upward through pores or cracks in concrete slabs
  - water migrating from crawl spaces into attics through foundation walls and wall framing
- Solved by completely sealing pores or gaps, increasing the size of the gaps (usually to a minimum of 1/8 inch), or installing a water proof, vapor retarding material to form a capillary break

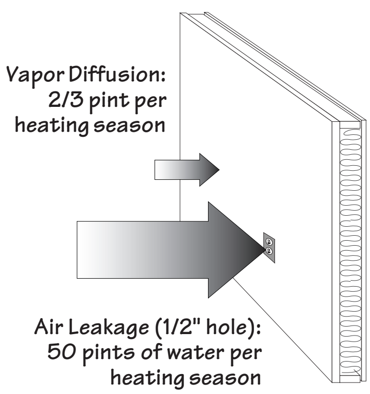
Figure 3-8
Capillary Action



Air transport

- Unsealed penetrations and joints between conditioned and unconditioned areas allow air containing water vapor to flow into enclosed areas. As shown in Figure 3-9, air transport can bring 50 to 100 times more moisture into wall cavities than vapor diffusion.
- Primary source is water vapor in air
- Causes include air leaking through holes, cracks, and other leaks between:
  - interior air and enclosed wall cavities
  - interior air and attics
  - exterior air and interior air, adding humidity to interior air in summer
  - crawl spaces and interior air
- Solved by creating an Air Barrier System

Figure 3-9
Typical Water Vapor Transport
(100 sq ft wall without a vapor retarder)



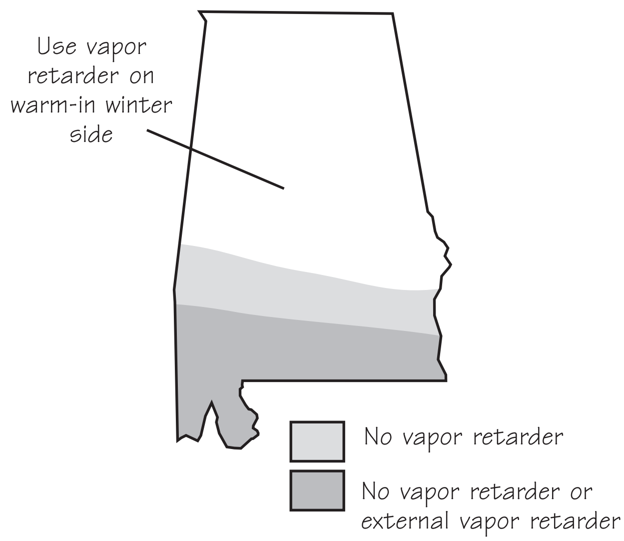
Vapor diffusion

- Water vapor in air moves through permeable materials (those having Perm ratings over 1)
- Primary source is water vapor in the air
  - interior moisture permeating wall and ceiling finish materials
  - exterior moisture moving into the home in summer
  - moist crawl space air migrating into the home
- Least important of the four modes of moisture migration.

Table 3-1
Perm Ratings of Different Materials

Asphalt-coated paper backing on insulation	0.40
Polyethylene plastic (6 mil)	0.06
Plywood with exterior glue	0.70
Plastic-coated insulated foam sheathing	under 0.30
Aluminum foil (.35 mil)	0.05
Vapor retarder paint or primer	0.45
Drywall (unpainted)	50.0

Figure 3-10
Vapor Retarder Recommendations



Air Barrier System

Air leakage can be detrimental to the long-term durability of homes. It can also cause a substantial number of other problems, including:

- High humidity levels in summer and dry air in winter
- Allergy problems
- Radon entry via leaks in the floor system
- Mold growth
- Drafts
- Window fogging or frosting
- Excessive heating and cooling bills
- Increased damage in case of fire

An air barrier system may sound formidable, but it is actually a simple concept—seal all leaks between conditioned and unconditioned spaces with durable materials. Achieving success can be difficult without diligent efforts, particularly in homes with multiple stories and changing roof lines.

Air barriers may also help a home meet local fire codes. One aspect of controlling fires is preventing oxygen from entering a burning area. Most fire codes have requirements to seal air leakage sites.

Chapter 4 describes a number of air barrier systems—all can be effective with proper installation. They are one of the key features of an energy efficient home. The basic approach is:

- Seal all air leakage sites between conditioned and unconditioned spaces:
  - caulk or otherwise seal penetrations for plumbing, electrical wiring, and other utilities
  - seal junctions between building components, such as bottom plates and band joists between conditioned floors
  - consider air sealing insulating materials, such as cellulose or plastic foam
- Seal bypasses—hidden chases, plenums, or other air spaces through which attic or crawl space air leaks into the home.
- Install a continuous air barrier material such as the airtight drywall approach.

Thermal Insulation System

Thermal insulation and energy efficient windows are intended to reduce heat loss and gain due to conduction. As with other aspects of energy efficient construction, the key to a successfully insulated home is quality installation.

Substandard insulation not only inflates energy bills, but may create comfort and moisture problems. Key considerations for effective insulation include:

- Install R-values equal to or exceeding Residential Energy Code of Alabama.
- Do not compress insulation.
- Provide full insulation coverage of the specified R-value; gaps dramatically lower the overall R-value and can create areas subject to condensation.
- Prevent air leakage through insulation—in some insulation materials, R-values decline markedly when subject to cold or hot air leakage.
- Air seal and insulate knee walls and other attic wall areas with a minimum of R-19 insulation.
- Support insulation so that it remains in place, especially in areas where breezes can enter or rodents may reside.

HVAC System

The heating, ventilation, and air conditioning system is designed to provide comfort and improved air quality throughout the year, particularly in winter and summer. Energy efficient homes, particularly passive solar designs, can reduce the number of hours during the year when the HVAC systems are needed.

These systems are often not well designed and may not be installed to perform as intended. As a consequence, homes often suffer higher heating and cooling bills and more areas with discomfort than necessary. Poor HVAC design often leads to moisture and air quality problems, too.

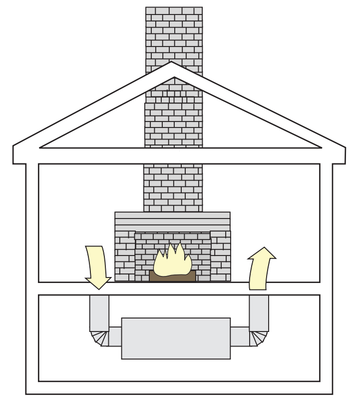
One major issue concerning HVAC systems is their ability to create pressure imbalances in the home. The sidebar on the following page shows that duct leaks can create serious problems. In addition, even closing a few doors can create situations that may endanger human health.

Pressure imbalances can increase air leakage, which may draw additional moisture into the home. Proper duct design and installation helps prevent pressure imbalances from occurring.

HVAC systems must be designed and installed properly, and maintained regularly by qualified professionals to provide continued efficient and healthy operation.

DUCT LEAKS AND INFILTRATION

Forced-air heating and cooling systems should be *balanced*—the amount of air delivered through the supply ducts should be equal to that drawn through the return ducts. If the two volumes of air are unequal, pressure imbalances may occur in the home, resulting in increased air leakage and possible health and safety problems.



Balanced Air Distribution

If **supply ducts** in unconditioned areas have more leaks than return ducts:

- Heated and cooled air will escape to the outside, increasing energy costs.
- Less air volume will be “supplied” to the house, so the pressure inside the house may become negative, thus increasing air infiltration.
- The negative pressure can actually *backdraft* flues—pull exhaust gases back into the home from fireplaces and other combustion appliances. The health effects can be deadly if flues contain substantial carbon monoxide.

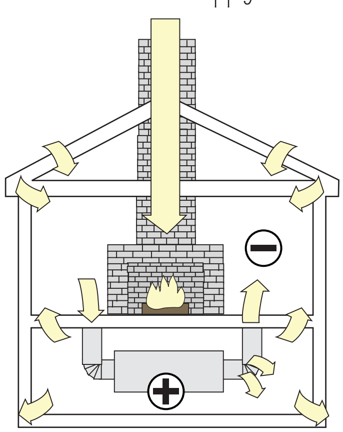
If **return ducts** in unconditioned spaces leak:

- The home can become pressurized, thus increasing air leakage out of the envelope.
- Hot, humid air is pulled into the ducts in systems in summer; cold air is drawn into the ducts in winter.
- Human health may be endangered if ducts are located in areas with radon, mold, or toxic chemicals from soil termite treatments, paints, cleansers, and pesticides.
- If combustion appliances are located near return leaks, the negative pressure created by the leaks can be great enough to backdraft flues and chimneys.

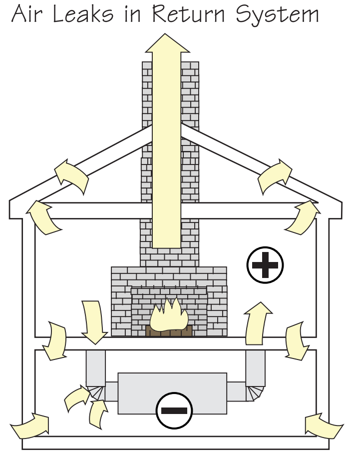
Pressure differences can also result in homes with tight ductwork if the home only has one or two returns. When interior doors are closed it may be difficult for the air in these rooms to circulate back to the return ducts. The pressure in the closed-off rooms increases, and the pressure in rooms open to the returns decreases.

Installing multiple returns, "jumper" ducts that connect closed off rooms to the main return, and undercutting doors to rooms without returns will alleviate these problems.

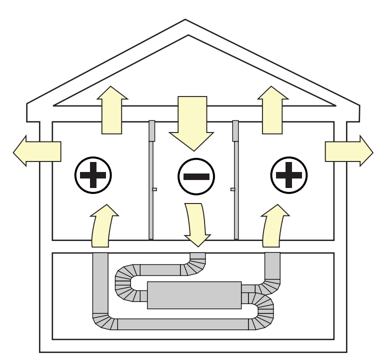
Air Leaks in Supply Ducts



Air Leaks in Return System



Return Blocked by Door



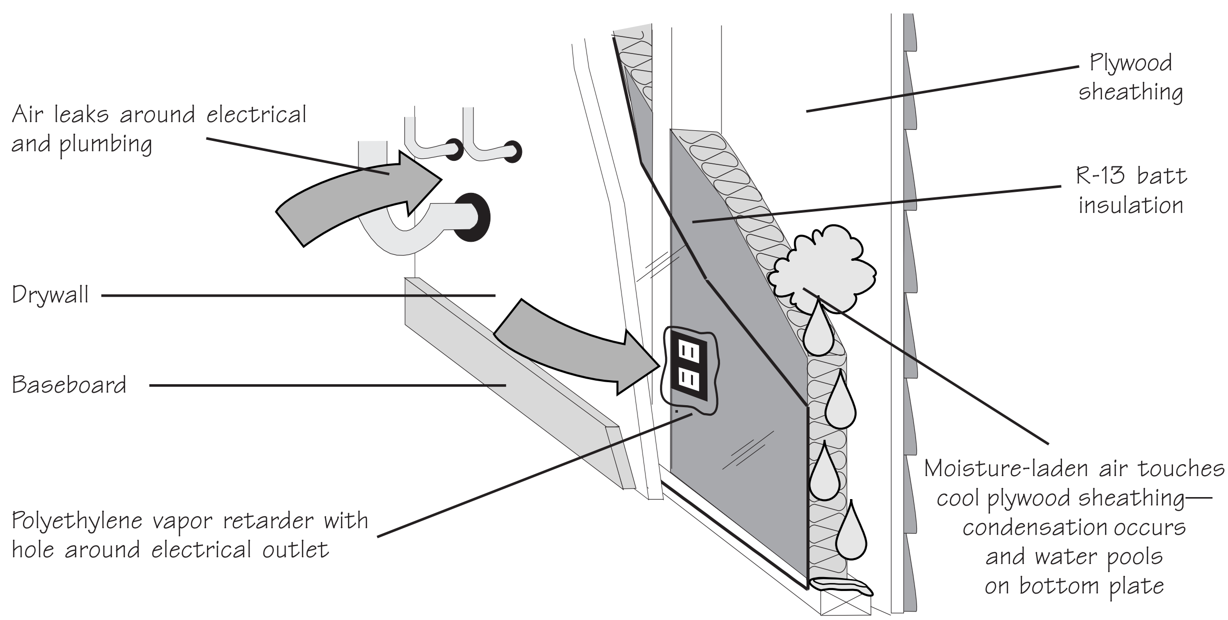
WALL MOISTURE EXAMPLE - THE WRONG WAY

The following pages describe two examples of building science problems due to common failures of the home's systems. These problems can be minimized through careful attention to the construction techniques described in this book.

A homeowner notices that paint is peeling on the exterior siding near the base of a bathroom wall. The drywall interior has mildew and the baseboard paint is peeling as well. What happened?

1. The interior of the wall has numerous air leaks—an air barrier system failure.
2. The door to the bathroom is usually closed. When the heating and cooling system operates, the room becomes pressurized, as it has no return and its door is not undercut at the bottom. This is a HVAC system failure.
3. The bath fan is installed improperly and does not exhaust moist air—another HVAC system failure.
4. When air leaks into the wall, it carries substantial water vapor, thus the failure of the air barrier and HVAC systems has led to a moisture control system failure.
5. The interior wall has a polyethylene vapor retarder. The exterior wall has CDX plywood sheathing, which is a vapor retarder.
6. When the air leaks carry water vapor into the wall cavity, the two vapor retarders hinder drying—a moisture control system failure.
7. In winter, the inner surface of the plywood sheathing will be several degrees cooler than foam sheathing would have been. Thus, the plywood-sheathed wall has more potential for condensation—a thermal insulation system failure.
8. As the water vapor condenses on the sheathing, it runs down the wall and pools on the bottom plate of the wall. Now the following problems occur:
    - The water threatens to cause structural problems by rotting the wall framing.
    - It wets the drywall, causing mold to grow.
    - It travels through the unsealed back surfaces of the wood siding and baseboard, causing the paint to peel when it soaks through the wood.
    - The multiple failures of the building systems create a potential structural disaster.

To solve this moisture problem the builder must address all of the failures. If only one aspect is treated, the problem may even become worse.

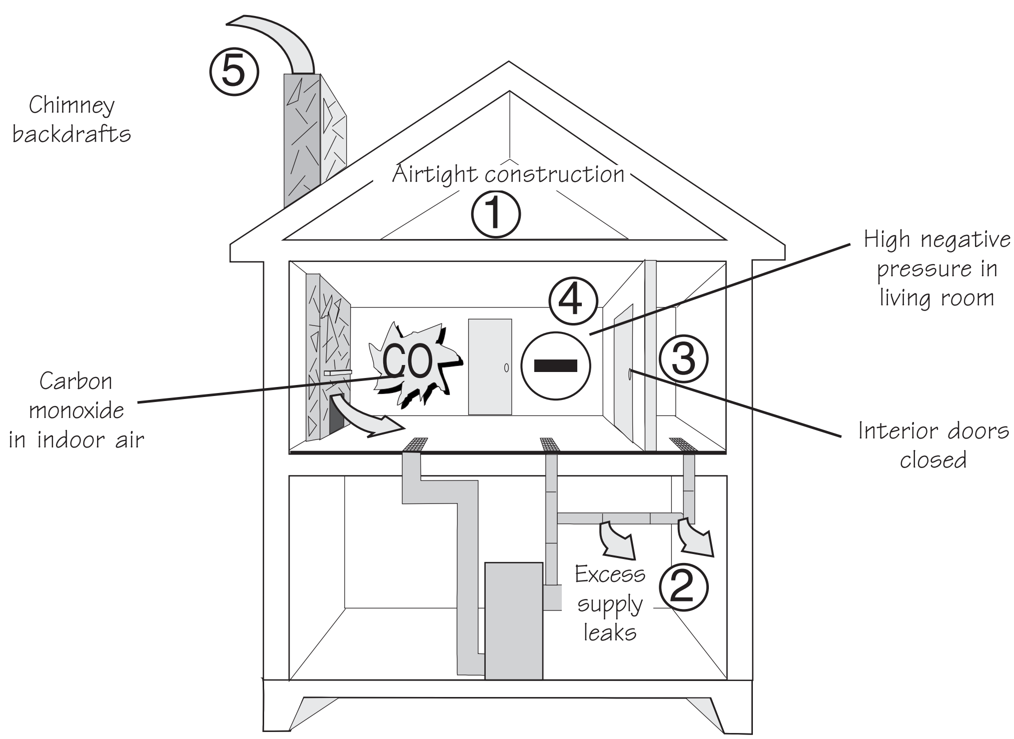


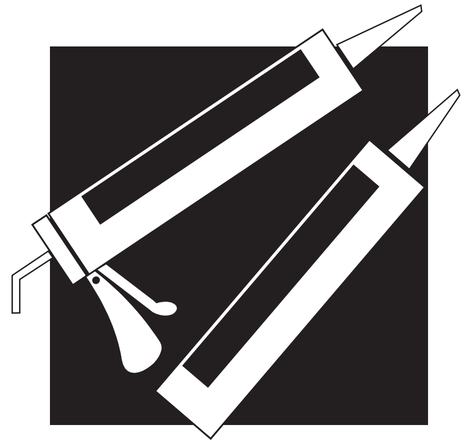
CARBON MONOXIDE - THE WRONG WAY CAN CREATE DISASTER

1. A home has been built to airtight specifications—an air barrier system success.
2. However, the home's ductwork was not well sealed—a HVAC system failure. It has considerably more supply leakage than return leakage which creates a strong negative pressure inside the home when the heating and cooling system operates.
3. The homeowners are celebrating winter holidays. With overnight guests in the home, many of the interior doors are kept closed. The home has only a single return in the main living room.
4. When the system operates, the rooms with closed doors become pressurized, while the central living area with the return becomes significantly depressurized. Because the house is very airtight, it is easier for these pressure imbalances to occur.
5. The home has a beautiful fireplace without an outside source of combustion air. When the fire in the unit begins to dwindle, the following sequence of events could spell disaster for the household.

- The fire begins to smolder and produces considerable carbon monoxide.
- Because the fire's heat dissipates, the draft pressure, which draws gases up the flue, decreases.
- The reduced output of the fire causes the thermostat to turn on the heating system. Due to the duct problems, the blower creates a relatively high negative pressure in the living room.
- Because of the reduced draft pressure in the fireplace, the negative pressure in the living room causes the chimney to backdraft—the flue gases are drawn back into the home. They contain carbon monoxide and can now cause severe, if not fatal, health consequences for the occupants.

This example is extreme, but similar conditions occur in a number of Alabama homes each year. The solution to the problem is not to build leakier homes—they can experience similar pressure imbalances. Instead, eliminate the causes of pressure imbalances and install an external source of combustion air for the fireplace.





Chapter 4
Air Leakage — Materials and Techniques

Air leakage is a major problem for both new and existing homes and can:

- Contribute to over 30 percent of heating and cooling costs.
- Create comfort and moisture problems.
- Pull pollutants such as radon and mold into homes.
- Serve as a prime entry for insects and rodents.

To reduce air leakage effectively requires a *continuous air barrier system*—a combination of materials linked together to create a tight building envelope. An air barrier also minimizes air currents inside the cavities of the building envelope which helps maintain insulation R-values.

The air barrier should seal all leaks through the building envelope—the boundary between the conditioned portion of the home and the unconditioned area. Most standard insulation products are not effective at sealing air leakage. The R-value for this material may drop if air leaks through the material.

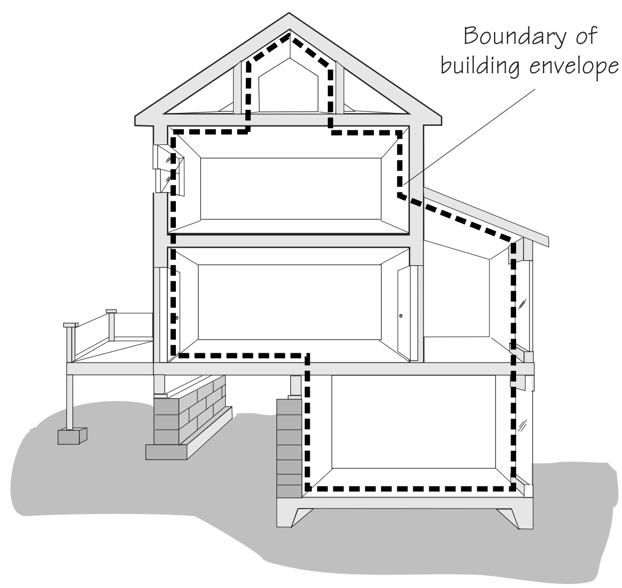
Some spray applied insulation materials can seal against air leakage. However, these materials are often only applied in framing cavities; therefore additional air sealing must be done between framing components.

The builder should work with their own crew and subcontractors to seal all holes through the envelope. Then install a continuous material, such as drywall, around the envelope. It is critical in the air sealing process to use durable materials and install them properly.

Materials

Most air barrier systems rely on a variety of caulks, gaskets, weatherstripping, and sheet materials, such as plywood, drywall, polyethylene plastic, and housewraps. The extra cost of these materials is usually under $500 for standard house designs.

Figure 4-1
Creating a Continuous Air Barrier



1. Install continuous insulation
2. Seal penetrations and bypasses
3. Install drywall as air barrier

Table 4-1
Leaks and Sealants

Type of Leak	Commonly Used Sealants
Thin gaps between framing and wiring, pipes or ducts through floors or walls	40-year caulking; one-part polyurethane is recommended
Leaks into attics, cathedral ceilings, wall cavities above first floor	Firestop caulking, foam sealant
Gaps, or cracks or holes over 1/8 inch in width not requiring firestop sealant	Gasket, foam sealant, or stuff with fiberglass or backer rod, and caulk on top
Open areas around flues, chases, plenums, plumbing traps, etc.	Attach and caulk a piece of plywood or fire-resistant sheet material that covers the entire opening. Seal penetrations. If a flue requires a non-combustible clearance, use a non-combustible metal collar, sealed in place, to span the gap
Final air barrier material sealed in place, or other air barrier system	Install Airtight Drywall Approach

Seal Penetrations and Bypasses

The first step for successfully creating an air barrier system is to seal all of the holes in the building envelope. Too often, builders concentrate on air leakage through windows, doors, and walls, and ignore areas of much greater importance. Many of the key sources of leakage—called *bypasses*—are hidden from view behind soffits for cabinets, bath fixtures, dropped ceilings, chases for flues and ductwork, or insulation. Attic access openings and whole house fans are also common bypasses. Sealing these bypasses is critical to reducing air leakage in a home and maintaining the performance of insulation materials.

The guidelines that follow in Figure 4-3 show important areas that should be sealed to create an effective air barrier. The builder must clearly inform subcontractors and workers of these details to ensure that the task is accomplished successfully.

Figure 4-2
Common Air Leakage Bypasses

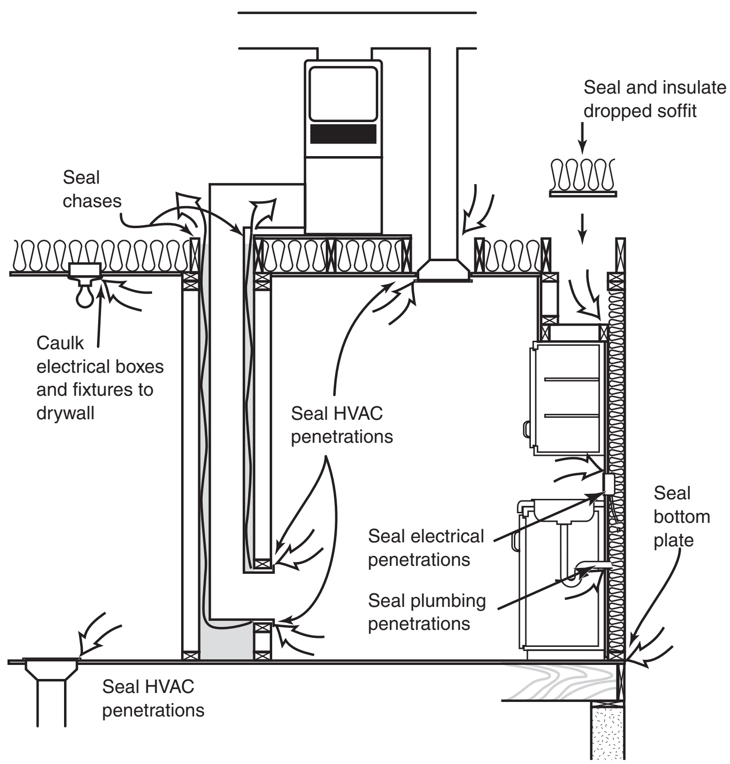
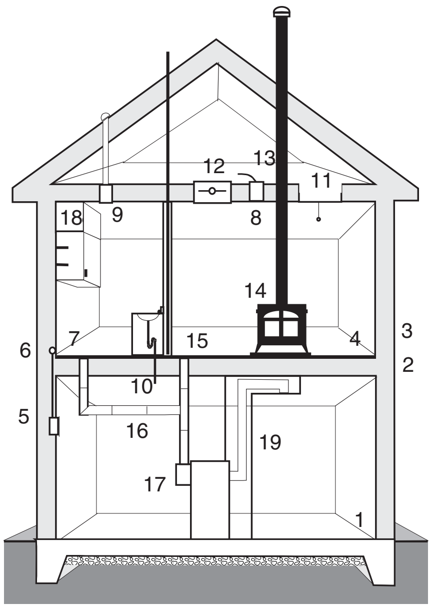


Figure 4-3
Typical Home Air Leakage Sites



1. *Slab Floors*—seal all holes in the slab to prevent entry of water vapor and soil gas. A 4- to 6-inch layer of gravel under the slab is important to stop the seepage of water by capillarity.

2. *Sill Plate and Rim Joist*—seal sill plates in basements and unvented crawl spaces. Caulk or gasket rim or band joists between floors in multi-story construction.

3. *Bottom Plate*—use either caulk or gasket between the plate and subflooring.

4. *Subfloor*—use an adhesive to seal the seams between pieces of subflooring.

5. *Electrical Wiring*—use wire-compatible caulk or spray foam to seal penetrations.

6. *Electrical Boxes*—use approved caulk to seal wiring on the outside of electrical boxes. Seal between the interior finish material and boxes.

7. *Electrical Box Gaskets*—caulk foam gaskets to all electrical boxes in exterior and interior walls before installing coverplates.

8. *Recessed Light Fixtures*—consider using surface-mounted light fixtures rather than recessed lights. When used, specify airtight models rated for insulation coverage (IC).

9. *Exhaust Fans*—seal between the fan housing and the interior finish material. Choose products with tight-fitting backdraft dampers.

10. *Plumbing*—locate plumbing in interior walls, and minimize penetrations. Seal all penetrations with foam sealant or caulk.

11. *Attic Access*—weatherstrip attic access openings. For pull-down stairs, use latches to hold the door panel tightly against the weatherstripping. Cover the attic access opening with an insulated box.

12. *Whole House Fan*—use a panel made of rigid insulation or plastic to seal the interior louvers.

13. *Flue Stacks*—install a code-approved flue collar and seal with fire-rated caulk.

14. *Combustion Appliances*—closely follow local codes for firestopping measures, which reduce air leakage as well as increase the safety of the appliance. Make certain all combustion appliances, such as stoves, inserts, and fireplaces, have an outside source of combustion air and tight-fitting dampers or doors.

15. *Return and Supply Registers*—seal all boots connected to registers or grilles to the interior finish material.

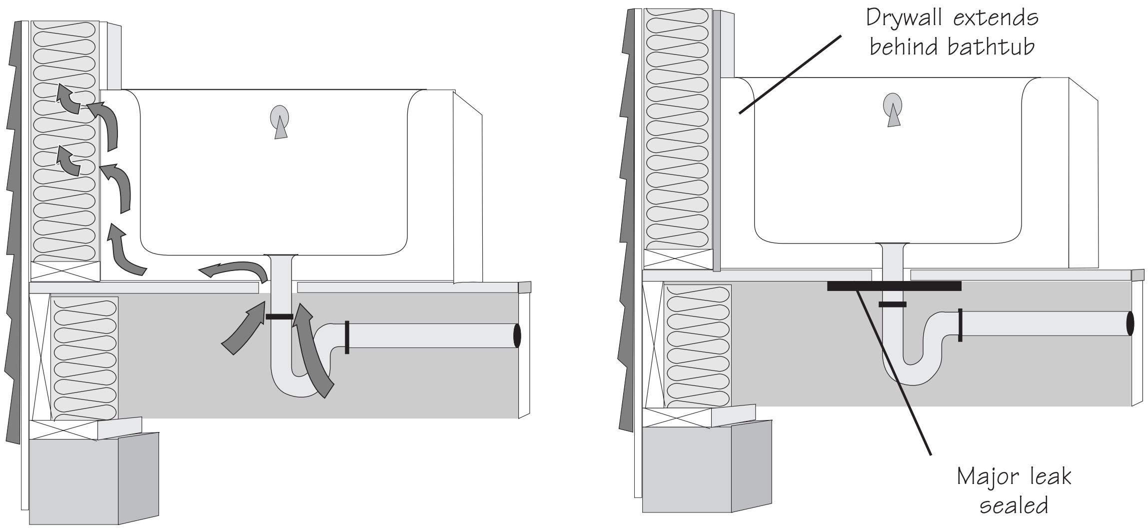
16. *Ductwork*—seal all joints in supply and return duct systems with mastic.

17. *Air Handling Unit* (for heating and cooling system)—seal all cracks and unnecessary openings with mastic. Seal service panels with tape.

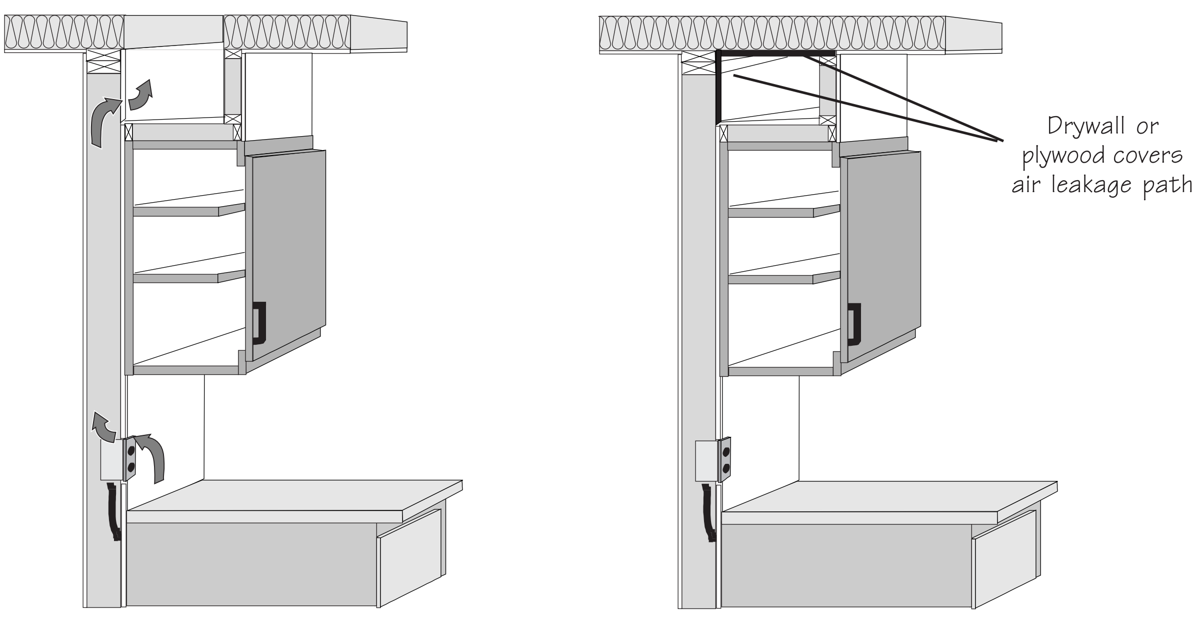
18. *Dropped Ceiling Soffit*—use sheet material and sealant to stop air leakage from attic into the soffit or wall framing, then insulate.

19. *Chases* (for ductwork, flues, etc.)—prevent air leakage through these bypasses with sheet materials and sealants.

Figure 4-4
Sealing Bypasses

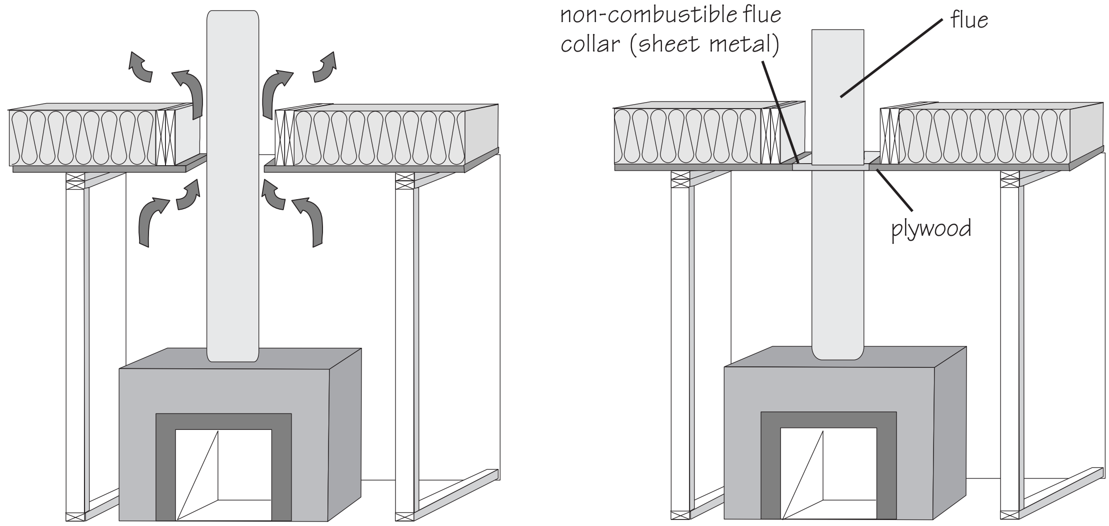


Plumbing—Seal penetrations, especially under bathtubs and other fixtures. Install drywall, plastic, or housewrap behind bathtub to provide an air barrier.

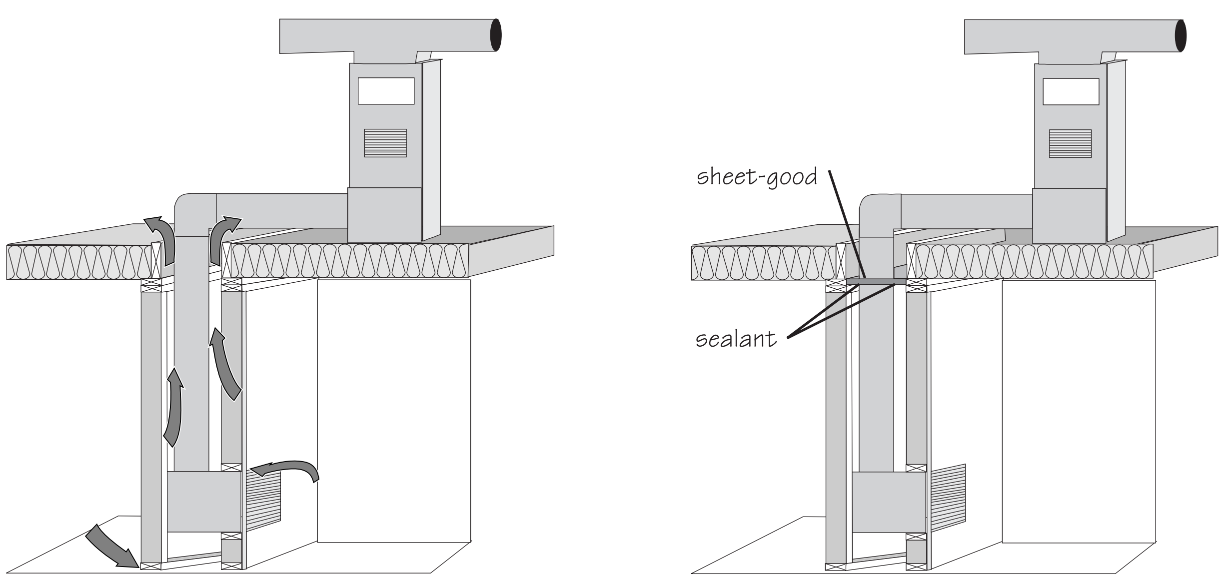


Dropped Ceiling Soffit—If kitchen cabinets or bath/shower enclosures have dropped soffits, provide a continuous seal at the attic floor.

Figure 4-5
Sealing Bypasses for Flues and Ductwork

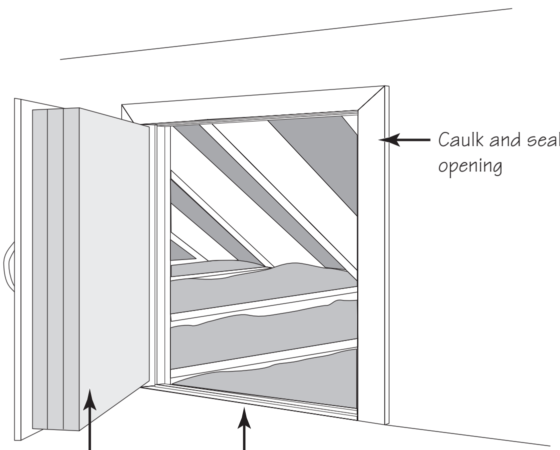


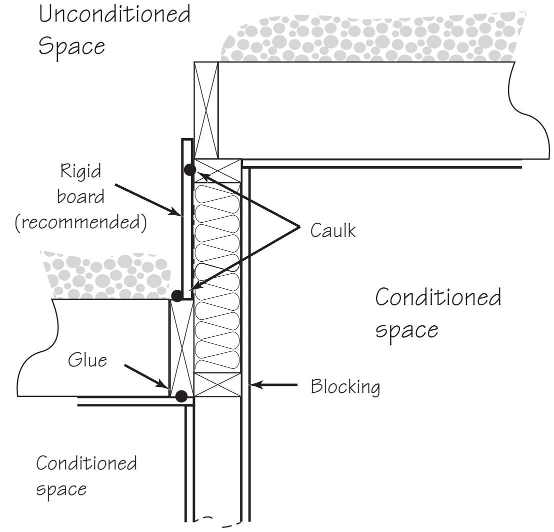
Chases—Framed chases for flues should be sealed at the attic floor. Use a continuous layer of plywood or other solid sheet-good. Seal between the flue and combustible materials with fire-rated caulk and a noncombustible flue collar.



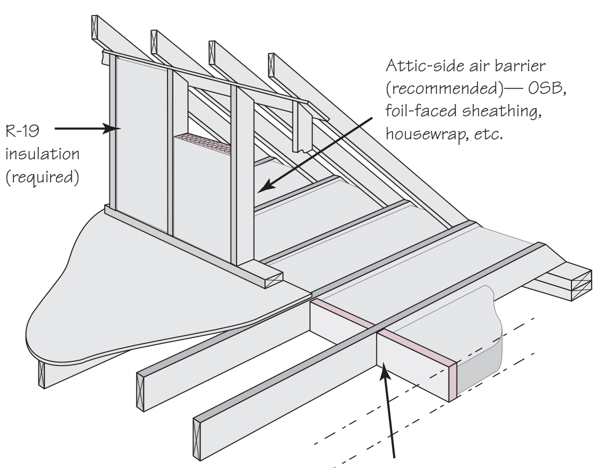
Return and Supply Plenums—Seal framed areas for ductwork.

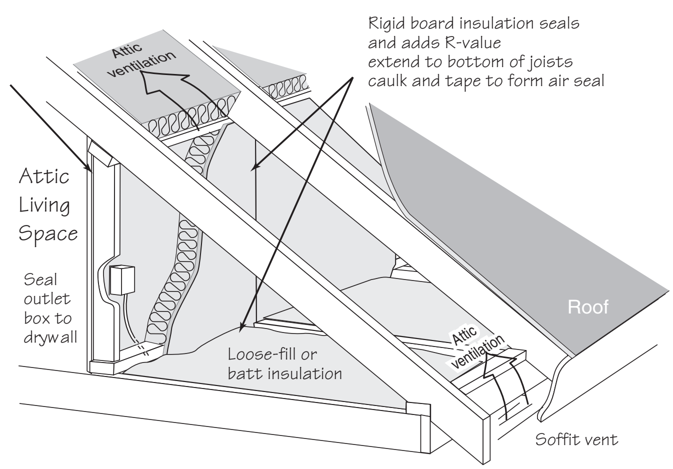
Figure 4-6
Attic knee wall and raised ceiling details





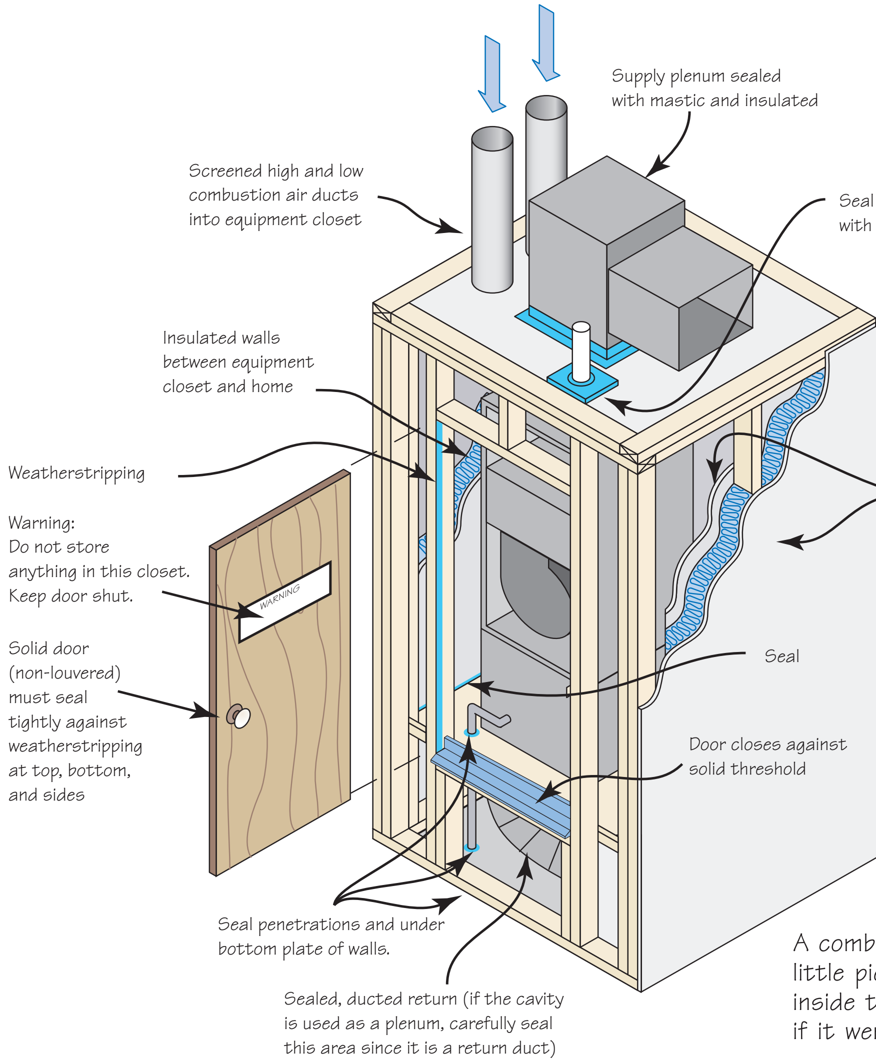
Attic knee walls require extra attention to detail when air sealing. Consider using foil-faced insulation board for blocking applications because of the added R-value.





Seal penetrations before insulating, provide for ventilation where applicable.

Figure 4-7
Sealed combustion closet



A combustion closet is like a little piece of the outside… inside the home. Air seal it as if it were.

Figure 4-8
Block and seal between garage and living space

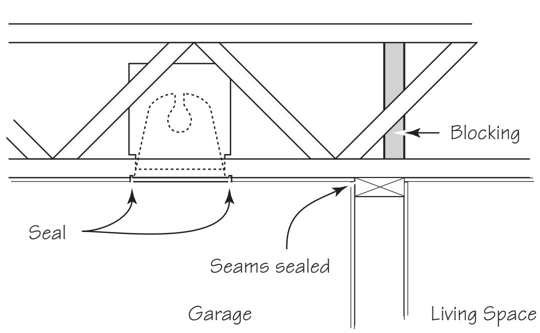
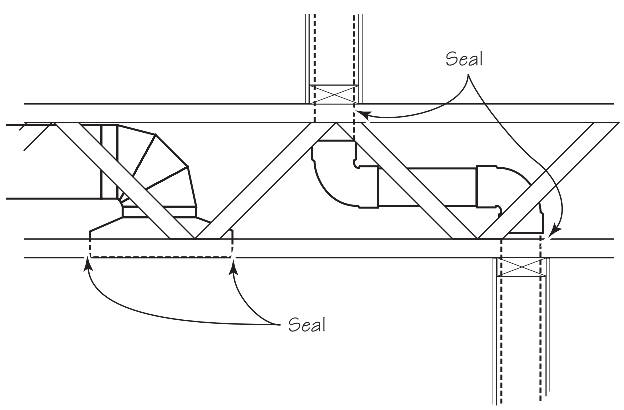


Figure 4-9
Seal penetrations between floor levels



AIR LEAKAGE DRIVING FORCES

Requirements for air leakage to occur:

- Holes—the larger the hole, the greater the air leakage. Large holes have higher priority for air sealing efforts.
- Driving force— a pressure difference that forces air to flow through a hole. Holes that experience stronger and more continuous driving forces have higher priority.

The common driving forces are:

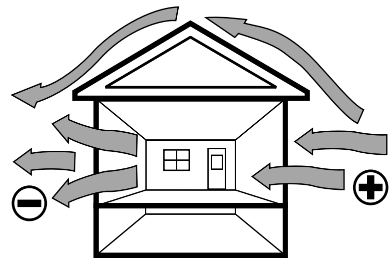
- *Wind*—caused by weather conditions.
- *Stack effect*—upward air pressure due to the buoyancy of air.
- *Mechanical blower*—induced pressure imbalances caused by operation of fans and blowers.

Wind is usually considered to be the primary driving force for air leakage. When the wind blows against a building, it creates a high pressure zone on the windward areas. Outdoor air from the windward side infiltrates into the building while air exits on the leeward side. Wind acts to create areas of differential pressure which cause both infiltration and exfiltration. The degree to which wind contributes to air leakage depends on its velocity and duration.

The temperature difference between inside and outside causes warm air inside the home to rise while cooler air falls, creating a driving force known as the *stack effect*. The stack effect is weak but always present. Most homes have large holes into the attic and crawl space or basement. Because the stack effect is so prevalent and the holes through which it drives air are often so large, it is usually a major contributor to air leakage, moisture, and air quality problems.

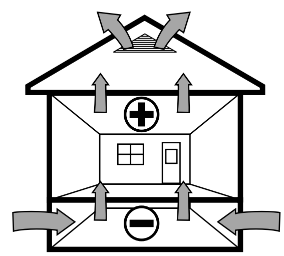
Poorly designed and installed forced-air systems can create strong pressure imbalances inside the home which can triple air leakage whenever the heating and cooling system operates. In addition, unsealed ductwork located in attics and crawl spaces can draw pollutants and excess moisture into the home. Correcting duct leakage problems is critical when constructing an energy efficient home.

Figure 4-10
Wind Driven Infiltration



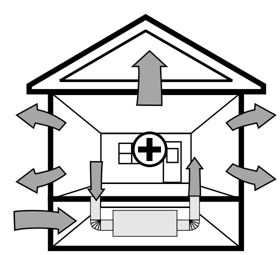
On average, wind in the Southeast creates a pressure difference of 10 to 20 Pascals on the windward side. However, most homes have only small cracks on the exterior.

Figure 4-11
The Stack Effect



The stack effect can create pressure differences between 1 to 3 Pascals due to the power of rising warm air. Crawl space and attic holes are often large.

Figure 4-12
Mechanical System Driven Infiltration



Leaks in supply and return ductwork can cause pressure differences of up to 30 Pascals. Exhaust equipment such as kitchen and bath fans and clothes dryers can also create pressure differences.

MEASURING AIRTIGHTNESS WITH A BLOWER DOOR

While there are many well known sources of air leakage, virtually all homes have unexpected air leakage sites called *bypasses*. These areas can be difficult to find and correct without the use of a *blower door*. This diagnostic equipment consists of a temporary door covering which is installed in an outside doorway and a fan which pressurizes (forces air into) or depressurizes (forces air out of) the building. When the fan operates, it is easy to feel air leaking through cracks in the building envelope. Most blower doors have gauges which can measure the relative leakiness of a building.

One measure of a home's leakage rate is air changes per hour (ACH), which estimates how many times in one hour the entire volume of air inside the building leaks to the outside. For example, a home that has 2,000 square feet of living area and 8-foot ceilings has a volume of 16,000 cubic feet. If the blower door measures leakage of 80,000 cubic feet per hour, the home has an infiltration rate of 5 ACH. The leakier the house, the higher the number of air changes per hour, the higher the heating and cooling costs, and the greater the potential for moisture, comfort, and health problems.

To determine the number of air changes per hour, many experts use the blower door to create a negative pressure of 50 Pascals. A *Pascal* is a small unit of pressure about equal to the pressure that a pat of butter exerts on a piece of toast—about 0.004 inches water gauge. Fifty Pascals is approximately equivalent to a 20 mile-per-hour wind blowing against all surfaces of the building. Energy efficient builders should strive for fewer than 5 air changes per hour at 50 Pascals pressure (ACH50).

Figure 4-13
Blower Door

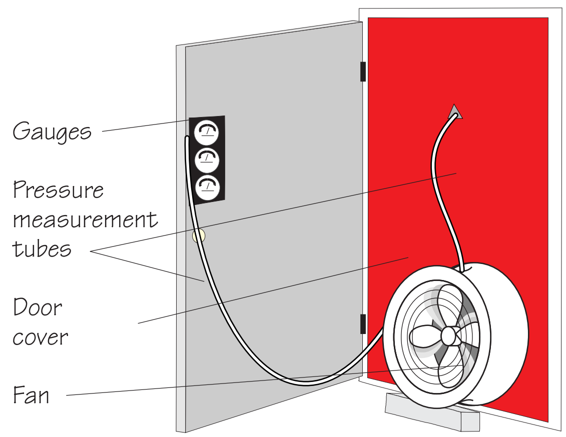


Table 4-2
Typical Infiltration Rates For Homes
(in air changes per hour at 50 Pascals - ACH50)

	ACH
New home with special airtight construction and a controlled ventilation system	1.5 - 2.5
Energy efficient home with continuous air barrier system	4.0 - 6.0
Standard new home	7.0 - 15.0
Standard existing home	10.0 - 25.0

Airtight Drywall Approach

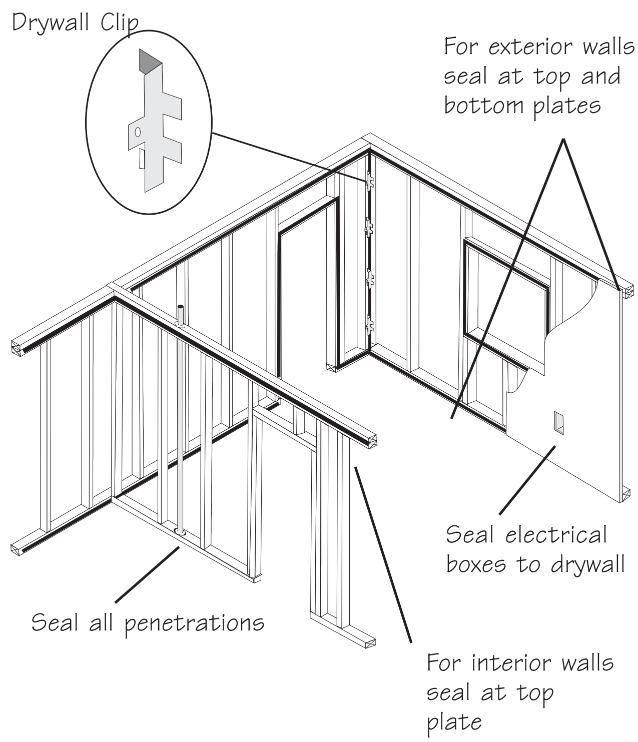
The Airtight Drywall Approach (ADA) is an air sealing system that connects the interior finish of drywall and other building materials together to form a continuous barrier. ADA has been used on hundreds of houses and has proven to be an effective technique to reduce air leakage as well as keep moisture, dust, and insects from entering the home.

In a typical drywall installation, most of the seams are sealed by tape and joint compound. However, air can leak in or out of the home in the following locations:

- Between the edges of the drywall and the top and bottom plates of exterior walls.
- From inside the attic down between the framing and drywall of partition walls.
- Between the window and door frames and drywall.
- Through openings in the drywall for utilities and other services.

ADA uses either caulk or gaskets to seal these areas and make the drywall a continuous air barrier system.

Figure 4-14
Airtight Drywall Approach Air Barrier



ADA Advantages

Effective—ADA has proven to be a reliable air barrier.

Simple—does not require specialized subcontractors or unusual construction techniques. If gasket materials are not available locally, they can be shipped easily.

Does not cover framing—the use of ADA does not prevent the drywall from being glued to the framing.

Scheduling—gaskets can be installed anytime between when the house is "dried-in" and the drywall is attached to framing.

Adaptable—builders can adapt ADA principles to suit any design and varying construction schedules.

Cost—materials and labor for standard designs should only cost a few hundred dollars.

ADA Disadvantages

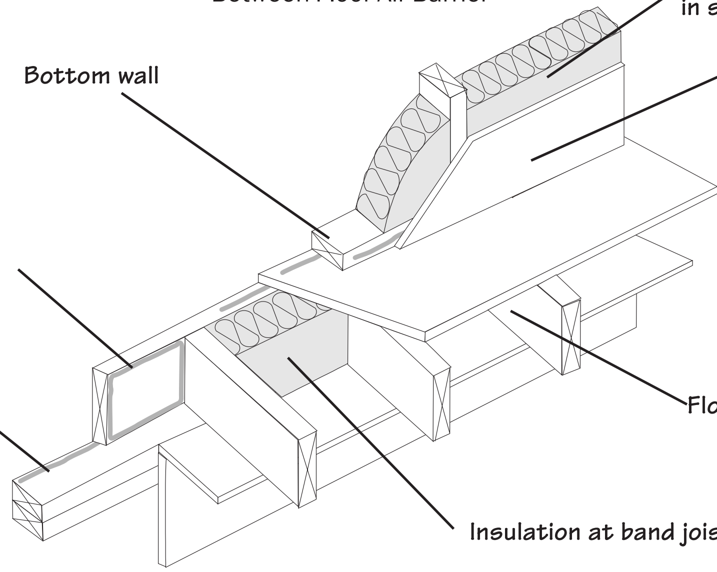
New—although ADA is a proven technique, many building professionals and code officials are not familiar with its use.

Not a vapor retarder— if required, a separate vapor retarder must be used with ADA. However, faced insulation batts, or vapor retarder paint work well.

Requires thought—while ADA is simple, new construction techniques require careful planning to ensure that the air barrier remains continuous. However, ADA is often the most error-free and reliable air barrier for unique designs.

Requires care—gaskets and caulking can be damaged or removed by subcontractors when installing the drywall or utilities.

Figure 4-15
Between Floor Air Barrier



ADA Installation Techniques

Wood framed floors

- Seal the rim joist to minimize air currents around floor insulation. Also, seal rim joists for multi-story construction.
- For unvented crawl spaces or basements, seal beneath the sill plate.
- Seal the seams between pieces of subflooring with good quality adhesive.

Slab floors

- Seal expansion joints and penetrations with a concrete sealant such as one-part urethane caulk.

Exterior framed walls

- Seal between the bottom plate and subflooring with caulk or gaskets.
- Install ADA gaskets or caulk along the face of the bottom plate so that when drywall is installed it compresses the sealant to form an airtight seal against the framing. Some builders also caulk the drywall to the top plate to reduce leakage into the wall.
- Use drywall joint compound or caulk to seal the gap between drywall and electrical boxes. Install foam gaskets behind coverplates and caulk holes in boxes.
- Provide for a vapor retarder where recommended by using faced insulation batts, or vapor retarder paint.
- Seal penetrations through the top and bottom plates for plumbing, wiring, and ducts. Local fire codes may require firestopping for leaks through top plates.

Partition walls

- Seal the drywall to the top plate of partition walls with unconditioned space above.
- Install gaskets or caulk on the face of the first stud in the partition wall. Sealant should extend from the bottom to the top of the stud to keep air in the outside wall from leaking inside.
- Seal the ductwork where it projects through partition walls.
- Seal penetrations through the top and bottom plates for plumbing, wiring, and ducts.

Windows and doors

- Seal drywall edges to either framing or jambs for windows and doors.
- Fill rough opening with spray foam sealant or suitable substitute.
- Caulk window and door trim to drywall with clear or paintable sealant.

Ceiling

- Follow standard finishing techniques to seal the junction between the ceiling and walls.
- When installing ceiling drywall do not damage ADA gaskets, especially in tight areas such as closets and hallways.
- Seal all penetrations in the ceiling for wiring, plumbing, ducts, attic access openings, and whole house fans.
- Seal all openings for chases and dropped soffits above kitchen cabinets and shower/ tub enclosures.
- Avoid recessed lights; where used, install airtight, IC-rated fixtures and caulk between fixtures and drywall.

Housewraps

Housewraps can serve as exterior air barriers and may help reduce air leakage through outside walls. Most products block only air leakage, not vapor diffusion, so they are not vapor barriers.

Typical products are rolled sheet materials that can be stapled and sealed to the wall between the sheathing and exterior finish material. For best performance, a housewrap must be sealed with caulk or tape at the top and bottom of the wall and around any openings, such as for windows, doors, and utility penetrations.

A housewrap can help reduce air leakage through exterior walls, but by itself is not a continuous air barrier for the entire envelope, and hence is not a substitute for the ADA system. Housewraps, recommended primarily as further insurance against air leakage and because they block liquid water penetration, can help protect the building from moisture damage.

In some instances, the exterior sheathing may be used as an outside air barrier. Careful sealing of all seams and penetrations is required.

Figure 4-16
Housewrap installation details

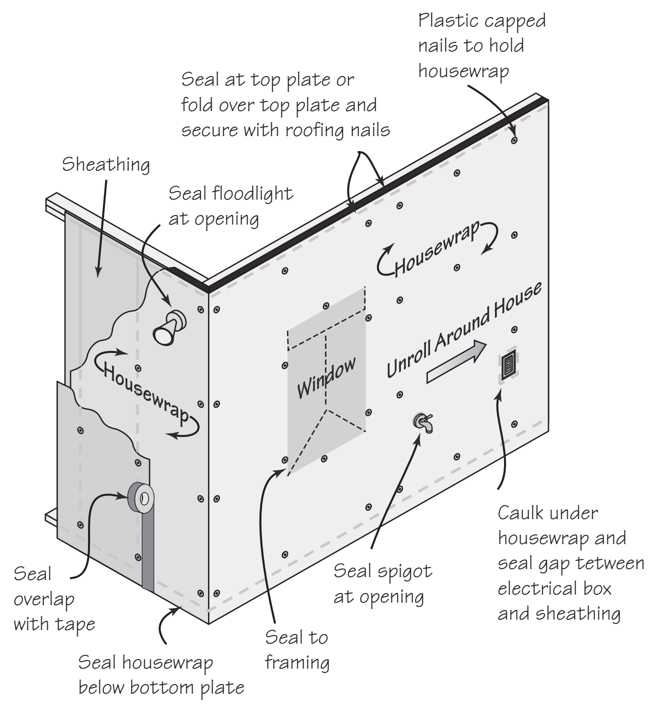
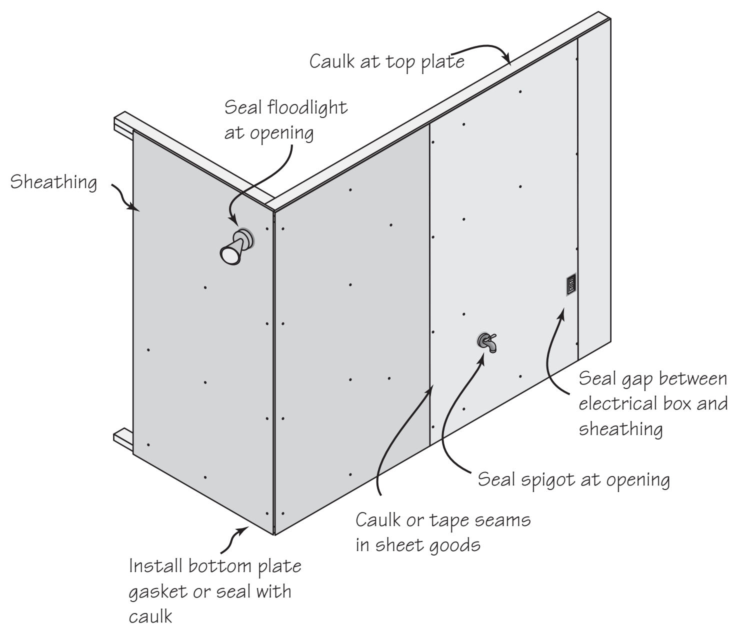
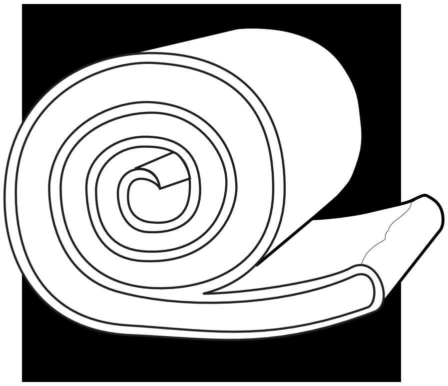


Figure 4-17
Exterior air sealing of sheathing

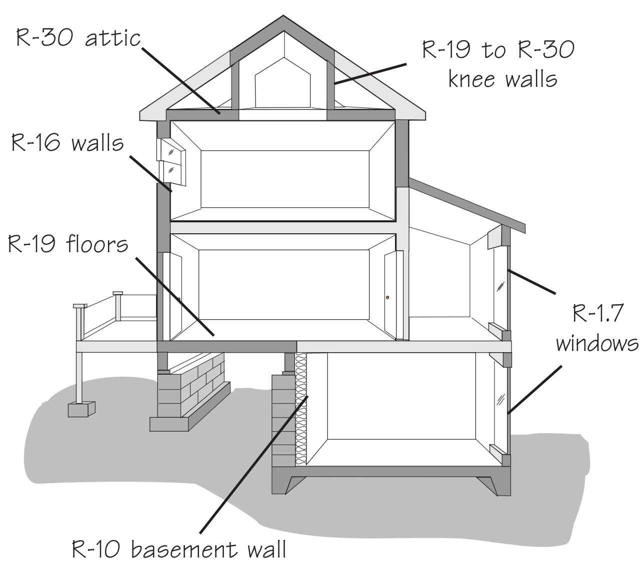




Chapter 5
Insulation Materials and Techniques

An energy efficient building envelope contains both a thermal barrier and an air barrier. The key to an effective thermal barrier is proper installation of quality insulation products. A house should have a continuous layer of insulation around the entire building envelope. Studies show that improper installation can cut performance by 20% or more. While some types of insulation offer reduced air infiltration, most do not, so always include an air barrier (see Chapter 4).

Figure 5-1
Insulating the Building Envelope — Minimum R-values



Insulation Materials

The wide variety of insulation materials makes it difficult to determine which products and techniques are the most cost effective.

- *Fiberglass and mineral wool* products come in batt, roll and loose-fill form, as well as a high-density board material. Many manufacturers use recycled glass in the production process. Fiberglass is used for insulating virtually every building component—from foundation walls to attics to ductwork.
- *Cellulose insulation*, made from recycled newsprint, comes primarily in loose-fill form. Cellulose batt insulation has also been introduced in the marketplace. Loose-fill cellulose is used for insulating attics and can be used for walls and floors when installed with a binder or netting. Because of its high density, cellulose has the advantage of helping reduce air leaks in addition to providing insulation value.
- *Rock wool insulation* is mainly available as a loose-fill product. It is fireproof and many manufacturers use recycled materials in the production process.
- *Expanded polystyrene* (EPS), often known as beadboard, is a foam product made from molded beads of plastic. While it has the lowest R-value per inch of the foam products, it is also the lowest in price. EPS is used in many alternative building products discussed in this chapter, including foam foundation forms and structural insulated panels.

Table 5-1
Fiberglass Batt Insulation Characteristics

Thickness (inches)	R-value	Cost (¢/sq.ft.)
3-1/2	11	12-16
3-5/8	13	15-20
3-1/2	15	25-31
6 to 6-1/4	19	19-26
5-1/4	21	24-30
8 to 8-1/2	25	27-35
8	30	34-38
9-1/2 to 9-3/4	30	30-34
12	38	40-45

This chart is for comparison only. Determine actual thickness,R-value, and cost from manufacturer or local building supply.

- *Extruded polystyrene* (XPS), also a foam product, is a homogenous polystyrene produced primarily by three manufacturers with characteristic colors of blue, pink, and green.
- *Polyisocyanurate and polyurethane* are insulating foams with some of the highest available R-values per inch. They are not designed for use below grade, unlike the other foam insulation products.
- *Open-cell polyurethane foam*, used primarily to seal air leaks and provide an insulating layer.
- *Aerated concrete*, including lightweight, autoclaved (processed at high temperature) concrete, can provide a combination of moderate R-values and thermal mass for floors, walls, and ceilings in addition to structural framing.

Insulation Strategies

Commonly used fiberglass and cellulose products are the most economical, while foam products should be used more judiciously. Builders should use fiberglass, rockwool, or cellulose insulation in attics, walls, and floors. In attics loose-fill products are usually less expensive than batts or blankets. Blown cellulose is more dense than fiberglass or rockwool, which helps it stop air leaks.

Foam insulation strategies

Foam products are primarily economical when they can be applied in thin layers as part of a structural system or to help seal air leaks. Examples include:

- Foundation wall or slab insulation
- Exterior sheathing over wall framing
- Forms in which concrete can be poured
- As part of a structural insulated panel for building walls
- Spray-applied foam insulation

Critical guidelines

When installing any insulating material, the following guidelines are critical for optimum performance:

- Seal all air leaks between conditioned and unconditioned areas.
- Obtain complete coverage of the insulation.
- Minimize air leakage through the material.
- Avoid compressing insulation.
- Avoid lofting (installing too much air) in loose-fill products.

Foundation Insulation

Slab-on-Grade Insulation

In many homes in Alabama, the bottom heated floor is a concrete slab-on-grade, meaning that a slab situated near ground level serves as the floor itself. Uninsulated slabs lose considerable heat in winter through their perimeter edges.

Termite problems in slab insulation

While slab insulation reduces energy bills, its use is questioned in the Southeast because termites can burrow undetected through slab insulation to gain access to the wood framing above. The industry is working on solutions to the termite problem, but in the meantime, check with pest control companies to ensure termite contracts are valid for insulated perimeter slabs.

The Residential Energy Code of Alabama prohibits foam plastic within 6 inches of grade, instead allowing builders to substitute extra attic insulation and other measures for slab insulation. Unfortunately, any uninsulated portion of the building envelope will increase energy bills and may create comfort problems. To avoid this, insulate slabs with non-plastic insulation (such as rigid fiberglass) or use a termite-resistant approach and obtain approval by the local inspector and a reputable termite company. Keep in mind these exceptions to the prohibition of foam plastic below grade:

- When approved protective membranes are provided that separate the foam plastic from the soil
- Foam filled doors
- Interior of basement walls

Preventing termite problems is a key goal of any building, especially where a visual inspection of the foundation is not possible. Among the important preventive measures are:

- **Good drainage**—slope soil away from home and install foundation drains.
- **Remove organic matter**—remove all wood from around the foundation before backfilling.
- **Direct moisture away from the home**—use well maintained gutters and downspouts that connect to a drainage system.
- **Provide continuous termite shields**—protect wooden sill plate and other framing members. The sill plate should be made of pressure-treated lumber.
- **Treat soil**—or use an approved termite monitoring system.

Foundation Wall Insulation

Foundation walls and other masonry walls are usually built of concrete block or poured concrete. Insulating foundation walls is more difficult than framed walls as there is no convenient cavity into which mineral wool batts can fit.

Insulating concrete block cores

Builders can insulate the interior cores of concrete block walls with insulation such as:

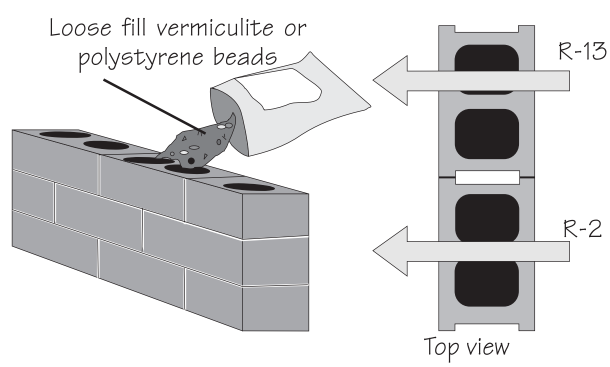
Vermiculite—R-2.1 per inch

Polystyrene inserts or beads—R-4.0 to 5.0 per inch

Urethane foam—R-7.2 per inch

Unfortunately, the substantial thermal bridging in the concrete connections between cores continues to depreciate the overall R-value. This approach is only a partial solution to providing a quality, well insulating wall.

Figure 5-2
Insulating Concrete Block Cores
(R-4 to R-6 overall)



Exterior rigid fiberglass or foam insulation

Rigid insulation is more expensive than mineral wool or cellulose; however, its rigidity is a major advantage. It can be placed directly over a foundation wall prior to backfilling and yield excellent insulating value. In addition, the exterior insulation will help protect waterproofing and will allow the block or concrete wall to provide thermal mass in winter and summer. However, it is difficult and expensive to obtain R-values as high as in framed walls.

SLAB INSULATION—TERMITE RESISTANT DETAILING

Detailing perimeter slab insulation should be planned carefully to prevent both aesthetic and moisture problems. The goals of detailing work are to blend foundation exterior finish with framed wall finish, prevent moisture problems, and create at least 2 feet of continuous perimeter insulation. Once again, make certain your termite contract covers homes with slab insulation.

Figure 5-3
Exterior Insulation with
Termite Resistant Membrane

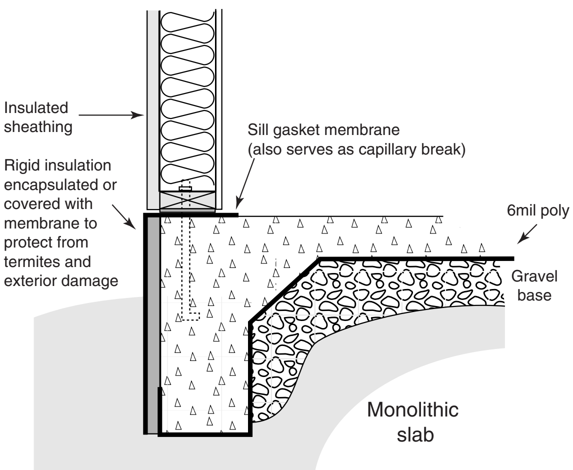


Figure 5-4
Interior L-shaped Insulation with Termite
Resistant Membrane

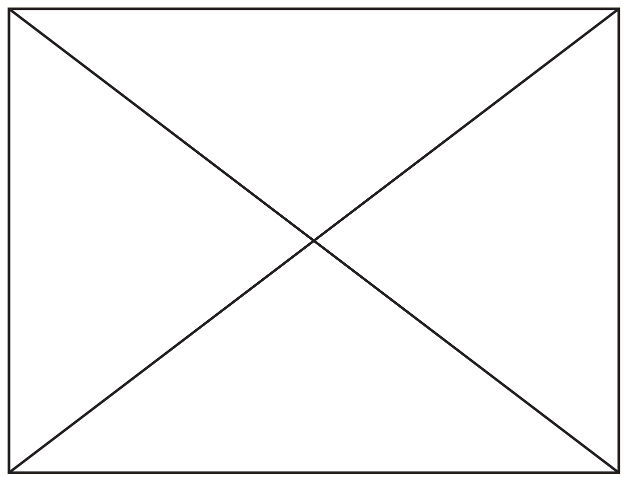


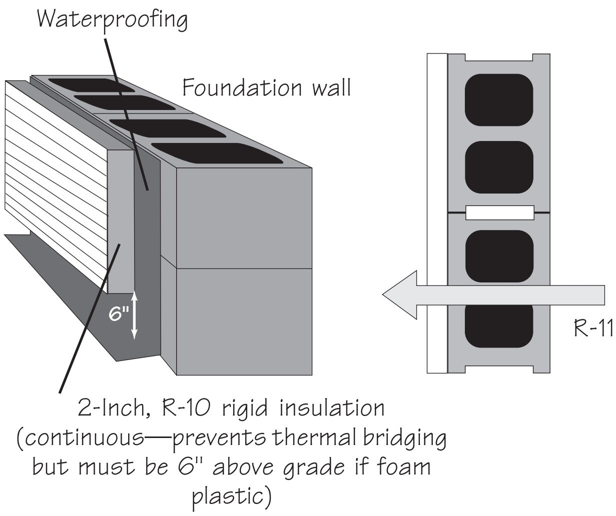
Table 5-2
Economics of Slab Floor Insulation*

Type of Treatment	Incremental Energy Savings ($/yr)	Incremental Installed Costs ($)	Annual Rate of Return	Incremental Mortgage Costs ($/yr)
1-inch perimeter insulation	70	260 - 737	16 - 37%	32 - 91
2-inch perimeter insulation	90	354 - 831	18 - 36%	44 - 103
2-inch perimeter insulation with 1-inch under floor of rooms on south side	n/a**	880 - 1,330	n/a	n/a

*Shows savings in Birmingham versus no slab insulation. Ranges reflect different techniques for finishing exposed edges of slab. The insulation should always be rated for below-grade applications. Estimates are for an 1,800-square-foot slab. See "Evaluating Energy Efficient Products" sidebar on page 17

**The energy savings for these options are difficult to predict accurately.

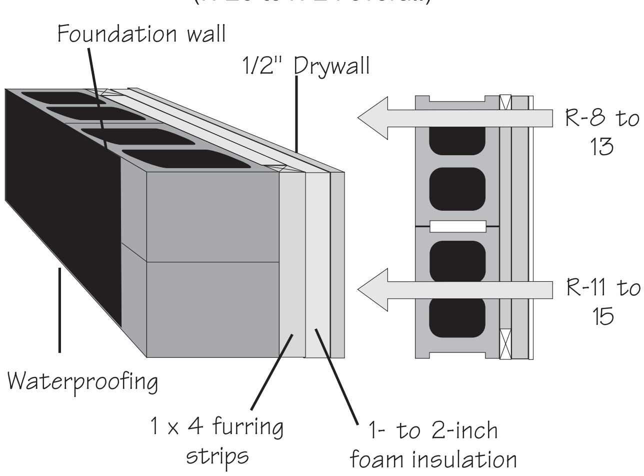
Figure 5-5
Exterior Foam Insulation
(R-11 to R-12 overall)



Interior foam wall insulation

Foam insulation can be installed on the interior of foundation walls; however, it must be covered with a material that resists damage and meets local fire code requirements. Half-inch drywall will typically comply, but furring strips will need to be installed as nailing surfaces. Furring strips are usually installed between sheets of foam insulation; however, to avoid the direct, uninsulated thermal bridge between the concrete wall and the furring strips, a continuous layer of foam should be installed underneath or on top (preferred) of the nailing strips.

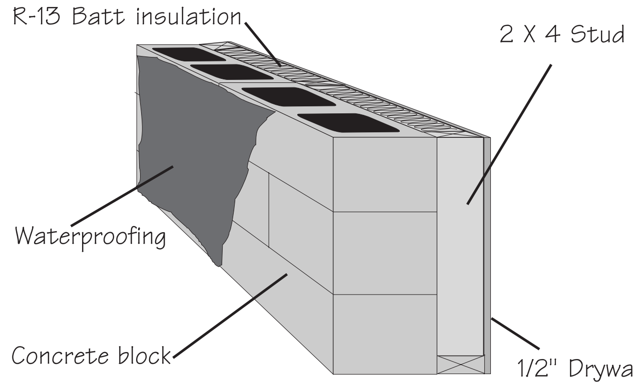
Figure 5-6
Interior Foam Wall Insulation
(R-10 to R-14 overall)



Interior framed wall

In some cases, designers will specify a framed wall on the interior of a masonry wall. Standard framed wall insulation and air sealing practice can then be applied.

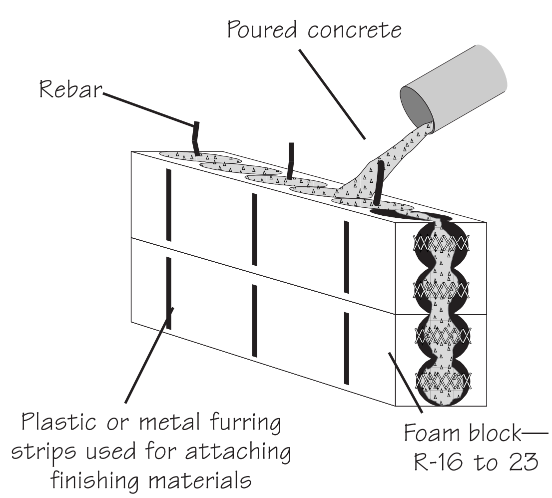
Figure 5-7
Interior Framed Wall
(R-11 to R-13 overall)



Insulated Concrete Foundation systems

Polystyrene or polyurethane foam can be used as formwork for poured or sprayed structural concrete. Many of these systems can be economically attractive in areas with substantial heating and cooling requirements.

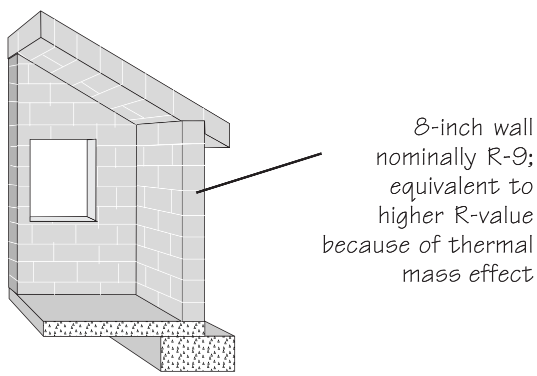
Figure 5-8
ICFs System (R-17 to R-24 overall)



Lightweight concrete products

Lightweight, aerated autoclaved concrete is an alternative wall system. The aerated concrete, which can be shipped as either blocks or panels, combines elevated R-values (compared to standard concrete) with thermal mass.

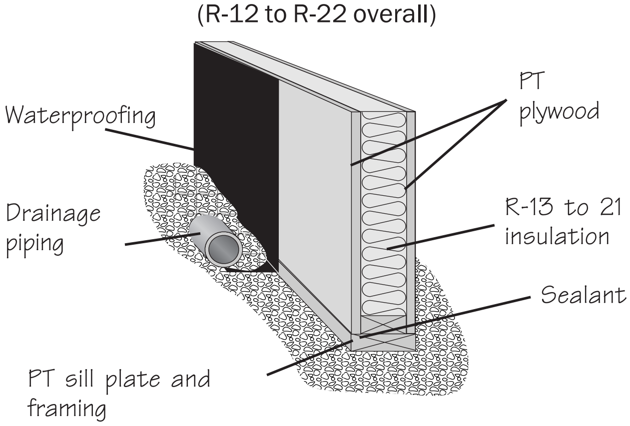
Figure 5-9
Lightweight Concrete Products
(R-1.1 per inch plus mass effect)



Permanent wood foundations

Wood foundations use pressure-treated (PT) plywood and framing to create a non-masonry foundation wall. These systems can be installed without concrete footers. The framed walls can be filled with mineral wool insulation, and the exterior, once waterproofed, can be covered with a drainage plane material. Builders must make certain to install effective drainage systems when using pressure-treated walls below grade to increase the longevity of the system.

Figure 5-10
Permanent Wood Foundations
(R-12 to R-22 overall)



Framed Floor Insulation

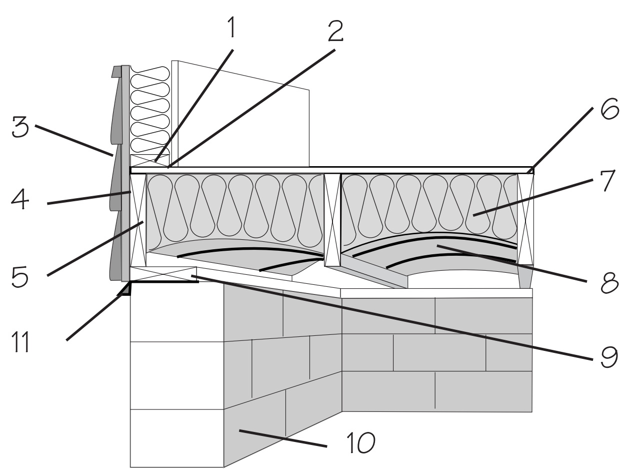
Insulating Under Floors

Most floors in conventional homes are constructed with 2x10 or 2x12 wood joists, wood I-beams, or trusses over unconditioned crawl spaces or basements. Generally, insulation is installed underneath the subfloor between the framing members. To meet the Residential Energy Code of Alabama most homes need R-13 to R-19 floor insulation, depending on climatic zone.

Most builders use insulation batts with an attached vapor barrier for insulating framed floors. The batts should be installed flush against the subfloor to eliminate any gaps which may serve as a passageway for cold air between the insulation and floor. Special rigid wire supports called "tiger teeth" hold the insulation in place. The vapor barrier of the insulation should face up toward the living area.

Run wiring, plumbing, and ductwork below the bottom of the insulation so that a continuous layer can be installed. Be certain to insulate all plumbing and ductwork in unconditioned spaces such as crawl spaces and unheated basements.

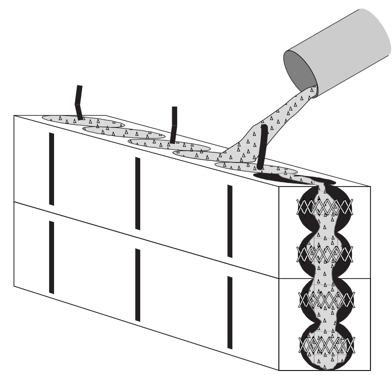
Figure 5-11
Insulated Wood Framed Floors



1. Bottom plate
2 Sealant
3. Exterior finish
4. Insulated sheathing
5. Band joist
6. Subfloor
7. 6-inch insulation batt with vapor barrier against subfloor
8. Wire support
9. Sill plate (pressure treated)
10. Foundation wall
11. Capillary break and termite shield

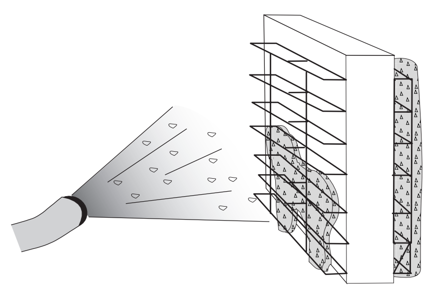
FOAM FORM FOUNDATION SYSTEMS

Foam insulation systems that serve as formwork for concrete foundation walls can save on materials and cut heat flow. Among these types of products are:

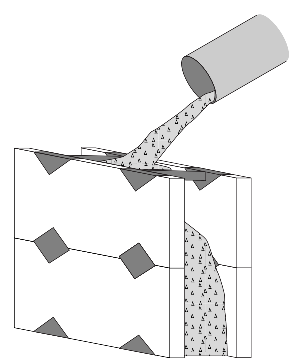


Foam blocks—Several companies manufacture foam blocks that can be installed quickly on the footings of a building. Once stacked, reinforced with rebar, and braced, they can be filled with concrete. Key considerations are:

- **Bracing requirements**—bracing the foam blocks before construction may outweigh any labor savings from the system. However some products require little bracing.
- **Stepped foundations**—make sure of the recommendations for stepping foundations—some systems have 12” high blocks or foam sections, while others are 16” high.
- **Reinforcing**—follow the manufacturer’s recommendations for placement of rebar and other reinforcing materials.
- **Concrete fill**—make sure that the concrete ordered to fill the foam foundation system has sufficient slump to meet the manufacturer’s requirements. These systems have been subject to frequent blow-outs when the installer did not fully comply with the manufacturer’s specifications. A blow-out is when the foam or its support structure breaks and concrete pours out of the form.
- **Termites**—these systems may require approval by code inspection officials. Also, be sure to consult with a reputable termite contractor.



Spray-on systems—Concrete can be sprayed onto foam panels which are covered by a metal reinforcing grid, part of which is exposed. Structural concrete mixture is sprayed onto the exposed reinforcing metal. As with foam block systems, installers must follow manufacturer’s recommendations carefully for a successful system.



Foam panel/snap tie systems—Some companies produce systems in which insulation panels are locked together with plastic snap ties. A space, typically eight inches, is created between the foam panels that is filled with concrete. As with foam block systems, installers must follow manufacturer’s recommendations carefully for a successful system.

Table 5-3
Economics of Framed Floor Insulation*

Type of Treatment	Incremental Energy Savings ($/yr)	Incremental Installed Costs ($)	Annual Rate of Return	Incremental Mortgage Cost ($/yr)
R-11 batt (compared to no insulation)	207	317	75%	29
R-13 batt (compared to R-11)	9	42	27%	4
R-19 batt (compared to R-11)	17	85	25%	8

*For a home in Birmingham with 1,056 square feet of framed floor over a crawl space or unheated basement.
See "Evaluating Energy Efficient Products" sidebar on page 17

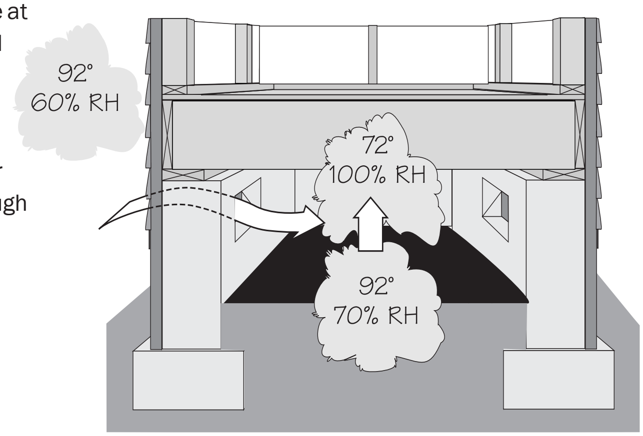
ARE FOUNDATION VENTS NECESSARY?

Considerable research has recently delved into the murky world of foundation insulation. Research in the Southeast is questioning venting crawl spaces. During summers, air conditioning often cools the floor framing and crawl spaces below the dewpoint temperature of outdoor air. Vapor barriers, such as polyethylene, installed over earth floors in crawl spaces, can virtually eliminate moisture migration from the soil below. In summer, crawl spaces become quite humid. Using warm or hot outdoor air to lower humidity is virtually impossible.

When outdoor air at 92°F-60% RH enters a crawl space at 72°F-90% RH, condensation occurs. Venting crawl spaces which have air conditioning ducts can be of particular concern. Often the ductwork is leaky and poorly insulated and creates a cold surface that causes moisture in the air to condense. In some cases water accumulating in duct insulation has become heavy enough to pull ductwork loose.

Given the poor ability of outdoor air to aid in dehumidifying crawl spaces in summer, and most builders' desire to avoid ventilation in winter in order to keep crawl spaces warmer, many building professionals feel that an unvented crawl space is the best option in homes with good exterior drainage systems. However, get approval from local code officials before omitting vents.

Figure 5-12
Relative Humidity (RH) and Foundation Vents



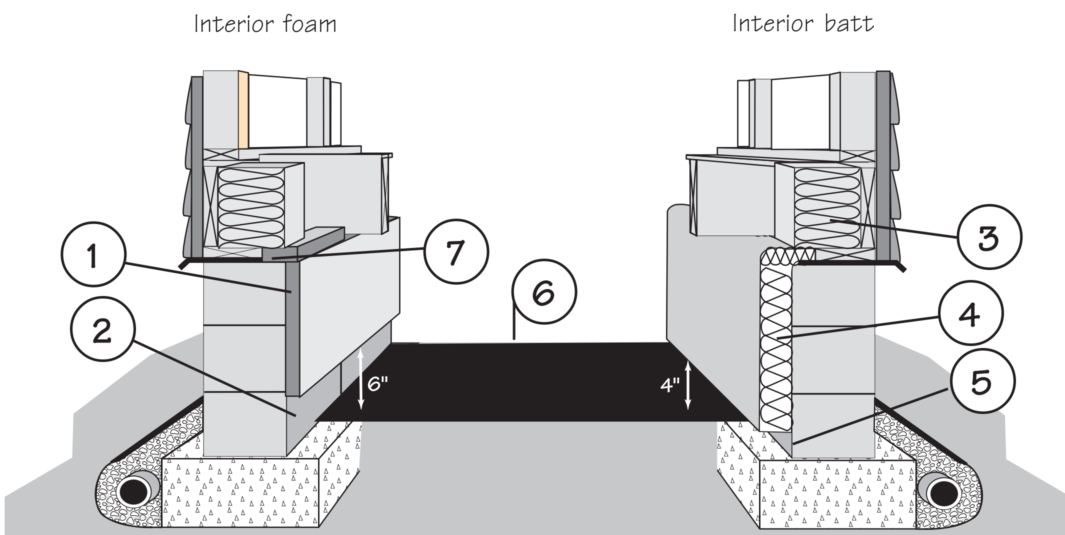
Insulating Crawl Space Walls

For years, building professionals have assumed the optimal practice for insulating floors over unheated areas was to insulate underneath the floor. However, studies performed in Tennessee several years ago found that insulating the walls in *well sealed crawl spaces* and unconditioned basements can be an effective alternative to underfloor insulation. While the annual heating bills in the homes tested were 1 to 3% higher than those with underfloor insulation, the cooling bills dropped by approximately the same amount. Because the crawl space remains cool in summer, the home can conduct heat to the crawl space if there is no insulation under the floor.

Crawl space wall insulation requirements:

- Cover the earth floor with 6- to 10-mil polyethylene (recommended in all homes).
- In winter, close the foundation vents. (As the sidebar on crawl space ventilation describes, it may be better to close the vents in summer as well.) Get approval from local code officials before omitting vents.
- Furnaces or water heaters that are located in these areas and require outside air for combustion should have a direct inlet duct from the outside.
- A 1- to 2-inch gap should be left at the bottom of the insulation to serve as a termite inspection strip.
- Insulate the band joist area in addition to the foundation wall.
- The crawl space or basement should be made airtight.
- Review plans for the insulation with local building officials to ensure code compliance.

Figure 5-13
Insulated Crawl Space Walls



1. 1- to 2-inch extruded polystyrene
2. 6-inch gap above ground
3. Insulation batt for band joist
4. R-13 to R-19 Batt
5. 4-inch termite inspection strip
6. Continuous poly coverage
7. Capillary break and termite shield

Table 5-4
Economics of Foundation Insulation Systems*

Type of Treatment	Net Energy Savings ($/yr)	Net Installed Costs ($)	Annual Rate of Return	Net Mortgage Costs ($/yr)
Masonry Wall				
Filled concrete blocks	7	50	18%	5
Exterior R-10 foam insulation	30	300	13%	28
Exterior R-5 foam insulation	20	170	15%	16
Interior R-10 foam insulation	30	270	14%	25
Interior R-5 foam insulation	20	140	18%	13
Interior framed wall (R-13 insulation)	30	400	9%	37

Alternatives
(due to highly variable costs and energy savings, the economics of these options are not evaluated)
Foam block wall, Spray-on-foam form, Foam panel with snap ties, Lightweight concrete block, Permanent wood foundation

* For 500 square feet of wall in Birmingham, Alabama; net savings or costs compared to an uninsulated concrete block wall. See "Evaluating Energy Efficient Products" sidebar on page 17

Table 5-5
2x4 Framed Wall Problems and Solutions

Problem	Solutions
Small space available for insulation	Install continuous exterior foam sheathing and medium (R-13) to high (R-15) density cavity insulation
Enclosed cavities are more prone to cause condensation, particularly when sheathing materials with low R-values are used	Install a continuous air barrier system and a vapor barrier if applicable. Use continuous foam sheathing
Presence of wiring, plumbing, ductwork, and framing members lessens potential R-value and provides pathways for air leakage	Locate mechanical systems in interior walls; avoid horizontal wiring runs through exterior walls; use air sealing insulation system

Advantages of crawl space wall insulation

- Less insulation required (around 800 square feet for a 2,000 square-foot crawl space with 4-foot walls)
- Pipe insulation is not required (spaces should stay warmer in winter)

Disadvantages of crawl space wall insulation

- The insulation may be damaged by rodents and other pests
- If the soil has high radon concentrations, a radon mitigation system will generally require ventilation of the crawl space to the exterior, which necessitates under floor insulation

- If the crawl space is leaky to the outside, the home will lose considerably more heat than standard homes with underfloor insulation

- Proper site drainage is essential to keep the crawl space dry

Wall Construction

Walls are the most complex component of the building envelope to provide adequate thermal insulation, air sealing, and moisture control. Throughout the United States, debates continue on optimal wall construction. Table 5-5 summarizes typical problems and solutions in walls framed with 2x4 studs.

2x4 Wall Insulation

To solve some of the energy and moisture problems in standard wall construction, builders should follow the steps shown in Chapter 1. Some of these steps involve preplanning, especially the first time these procedures are used. In addition to standard framing lumber and fasteners, the following materials will also be required during construction:

- Foam sheathing for insulating headers
- 1x4 or metal T-bracing for corner bracing
- R-13 batts for insulating areas during framing behind shower/tub enclosures and other hidden areas
- ½-inch drywall or other sheet material where needed for sealing behind shower-tub enclosures and other areas that cannot be reached after construction
- caulking or foam sealant for sealing areas that may be more difficult to seal later

Avoid side stapling

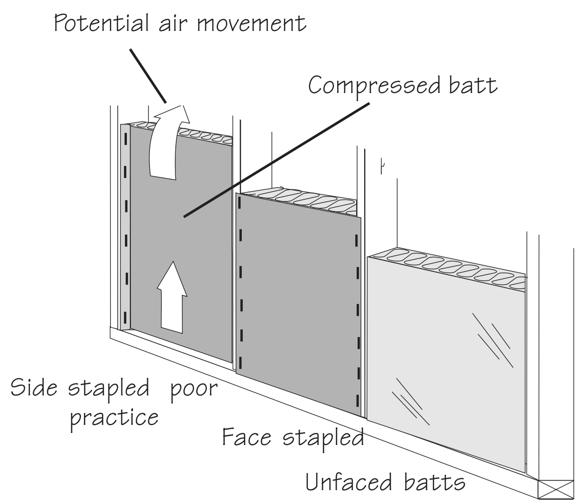
Walls are usually insulated with fiberglass batts having an attached vapor retarder facing. The facing material has a flange that is often stapled to the sides of the studs in order to leave the face of the studs bare so that the drywall subcontractor can glue the interior finish to the wall studs. Gluing drywall requires fewer fasteners, thus saving on both installation and finishing costs. It can also reduce callbacks due to nail popping.

However, side stapling can compress the insulation and create an air space between the insulation and the interior finish, which allows cold air to circulate within the wall cavity. The combined effect of the compressed insulation and air circulation can reduce the effective insulating value of a R-13 batt to a value below R-10.

The insulation flange is designed to be stapled to the face of the studs at 12-inch intervals. Drywall cannot be glued over the flange, so it must be secured with fasteners. Face stapling the batt ensures that the insulation will completely fill the stud cavity and minimize air circulation. The facing has too many tears and seams to function as an adequate air barrier.

An alternative to side stapling insulation batts with flanges is to use unfaced batts. They are slightly larger than the standard 16- or 24-inch stud spacing and rely on a friction-fit for support. Since unfaced batts are not stapled, they can often be installed in less time. In addition, it is easier to cut unfaced batts to fit around wiring, plumbing, and other obstructions in the walls.

Figure 5-14
Insulating Walls With Batts



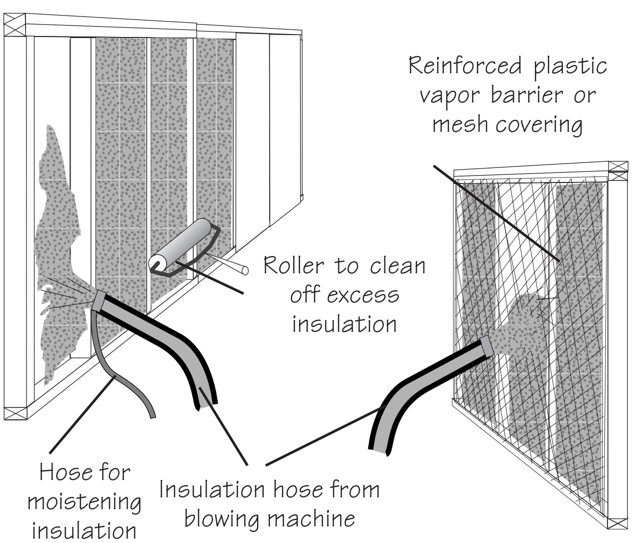
Blown loose-fill insulation

Loose-fill cellulose, fiberglass, cotton, and rock wool insulation can also be used to insulate walls. It is installed with a blowing machine and held in place with a glue binder or netting. This technique can provide good insulation coverage in the stud cavities, however it is important that excess moisture in the binder be allowed to evaporate before the wall cavities are enclosed by a vapor barrier or interior finish—the recommended period is five days.

Loose-fill materials with high densities, such as cellulose installed at around 3-4 pounds per cubic foot, are not only excellent insulators, but also reduce air leaks. Fiberglass is less dense than cellulose and does not provide as much resistance to air circulation. Therefore, the additional benefits of air sealing must be considered when evaluating the economics of blown cellulose.

Neither unfaced insulation batts nor loose-fill products provides a vapor retarder. Only spray foams are recognized by IECC as insulation and air sealer. A vapor retarder is not recommended for wet-spray installed insulation such as cellulose.

Figure 5-15
Blown Sidewall Insulation Options



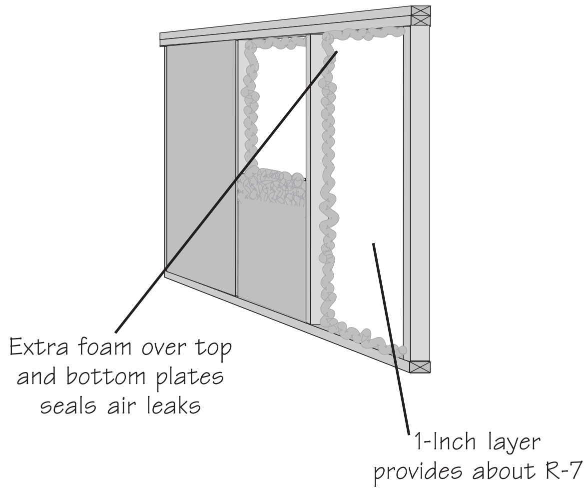
Blown foam insulation

Some insulation contractors are now blowing polyurethane or icynene insulation into walls of new homes. This technique provides high R-values in relatively thin spaces and seals air leaks effectively. The economics of foam insulation should be examined carefully before deciding on its use.

Structural insulated panels

Another approach to wall construction is the use of structured insulated panels (SIP), also known as stress-skin panels. They consist of 4-inch or 6-inch thick foam panels onto which sheets of structural plywood or

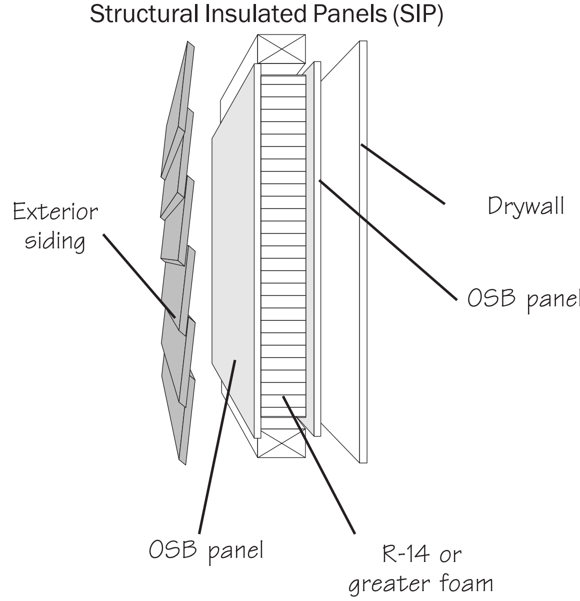
Figure 5-16
Blown Foam Insulation



oriented strand board have been glued. They reduce labor costs, and because of the reduced framing in the wall, have higher R-values and less air leakage than standard walls.

SIPs are 4 feet wide and generally 8 to 12 feet long. There is a wide variety of manufacturers, each with its own method of attaching panels together. Procedures for installing windows, doors, wiring, and plumbing have been worked out by each manufacturer. In addition to their use as wall framing, SIPs can also form the structural roof of a building.

Figure 5-17
Structural Insulated Panels (SIP)



While homes built with SIPs may be more expensive than those with standard framed and insulated walls, research studies have shown SIP-built homes have higher average insulating values and are tighter. Thus, they can provide substantial energy savings.

Metal framing

Builders and designers are well aware of the increasing cost and decreasing quality of framing lumber. As a consequence, interest in alternative framing materials, such as metal framing, has grown. While metal framing offers advantages over wood such as consistency of dimensions, lack of warping, and resistance to moisture and insect problems, it has distinct disadvantages from an energy perspective.

Metal framing serves as an excellent conductor of heat. Homes framed with metal studs and plates usually have metal ceiling joists and rafters as well. Thus, the entire structure serves as a highly conductive thermal grid. Insulation placed between metal studs and joists is much less effective due to the extreme thermal bridging that occurs across the framing members.

The American Iron and Steel Institute is well aware of the challenges involved in building an energy efficient steel structure. In their publication *Thermal Design Guide for Exterior Walls* (Publication RG-9405), the Institute provides information on the thermal performance of steel-framed homes. Table 5-6 summarizes some of their findings.

There have been moisture-related problems in metal frame buildings in Alabama that do not use insulated sheathing on exterior walls. Metal studs cooled by the air conditioning system can cause outdoor air to condense leading to mildew streaks. In winter, conduction through the studs cooled by outside temperatures can also cause streaking.

Wall Sheathings

Many Alabama builders use ½ inch wood sheathing (R-0.6) or asphalt-impregnated sheathing, usually called blackboard (R-1.3), to cover the exterior walls of a building before installing the siding. Instead, use expanded polystyrene (R-2), extruded polystyrene (R-2.5 to 3), polyisocyanurate or polyurethane (R-3.4 to 3.6) foam insulated sheathing. (All R-values are per ½ inch.)

Advantages of foam sheathing over wood or blackboard include:

- Saves energy
- Easier to cut and install
- Protects against condensation (Figure 5-18)
- Less expensive than plywood or oriented strand board

The recommended thickness of the sheathing is based on the desired R-value and the jamb design for windows and doors—usually ½ inch. Be certain that the sheathing completely covers the top plate and band joist at the floor. Most manufacturers offer sheathing products in 9- or 10-foot lengths to allow complete coverage of the wall. Once it is installed, patch all holes.

Because of its advantages over plywood, foam sheathing should be used continuously in combination with let-in bracing, which provides structural support.

Table 5-6
Effective Steel Wall R-values

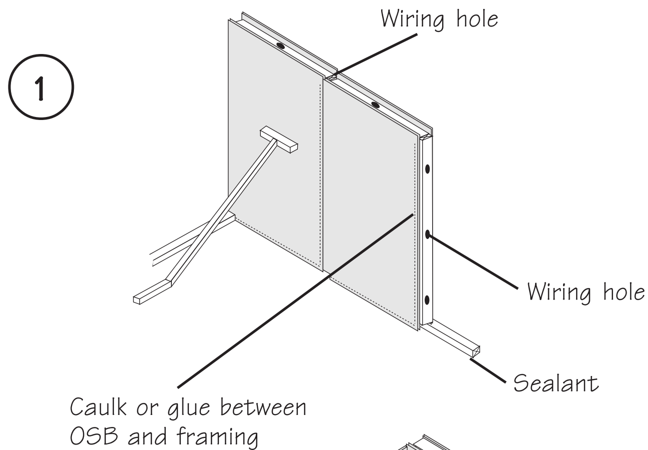
Cavity Insulation	Sheathing	Effective Overall R-value
11	2.5	9.5
11	5	13
11	10	18
13	2.5	10
13	5	14

Table 5-7
Sheathing Costs*

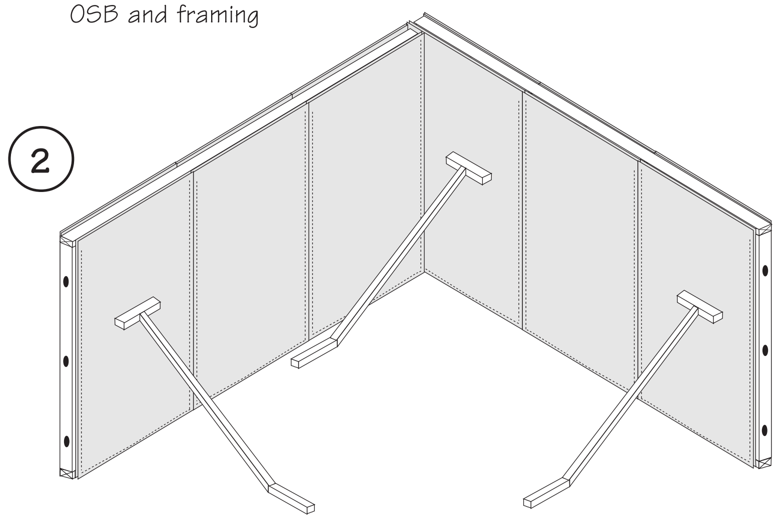
Material	Cost ($)	R-Value
1/2" oriented strand board (OSB)	350	0.60
1/2" extruded polystyrene	383	2.5
1/2" blackboard	255	1.3
1/2" polyisocyanurate	383	3.5 - 3.7
1/2" beadboard (EPS)	255	2.0

* For an 1,824-square-foot home using 64 sheets of 4 x 8 material.

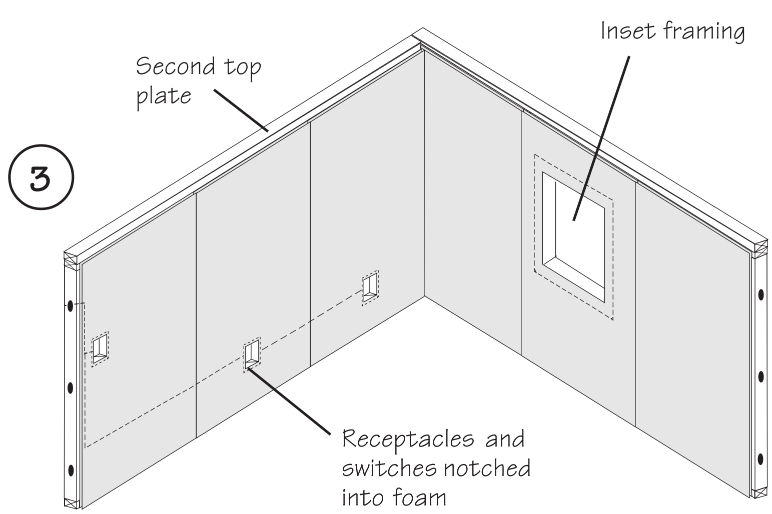
STRUCTURAL INSULATED PANELS CONSTRUCTION



- Install first panel on top of bottom plate—caulk in place
- Be careful to install panel plumb and level

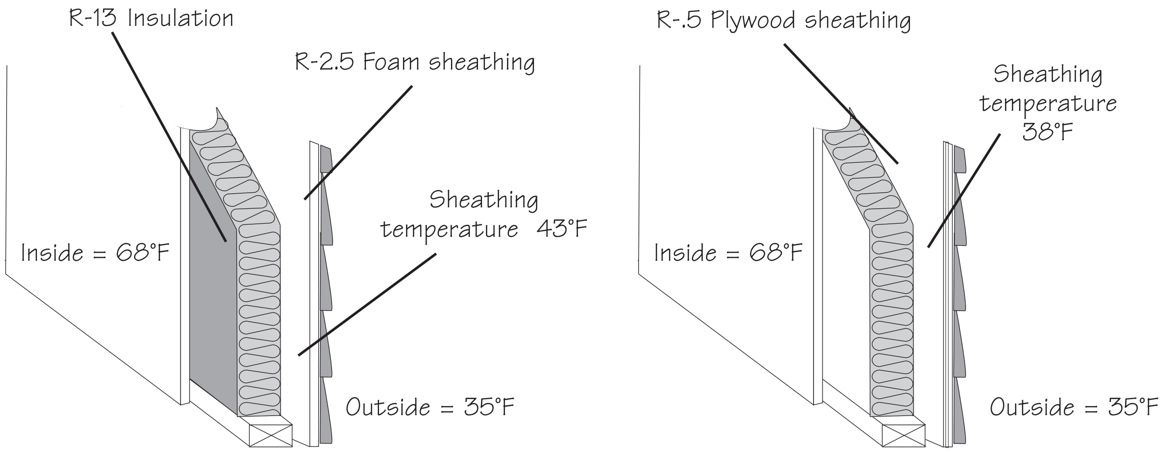


- Continue installing panels, caulking all seams, and checking for plumb and level
- Install continuous top plate



- Install second top plate
- Run wiring
- Cut holes for windows if necessary
- Notch into foam using a special tool for inset framing around rough openings
- Install and caulk framing

Figure 5-18
Foam Sheathing Keeps Walls Warmer



Water vapor will condense on cool surfaces below the 40°Fdewpoint of air in the wall cavity.
The foam sheathing is 5°F warmer, thus helping prevent condensation.

2x6 Wall Construction

There has been some interest in Alabama in the use of 2x6s for construction. In most code jurisdictions, 2x6s can be spaced on 24-inch centers, rather than 16-inch centers required for 2x4s. The advantages of using wider wall framing are:

- More space provides room for R-19 or R-21 wall insulation
- Thermal bridging across the studs is less of a penalty due to the higher R-value of 2x6s
- Less framing reduces labor costs
- There is more space for insulating around piping, wiring, and ductwork

Disadvantages of 2x6 framing include:

- Wider spacing may cause the interior finish or exterior siding to bow slightly between studs
- Window and door jambs must be wider and can add $12 to $15 per opening
- Walls with substantial window and door area may require almost as much framing as 2x4 walls and leave relatively little area for actual insulation

The economics of 2x6 wall insulation are affected by the number of windows in the wall, since each window opening adds extra studs and may require the purchase of a jamb extender. Table 5-8 shows a comparison of 2x4 versus 2x6 framing. Walls built with 2x6s having few windows provide a positive economic payback. However, in walls in which windows make up over 10% of the total area, the economics become more questionable.

Ceilings and Roofs

Attics over flat ceilings are usually the easiest part of a home's exterior envelope to insulate. They are accessible and have ample room for insulation. However, many homes use cathedral ceilings that provide little space for insulation. It is important to insulate both types of ceilings properly.

Attic Ventilation

In winter, properly designed roof vents expel moisture which could otherwise accumulate and deteriorate insulation or other building materials. In summer, ventilation reduces roof and ceiling temperatures, thus potentially saving on cooling costs and lengthening the life of the roof.

At present, several research studies are investigating whether attic ventilation is beneficial. For years, researchers have believed the cooling benefits of ventilating a well insulated attic are negligible. However, some experts are now questioning whether ventilation is even effective at moisture removal. Until the results of current research have been accepted, builders should follow local code requirements, which usually dictate attic ventilation.

Vent selection

If ventilating the roof, locate vents high along the roof ridge and low along the eave or soffit. Vents should provide air movement across the entire roof area. There are a wide variety of products available including ridge, gable, soffit, mushroom, and turbine vents.

The combination of continuous ridge vents along the peak of the roof and continuous soffit vents at the eave provides the most effective ventilation. Ridge vents come in a variety of colors to match any roof. Some brands are made of plastic covered by cap shingles to hide the vent from view.

Powered attic ventilator problems

Electrically powered roof ventilators can consume more electricity to operate than they save on air conditioning costs and are not recommended for most designs. Power vents can create negative pressures in the home which may have detrimental effects such as:

- Drawing air from the crawl space into the home
- Pulling pollutants such as radon and sewer gases into the home
- Backdrafting fireplaces and fuel-burning appliances

Table 5-8
Analysis of 2x6 Walls*

Description of wall	Average R-values		Extra Costs or Savings $		
	Wall Only	Average with Windows**	Costs ($)	30-year Savings ($)	Net Savings
no windows					
2x4	15.37	same	-	-	-
2x6	19.94	same	18	60	$42
2 windows (double-paned)					
2x4	14.94	9.65	-	-	-
2x6	19.78	11.31	31	59	$26
5 windows (double-paned)					
2x4	14.20	6.20	-	-	-
2x6	19.15	6.82	103	57	(-$46)

* 400 sq.ft. (or 8ft high by 50ft long wall section) with R-13, 2x4 construction versus R-19, 2x6 construction. Costs reflect amount above what standard construction would cost. See "Evaluating Energy Efficient Products" sidebar on page 17
**All windows double-glazed, 15 square feet

Figure 5-19
Let-In Bracing

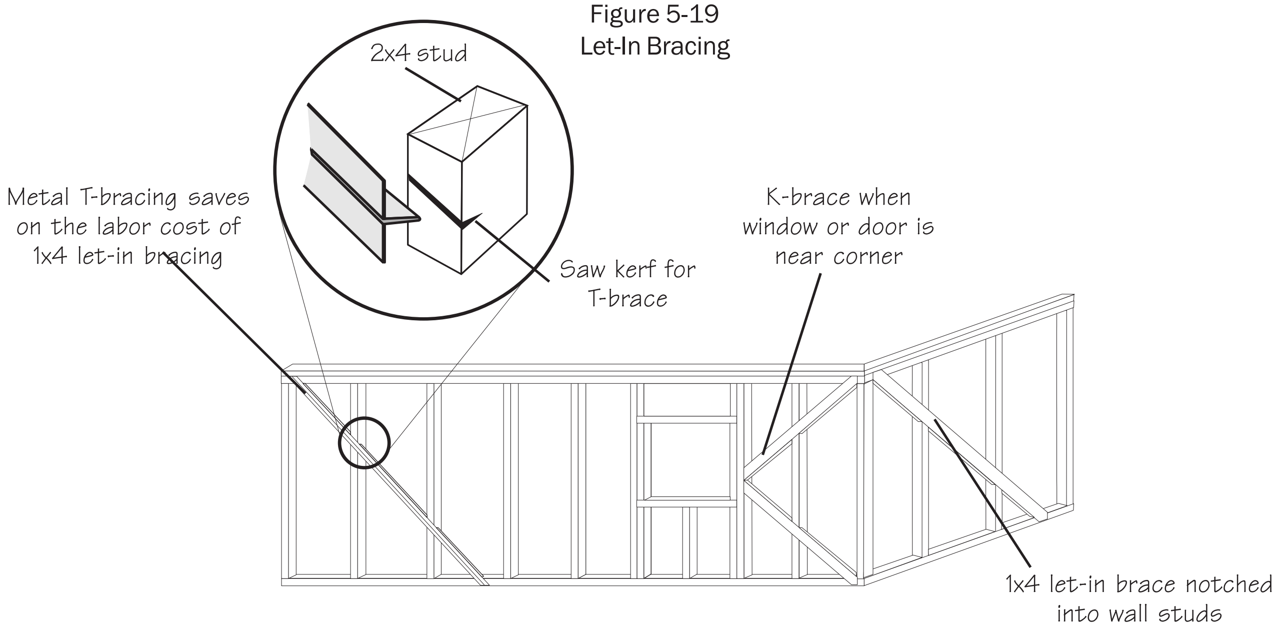
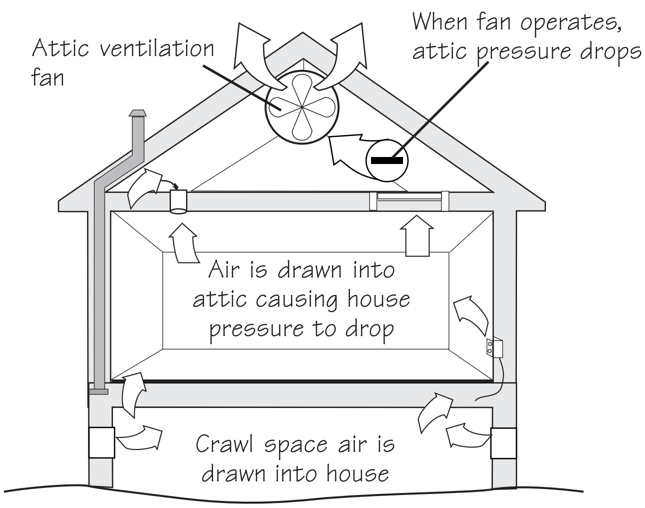


Table 5-9
Economics of Wall Insulation Systems*

Type of Treatment	Incremental Energy Savings ($/yr)	Incremental Installed Costs ($)	Annual Rate of Return	Incremental Mortgage Costs ($/yr)
2x4 Wall				
1. R-11 batts, OSB corner sheathing, R-2.6 insulated foam sheathing elsewhere (compared to a home with blackboard sheathing)	20	217	10.1%	20
2. R-11 batts, R-2.6 sheathing, insulation detailing (compared to Case 1)	9	31	36.0%	3
3.R-13 batts and treatment in Case 2 (compared to Case 2)	11	102	14.2%	9
4. R-15 batts and treatment in Case 2 (compared to Case 3)	9	213	3.4%	20
5. R-11 batts, R-5.2 sheathing, insulation detailing (compared to Case 2)	23	753	1.6%	69
2x6 Wall				
6.R-19 batts, R-2.6 sheathing, insulation detailing (compared to Case 2)	22	785	minimal	72
7.R-21 batts, R-2.6 sheathing, insulation detailing (compared to Case 2)	24	865	minimal	80

*For a home with 1,862 square feet of wall area located in Birmingham, Alabama. Additional installed costs written into the mortgage costs are offset by energy savings. See "Evaluating Energy Efficient Products" sidebar on page 17

Figure 5-20
Pressure Problems Due to Powered Attic Ventilators

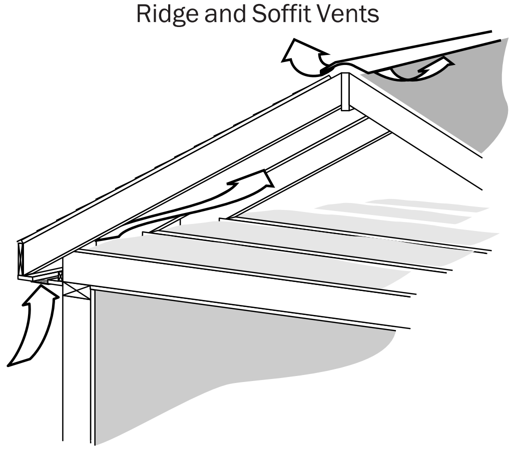


Guidelines for attic/roof ventilation

The amount of attic ventilation needed is determined by the size of the attic floor and the amount of moisture entering the attic. General guidelines are:

- 1 square foot of attic vent for each 150 square feet of attic floor area without a ceiling vapor retarder.
- 1 square foot of vent for each 300 square feet if there is a vapor retarder (example: kraft-faced insulation). 1 square foot of vent for each 150 square feet is preferred.

Figure 5-21
Ridge and Soffit Vents



- The total vent area should be divided equally between high and low vents.

Attic Floor Insulation Techniques

Either loose-fill or batt insulation can be installed on an attic floor. Batts with attached vapor retarders should be installed with the backing next to the ceiling. As shown in Table 5-10, blowing loose-fill attic insulation is usually less expensive than installing batts or rolls. Most attics have either blown fiberglass, rock wool or cellulose.

Steps for installing loose-fill attic insulation

1. Seal attic air leaks, as prescribed by fire and energy codes.
2. Follow manufacturers clearance requirements for heat-producing equipment found in an attic, such as flues or exhaust fans. Other blocking requirements may be mandated by local building codes. Use either metal flashing, plastic or cardboard baffles, or pieces of batt insulation for blocking. Attic blocking requirements are shown in the sidebar.
3. Use cardboard baffles, R-30 batts, or other baffle materials to preserve ventilation space at eave of roof for soffit vents.
4. Insulate the attic hatch or attic stair. There are foam boxes for providing a degree of insulation over a pull-down attic stairway.

Table 5-10
Typical Attic Insulation Costs*

Flat Ceiling

R-19 Batt Insulation	$371
R-30 Batt Insulation	540
R-19 Blown Insulation	264
R-30 Blown Insulation	360
R-38 Blown Insulation	443

*For a 1,056-square-foot attic

5. Determine the attic insulation area; based on the spacing and size of the joists, use the chart on the insulation bag to determine the number of bags to install. Table 5-12 shows a sample chart for cellulose insulation.

6. Avoid fluffing the insulation (blowing with too much air) by using the proper air-to-insulation mixture in the blowing machine. A few insulation contractors have "fluffed" (added extra air to) loose-fill insulation to give the impression of a high R-value. The insulation may be the proper depth, but if too few bags are installed, the R-values will be less than claimed.

7. Obtain complete coverage of the blown insulation at relatively even insulation depths. Use attic rulers to ensure uniform depth of insulation.

Steps for installing batt insulation

1. Seal attic air leaks, as prescribed by fire and energy codes.

2. Block around heat-producing devices, as described in Step 2 for Loose-fill Insulation.

3. Insulate the attic hatch or attic stair as described in Step 4 for Loose-fill Insulation.

4. Determine the attic insulation area; based on the spacing and size of the joists, order sufficient R-30 insulation for the flat attic floor. Choose batts that are tapered—cut wider on top—so that they cover the top of the ceiling joists. (Figure 5-22)

5. When installing the batts, make certain they completely fill the joist cavities. Shake batts to ensure proper loft. If the joist spacing is uneven, patch gaps in the insulation with scrap pieces. Try not to compress the insulation with wiring, plumbing or ductwork. In general, obtain complete coverage of full-thickness, non-compressed insulation.

6. Attic storage areas can pose a problem. If the ceiling joists are shallower than the depth of the insulation (generally less than 2x10s), raise the finished floor using 2x4s or other spacing lumber. Install the batts before nailing the storage floor in place. (Figure 5-23)

Figure 5-22
Full Width Batts

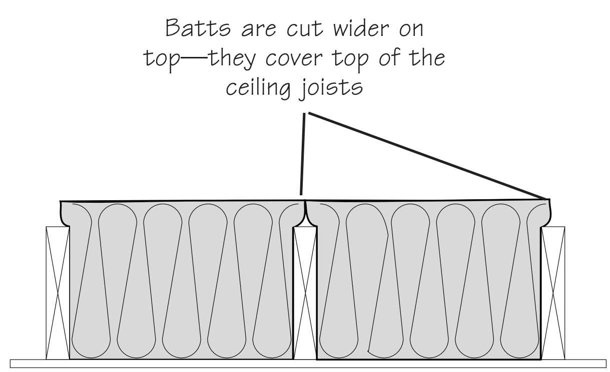
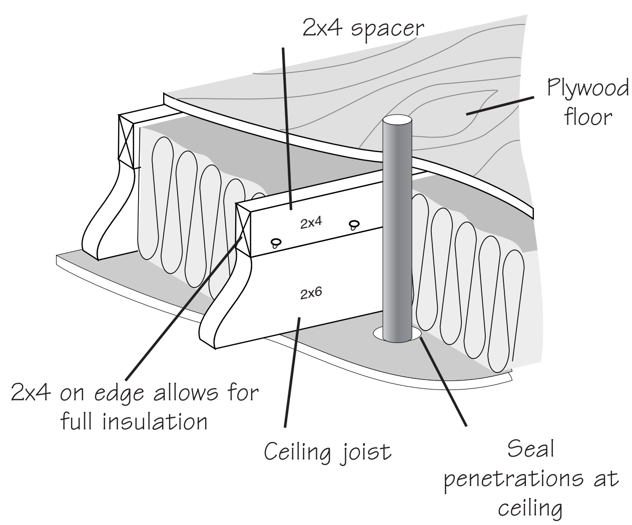
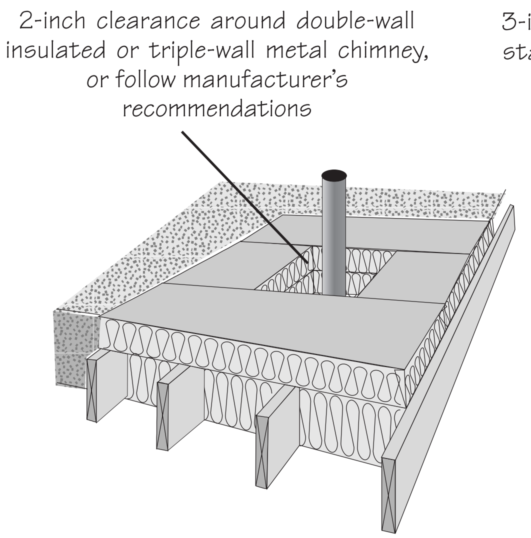
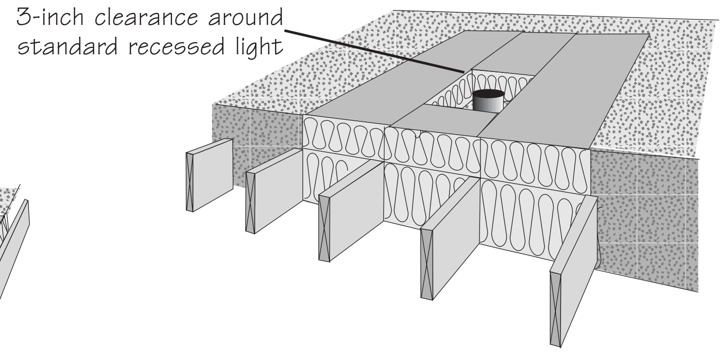


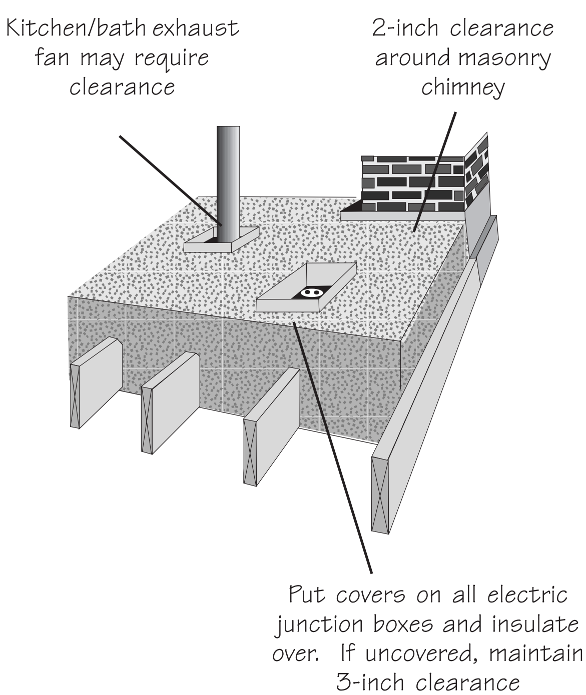
Figure 5-23
Insulating Under Attic Floors



ATTIC BLOCKING REQUIREMENTS







Object	Recommended Action*
Recessed light	3-inch clearance on all sides, unless rated as Insulated Coverage (IC)
Doorbell transformer	Do not cover; no clearance on sides required
Masonry chimney	2-inch clearance
Metal chimney	2-inch clearance or follow manufacturer's recommendations
Vent pipes from fuel-burning equipment	Follow manufacturer's recommendations
Kitchen/bath exhaust	Duct to the outside; leave 3-inch clearance at mouth of blower if not ducted
Heat/light/ventilation	3-inch clearance on all sides
Uncovered electric junction boxes	Cover the box and insulate over it. If it is left uncovered, leave a 3-inch clearance
Whole house fan	Install blocking up to the fan housing; leave 3-inch clearance around fan motor
Attic access door	Block around the door if blowing in loose-fill insulation

*These are general guidelines. Follow specific manufacturer's recommendations.

Table 5-11
Economics of Attic Insulation*

Type of Treatment	Incremental Energy Savings ($/yr)	Incremental Installed Costs ($)	Annual Rate of Return	Incremental Mortgage Costs ($/yr)
1. R-30 blown insulation (compared to R-19 blown insulation)	25	96	33.0%	9
2. R-38 blown insulation (compared to Case 1)	12	83	18.0%	8
3. R-30 batts (compared to R-19 batts)	23	169	17.0%	16

*For a home with a 1,056-square-foot attic area located in Birmingham, AL. Additional installed costs written into the mortgage costs are offset by energy savings. Annual rate of return indicates which packages provide the best cost benefit.

Table 5-12
Blown Cellulose in Attics

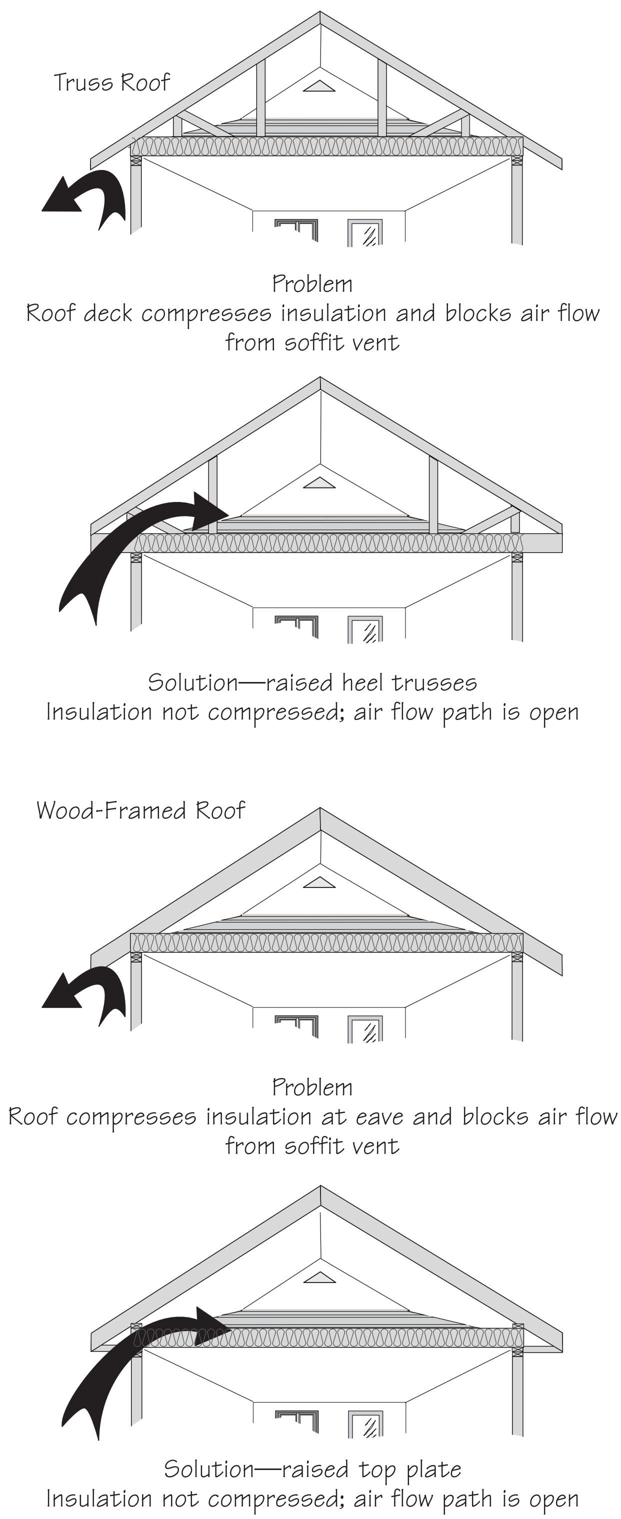
			2x6 Joists Spaced 24 Inches on Center		2x6 Joists Spaced 16 Inches on Center	
R-value at 75°F	Minimum Thickness (in)	Minimum Weight (lb/ft²)	Coverage per 25-lb. bag (sq ft)	Bags per 1,000 sq ft	Coverage per 25-lb bag (sq ft)	Bags per 1,000 sq ft
R-40	10.8	2.10	12	83	13	77
R-32	8.6	1.60	16	63	18	56
R-24	6.5	.98	21	48	23	43
R-19	5.1	.67	37	27	41	24

Increasing the roof height at the eave

One problem area in many standard roof designs is at the eave, where there is not enough room for full R-30 insulation without preventing air flow from the soffit vent or compressing the insulation, which reduces its R-value. Figure 5-24 shows several solutions to this problem. If using a truss roof, purchase *raised heel trusses* that form horizontal overhangs. They should provide adequate clearance for both ventilation and insulation.

In stick-built roofs, where rafters and ceiling joists are cut and installed on the construction site, an additional top plate that lays across the top of the ceiling joists at the eave will prevent compression of the attic insulation. The rafters sitting on this *raised top plate* allow for both

Figure 5-24
Insulation Options for Eaves



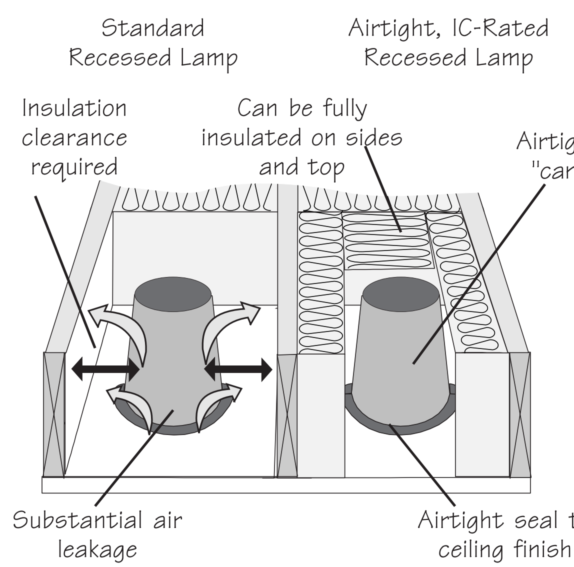
insulation and ventilation.

Problems with recessed lights

Standard recessed fixtures require a clearance of several inches between the sides of the lamp's housing and the attic insulation. In addition, insulation cannot be placed over the fixture. Even worse, recessed lights leak considerable air between attics and the home.

IC-rated fixtures have a heat sensor switch which allows the fixture to be covered with insulation. However, these units also leak air. Airtight, IC-rated fixtures are now required by the Residential Energy Code of Alabama, which has specific air tightness requirements. There are alternatives to recessed lights, including surface-mounted ceiling fixtures and track lighting.

Figure 5-25
Choose Quality Recessed Lamps



Cathedral Ceiling Insulation Techniques

Cathedral ceilings are a special case because of the limited space for insulation and ventilation within the depth of the rafter. Fitting in a 10-inch batt (R-30) and still providing ventilation is impossible with a 2x6 or 2x8 rafter.

The Residential Energy Code of Alabama may allow R-19 cathedral ceiling insulation for some house designs, depending on the climatic zone. For most areas of the state, R-25 to R-30 insulation is recommended. Builders may find some installation cost savings using R-25 batts; however, they are about the same thickness as high density R-30 batts and would follow the same construction practices as outlined below.

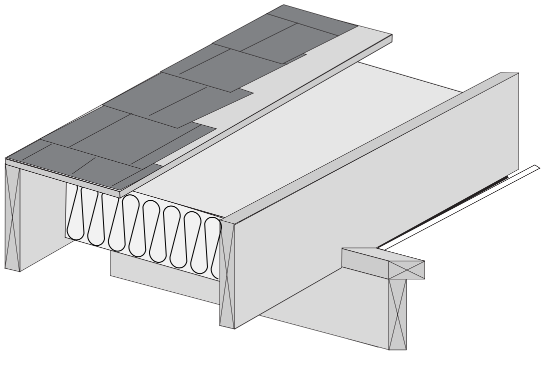
Building R-30 cathedral ceilings

Cathedral ceilings built with 2x12 rafters can be insulated with standard R-30 batts and still have plenty of space for ventilation. Some builders use a *vent baffle* between the insulation and roof decking to ensure that the ventilation channel is maintained.

According to *ASHRAE Fundamentals 1997*, roof ventilation may not be necessary: “Because vents in cathedral ceilings are less likely to provide effective ventilation, potential beneficial effects on moisture conditions, shingle life, and energy conservation during the cooling season are very limited. Therefore, the benefits of vents in cathedral ceilings do not clearly outweigh their potential drawbacks and should not be required in cases where adding vents is particularly difficult or undesirable.” Check with the local inspector to see if space for ventilation is required.

If 2x12s are not required structurally, most builders find it cheaper to construct cathedral ceilings with 2x10 rafters and high-density R-30 batts, which are 8¼ inches thick.

Table 5-13
Cathedral Ceiling Insulation Options



Rafter	Batt	Typical Cost*
2x10	R-25	$1.50/sq ft
2x10	R-30 High Density	$1.65/sq ft
2x12	R-30 Regular Density	$1.95/sq ft

* Typical labor and materials cost for rafter framing and insulation.

Some contractors wish to avoid the higher cost of 2x10 lumber and use 2x8 rafters. These roofs are usually insulated with R-19 batts. However, by using lower grade 2x10 lumber, such as a HemFir product, the additional costs may be avoided. In fact, the cost of a cathedral ceiling built with 2x10 HemFir may actually be less than one built with 2x8, #2 spruce or pine if the rafters can be spaced farther apart. Another option is to lag 2x2s either in-line or perpendicular to the 2x8s to create additional space for insulation.

Figure 5-26
Cathedral Ceiling—Exterior Roof Insulation

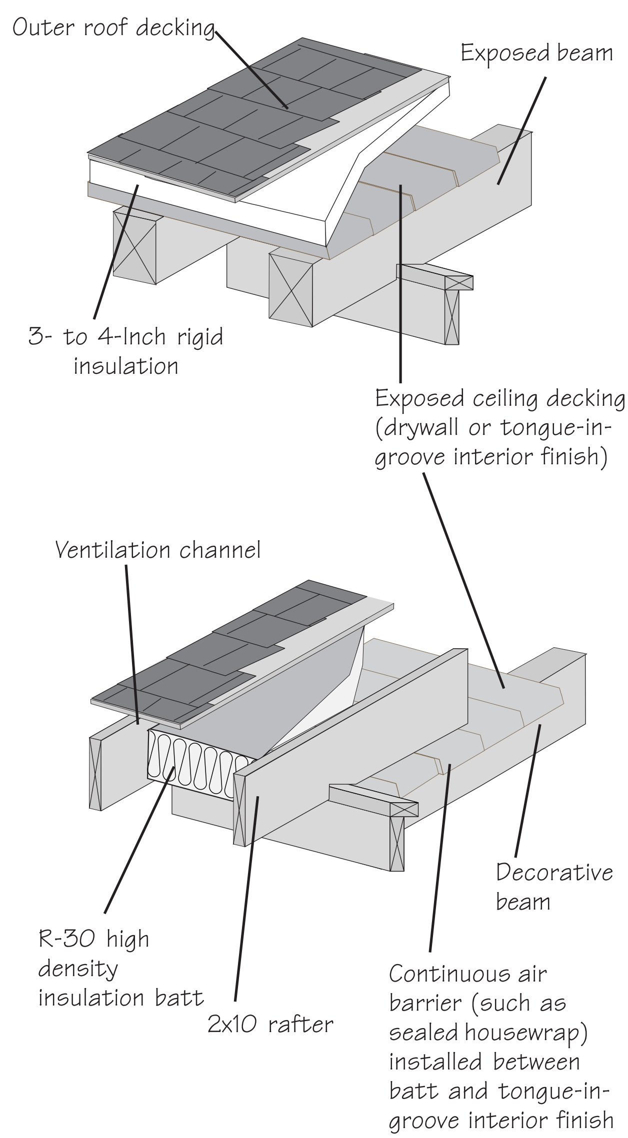


Table 5-14
Economics of Cathedral Ceiling Insulation*

Type of Treatment	Net Energy Savings ($/yr)	Net Installed Costs ($)	Annual Rate of Return	Net Mortgage Costs ($/yr)
1. 2x12 rafters** and R-30 batts	16	276	6.0%	25
2. 2x8 rafters, R-19 batts, and 1-inch rigid insulation on interior face of rafters	12	307	minimal	28
3. 2x10 rafters and R-25 batts	10	153	8.0%	14
4. 2x10 rafters and high-density R-30 batts	16	202	9.0%	19
5. Cathedral ceiling with 4-inch R-27 foam insulation and exposed beams	13	1,000 or more	minimal	92 or more

*For a home with 614 square feet of cathedral ceiling area located in Birmingham, Alabama; compared to a cathedral ceiling space with R-19 insulation.

** Rafters are deeper than insulation to allow a ventilation space.

In framing with 2x6 and 2x8 rafters, higher insulating values can be obtained by installing rigid foam insulation under the rafters. However, foam can be expensive and using thicker rafters may be substantially less costly. Note that the rigid foam insulation must be covered with a fire-rated material when used on the interior of the building. Half-inch drywall usually meets the requirement. Check with local building codes if unsure.

Scissor trusses

Scissor trusses are another cathedral ceiling framing option. Make certain they provide adequate room for both R-30 insulation and ventilation, especially at their ends, which form the eave section of the roof.

Difficulties with exposed rafters

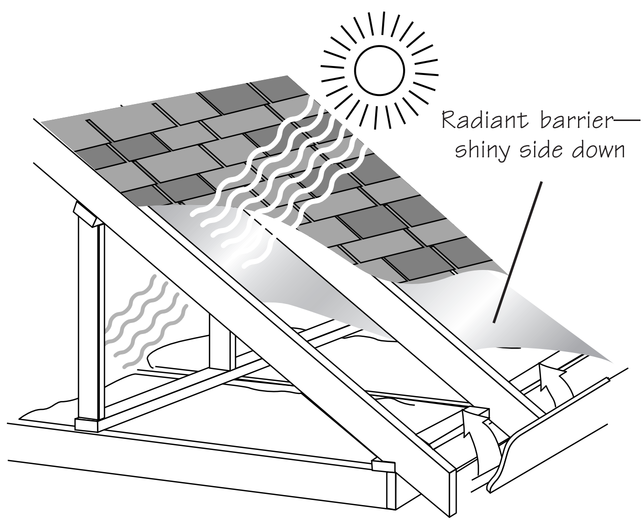
A cathedral ceiling with exposed rafters or roof decking is difficult and expensive to insulate well. Often, foam insulation panels are used over the attic deck as shown in Figure 5-26. However, to achieve R-30, 4 to 7 inches of foam insulation, which typically cost $1 to $3 per square foot, are needed. Ventilation is also a problem and some shingle manufacturers do not offer product warranties unless the outer roof decking is ventilated.

In homes where exposed rafters are desired, it may be more economical to build a standard, energy efficient cathedral ceiling, and then add exposed decorative beams underneath. Note that homes having tongue-and-groove ceilings can experience substantially more air leakage than solid, drywall ceilings. Install a continuous air barrier, sealed to the walls, above the tongue-and-groove roof deck.

Radiant heat barriers

Radiant heat barriers (RHB) are reflective materials that can reduce summer heat gain by the insulation and building materials in attics and walls. RHBs work two ways: first, they *reflect* thermal radiation well and second, they *emit* (give off) very little heat. RHBs should always face a vented airspace and be installed to prevent dust build-up. They are usually attached to the underside of the rafter or truss top chord or to the underside of the roof decking and may be cost effective in hot climates. Consider roof decking sheet goods with a radiant barrier laminated to the surface.

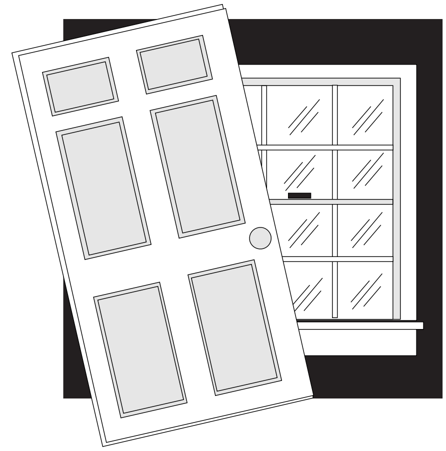
Figure 5-27
Radiant Heat Barrier



Radiant heat barriers lower attic temperatures and may be beneficial in reducing air conditioning requirements.

Notes:

Notes:



Chapter 6

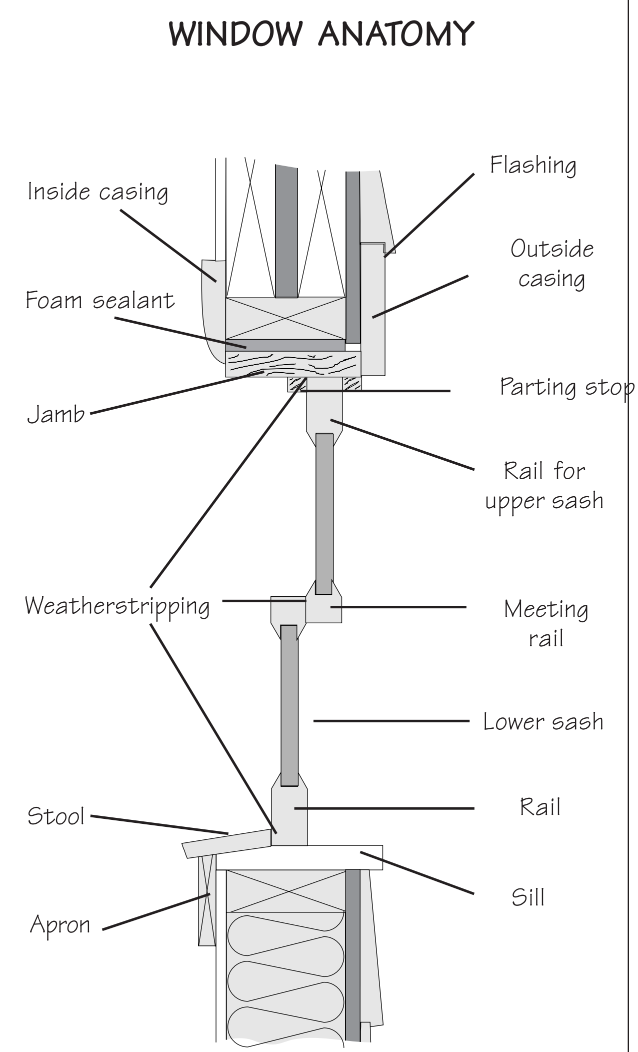
Windows and Doors

Windows connect the interior of a house to the outdoors, provide ventilation and daylighting, and are one of the key aesthetic elements. In passive solar homes, windows can provide a significant amount of heat for a house in the winter.

Windows and doors are often the architectural focal point of residential designs, yet they provide the lowest insulating value in the building envelope. Although recent developments in energy efficient products have markedly improved the efficiency of windows, they still represent one of the major energy liabilities in new construction.

The type, size, and location of windows greatly affect heating and cooling costs. Select good quality windows, but shop wisely for the best combination of price and performance. Many housebuilding budgets have been blown by spending thousands of additional dollars on premium windows with marginal energy savings. In general, if the windows are double-glazed, well-built and have good weatherstripping, they will serve you well. Even better, consider low-emissivity, gas-filled windows for additional energy savings as these are available at relatively low extra cost.

Typical costs for several types of windows are shown in Table 6-1. Well designed homes carefully consider window location and size. In summer, unshaded windows can double the costs of keeping a house cool. Year round, poorly designed windows can cause glare, fading of fabrics, and reduced comfort.



Windows

To understand new window technologies, it is helpful to understand how they lose and gain heat:

- Conduction though the glass and frame
- Convection across the air space in double- and triple-glazed units
- Air leakage around the sashes and the frame
- Radiant energy from the sun travels through the glazing

Goals of Efficient Windows

- High R-values—a minimum of R-1.7 which requires double-glazed glass
- Low air leakage rates—
  - less than .25 cfm per linear foot of sash opening for double-hung windows
  - less than .10 cfm per linear foot for casement, awning, and fixed windows
- Moderate to high transmission rates of visible light
- Low transmission rates of invisible radiation—ultraviolet and infrared light energy

Figure 6-1
Winter Heat Loss in a Double-glazed Window

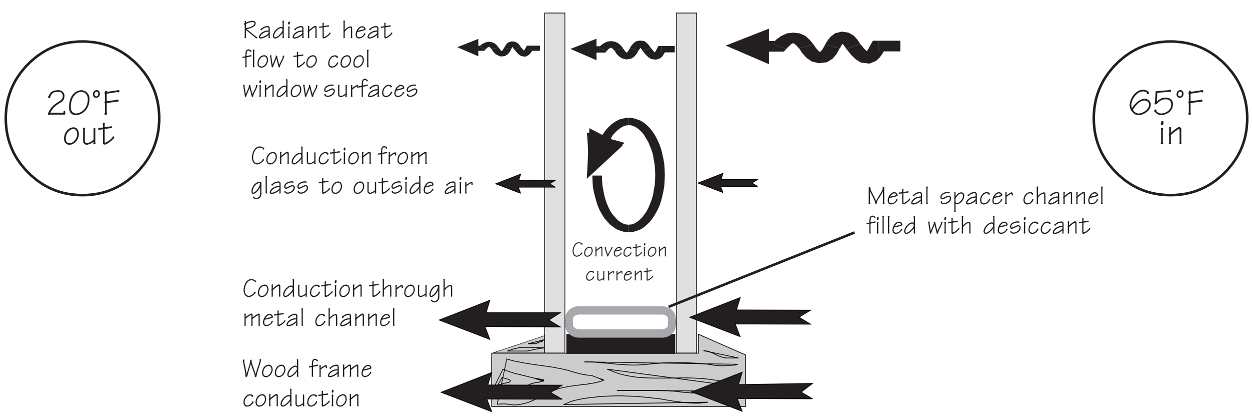


Figure 6-2
Summer Heat Gain in a Double-glazed Window

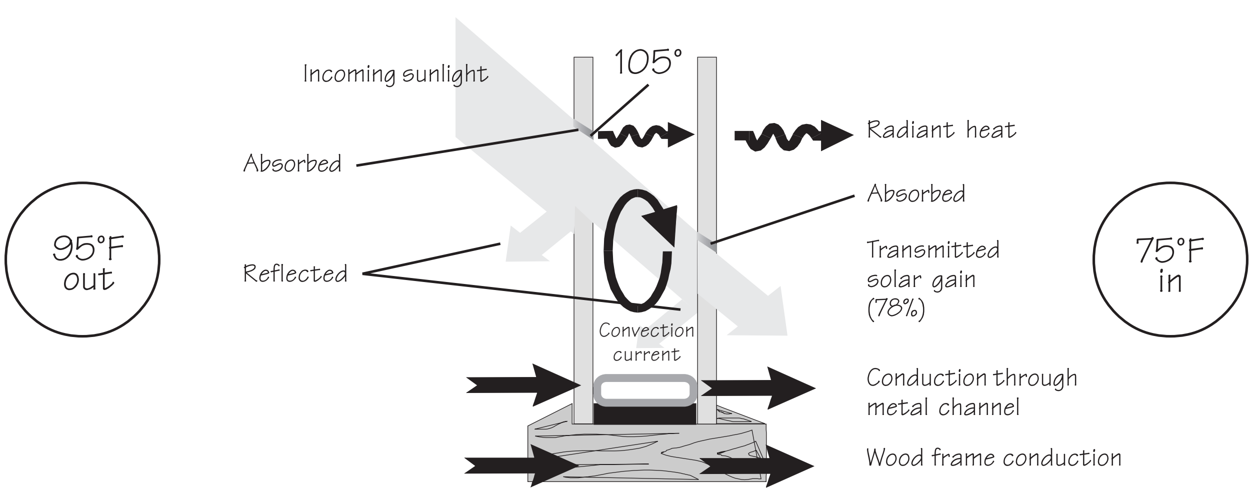


Table 6-1
Cost Comparison of Window Alternatives

Type of Window	Cost per Square Foot of Rough Opening ($)* Builder's Quality	Premium Quality
Single-glazed:		
Double-hung wood	5	11 - 18
Double-glazed:		
Double-hung—wood	8	11 - 18
Double-hung—vinyl or aluminum clad	10	12 - 25
Casement or awning—wood	14 - 18	20 - 27
Casement or awning—aluminum or vinyl clad	19 - 23	25 - 31
Sliding glass door—metal	5 - 8	7 - 10
Sliding glass door—wood	9 - 14	10 - 15
Fixed/hinged operable door combination	n/a	11 - 18

*Windows generally cost about $50 in labor to install. Sealed, double-glazed glass units cost about $2.50 per square foot not including labor and trim, which may run about $7 per square foot.

Few windows can meet all of these goals, but in the past several years, the window industry has unveiled an exciting array of higher efficiency products. The most notable developments include:

- Low-emissivity coatings, which hinder radiant heat flow.
- Inert gas fills, such as argon and krypton, that help deaden the air space between layers of glazing and thus increase the insulating values of the windows.
- Tighter weatherstripping systems to lower air leakage rates.
- Thermal breaks to reduce heat losses through highly conductive glazing systems and metal frames.

The Problem of Reporting Window Insulating Values

Window insulating values are typically reported in U-values—the inverse of R-values. Double-glazed products have R-values as high as 2.0, or U-values of about 0.50 (1/R = ½ = 0.50). Single-glazed windows generally have R-values of 1.0 and thus have U-values of 1.0.

The National Fenestration Rating Council (NFRC) offers a voluntary testing program for window and door products. The NFRC reports an average whole window U-value and R-value. If windows used in your home are listed by the NFRC, they will include a label showing test data for your windows.

Occasionally, window R-values are reported as the insulating value through the glass surface alone. However, windows are made of more than just glass. They have a frame or sash, spacer strips, typically made of aluminum, that hold the sections of glass in a double-glazed window apart, and a jamb. The claimed R-value should reflect the overall insulating value of all of the components. New procedures are encouraging all manufacturers to report window R-values consistently and accurately.

For example, there are two companies which produce extremely efficient windows. Both have two outer glass panes and two inner layers of low-e coated film. In one case, all air spaces are filled with argon, providing an R-value of 7.8 for the glass. However, losses through the edges and frames lower the overall window R-value to 4.0. Another window is filled with air rather than argon yielding an R-value of 6.6 for the glass. Due to its unique edge system, which has thermal breaks made of nylon spacers with insulation in between, the overall window R-value is about 6.3—50% greater than that for the

Table 6-2
Typical R-Values for Windows with Various Frame Types

Frame Type	Glazing System: Single Glass	Double Glass	Triple Glass
All Glass Window	.91	2.04	3.20
Window with Wood Frame	1.06	1.79	2.75
Window with Metal Frame and Thermal Break	0.93	1.49	2.25
Window with Metal Frame and No Thermal Break	0.77	1.15	1.60

Note: Double and triple glass systems have 0.5" air spaces between the layers of glass.

LOW-EMISSIVITY COATINGS

Low-e coatings are primarily designed to hinder radiant heat flow through multi-glazed windows. Some surfaces, such as flat black metal used on wood stoves, have high emissivities and radiate heat readily. However, other surfaces, such as shiny aluminum, have low emissivities and radiate little heat, even when at elevated temperatures.

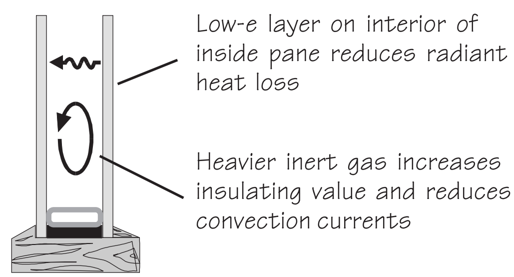
Low-e coatings are usually composed of a layer of silver applied between two protective layers. The coatings have swept through the window industry. Several window companies rarely sell products without low-e layers applied.

Low-e windows have additional benefits:

- Screen ultraviolet radiation, which reduces fabric fading
- Increase the surface temperature of inside glass, which makes us feel warmer because we radiate less heat.
- Helps prevent condensation and frost formation

Figure 6-3
Low-e, Gas-Filled Windows

Winter Performance



Summer Performance

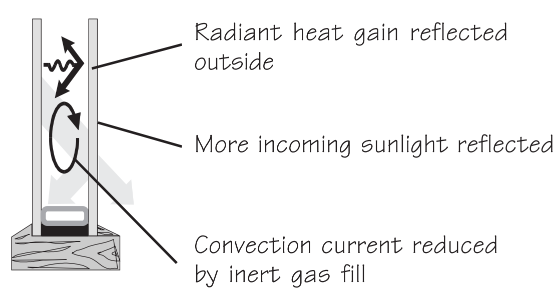


Figure 6-4
Sample NFRC Label

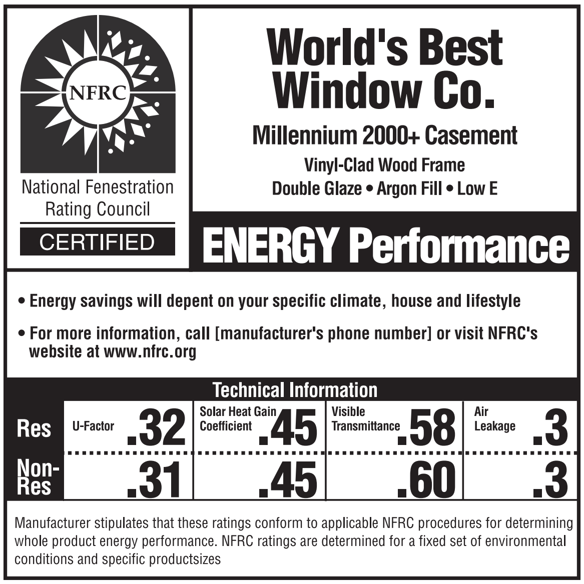
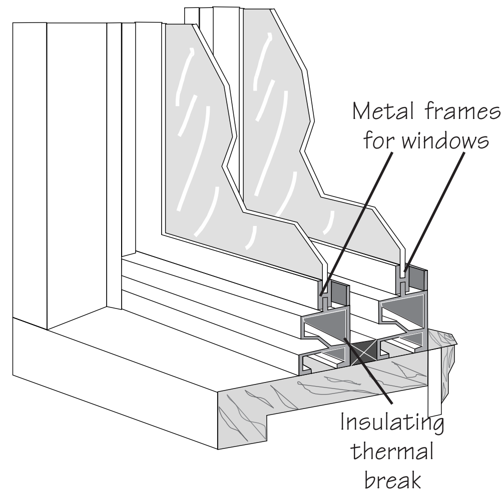


Figure 6-5
Metal Window Frame With Thermal Break



window with higher glass R-value. Future development in windows will concentrate on both glass technology and the balance of the window—edge, seals, and frames.

NFRC also has an approved procedure to determine air infiltration of other fenestration products. NFRC labels will also provide:

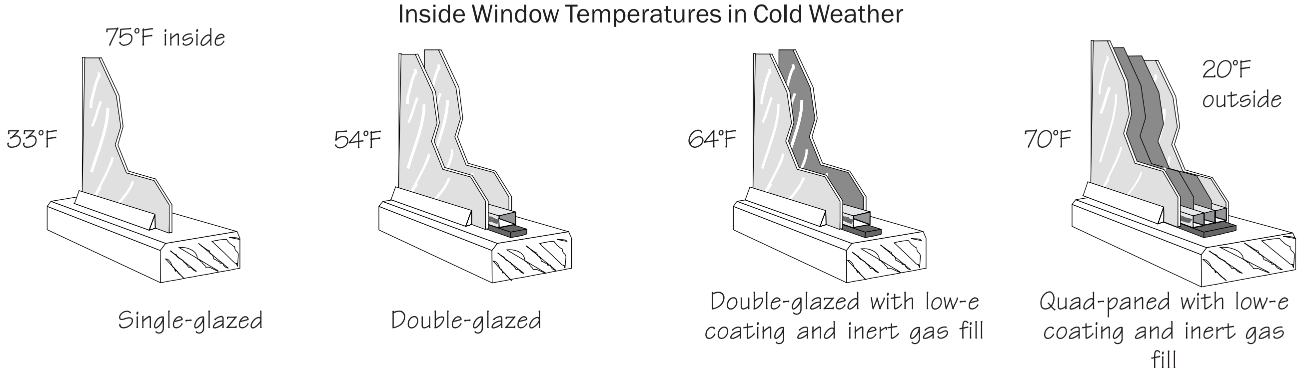
- Air leakage rates (AL)
- Solar Heat Gain Coefficient (SHGC)—the fraction of sunlight transmitted through the window
- Visible Transmission (VT)—the fraction of visible light that is transmitted

Thermal Breaks and Window Spacers

Thermal breaks in metal window frames are of particular importance. Metal is a very poor insulator—in fact, it is a conductor of heat. A thermal break separates inside and outside pieces of the window frame with an insulating material, thus improving R-values. Always specify windows with thermal breaks, listed as "T.I.M" (thermally improved metal) when purchasing metal windows.

Thus, when shopping for windows, find out the total R-value, not just that for the glass. Also, ask how the R-value was determined and whether any standard test procedure was used to derive it. It makes no sense to pay top dollar for a window that looks great on paper, but performs poorly in the real world.

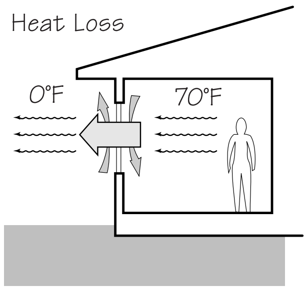
Figure 6-6:
Inside Window Temperatures in Cold Weather



Guidelines for Comparing Window Properties in the Southeast Region

The Southeast Region is a cooling dominated climate to the south and a mixed climate requiring both heating and cooling to the north.

U-Factor



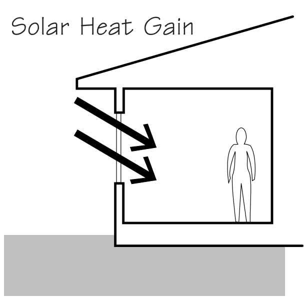
The rate of heat loss is indicated in terms of the U-factor (U-value) of a window assembly. The insulating value is indicated by the R-value which is the inverse of the U-value. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating value.

Recommendation:

Both Heating and Cooling/North Alabama: Select windows with a U-factor of 0.40 or less. The larger the heating bill, the more important a low U-factor becomes.

Mostly Cooling/South Alabama: A low U-factor is useful during cold days when heating is needed. A low U-factor is also helpful during hot days when it is important to keep the heat out, but it is less important than SHGC in warm climates. Select windows with a U-factor lower than 0.75 and preferably lower than 0.60.

Solar Heat Gain Coefficient (SHGC)



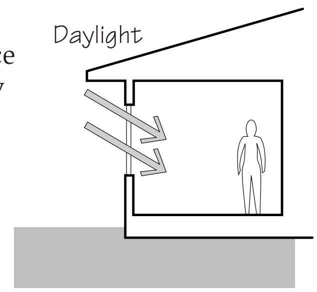
The SHGC is the fraction of incident solar radiation admitted through a window. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits.

Recommendation:

Both Heating and Cooling/North Alabama: If there are significant air conditioning costs or summer overheating problems, look for SHGC values of 0.40 or less. For moderate air conditioning requirements, select windows with a SHGC of 0.55 or less. While windows with lower SHGC values reduce summer cooling and overheating, they also reduce free winter solar heat gain. Use a computer program such as RESFEN to understand heating and cooling trade-offs.

Mostly Cooling/South Alabama: A low SHGC is the most important window property in warm climates. Select windows with a SHGC less than 0.40.

Visible Transmittance (VT_{glass} and VT_{window})

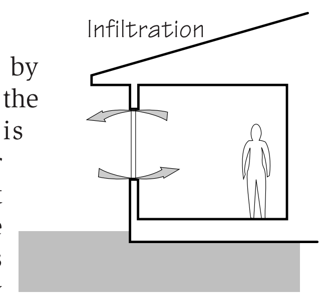


The visible transmittance (VT) is an optical property that indicates the amount of visible light transmitted. VT is expressed as a number between 0 and 1. The higher the VT, the more daylight is transmitted. A high VT is desirable to maximize daylight.

Recommendation:

A window with VT_{glass} above 0.70 (for the glass only) is desirable to maximize daylight and view. This translates into a VT_{window} above 0.50 (for the total window including a wood or vinyl frame).

Air Leakage (AL)



Heat loss and gain occur by infiltration through cracks in the window assembly. AL is expressed in cubic feet of air passing through a square foot of window area. The lower the AL, the less air will pass through cracks in the window assembly. While many think that AL is extremely important, it is not as important as U-factor and SHGC.

Recommendation:

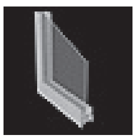
Select a window with an AL of 0.30 or below (units are CFM/sq ft).

Source: This section adapted with permission from the Efficient Windows Collaborative, Alliance to Save Energy, 1200 18th St., NW, Suite 900, Washington, DC 20036, http://www.efficientwindows.org.

Comparing Window Performance in Birmingham

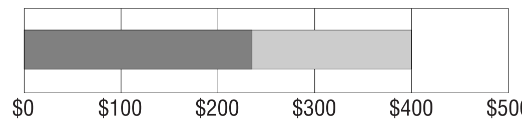
The annual energy performance figures shown here were generated using RESFEN for a typical 2000 sq ft house with 300 sq ft of window area (15% of floor area). The windows are equally distributed on all four sides of the house and include typical shading (interior shades, overhangs, trees and neighboring buildings). The heating system is a gas furnace with air conditioning for cooling. The figures are based on typical energy costs for this location (natural gas: $0.60/therm and electricity: $0.082/kWh). U-Factor, SHGC, and VT are for the total window including frame.

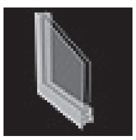
Case Studies | **Properties** | **Annual Energy Use** (Range)



Window 1
Single Glazing
Clear Glass
Aluminum Frame

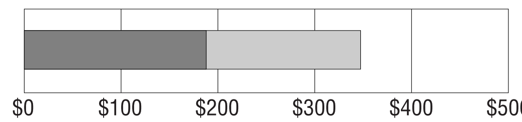
U = 1.25
SHGC = 0.76
VT = 0.74

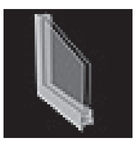




Window 2
Double Glazing
Clear Glass
Aluminum Frame

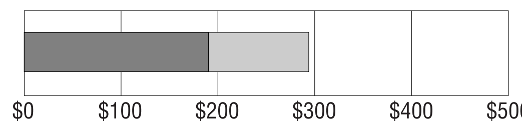
U = 0.79
SHGC = 0.68
VT = 0.67

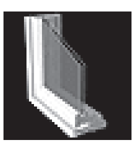




Window 3
Double Glazing
Low-E Coating
(low solar gain)*
Aluminum Frame
with Thermal Break

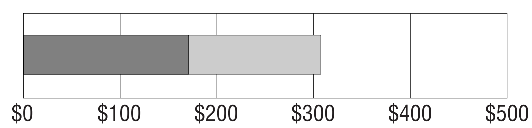
U = 0.48
SHGC = 0.34
VT = 0.53

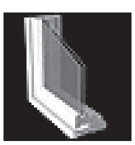




Window 4
Double Glazing
Clear Glass
Wood, Vinyl, Clad or
Hybrid/Composite Frame

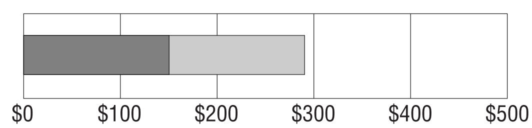
U = 0.49
SHGC = 0.56
VT = 0.58

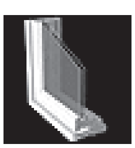




Window 5
Double Glazing
Low-E Coating
(high solar gain)
Wood, Vinyl, Clad or
Hybrid/Composite Frame

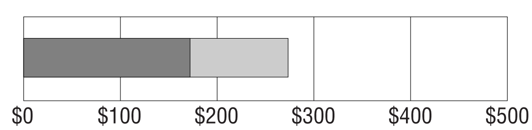
U = 0.36
SHGC = 0.52
VT = 0.53





Window 6
Double Glazing
Low-E Coating
(low solar gain)*
Wood, Vinyl, Clad or
Hybrid/Composite Frame

U = 0.32
SHGC = 0.30
VT = 0.50



*Spectrally Selective

Source: Adapted with permission from the Efficient Windows Collaborative.

Future Window Options

Electronic windows

A new genre of windows is composed of special materials that can darken the glazing by running electricity through the unit. Some manufacturers already have prototypes of these high technology windows in operation. At night and on sunny days, an electric switch can be turned on to render the windows virtually opaque.

Solid windows

Another new window technology uses gel-type material up to one inch thick between layers of glazing. The window offers increased insulating value, but at present is not completely transparent and is not economical in Alabama.

PROPER WINDOW INSTALLATION

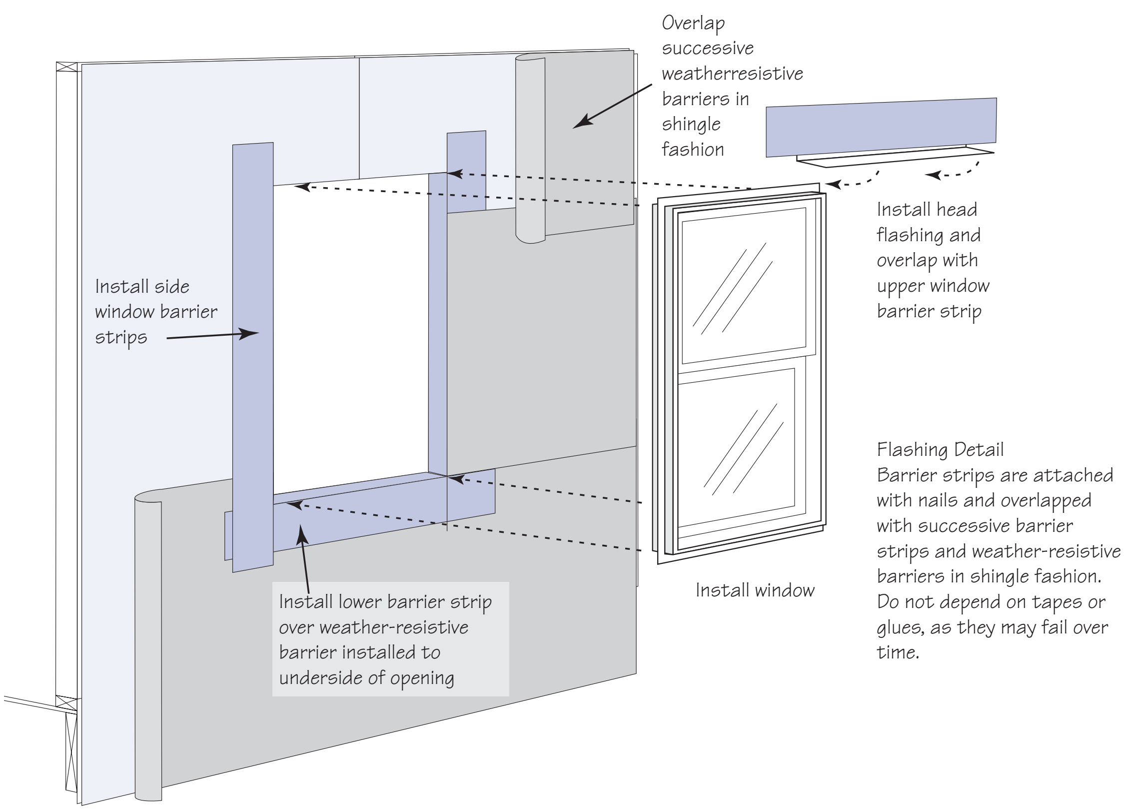
Step 1: Make sure window fits in rough opening and that the sill is level.

Step 2: Install window level and plumb according to the manufacturer's instructions.

Step 3: Use non-expanding foam sealant to seal between the jamb and the rough opening, or stuff the gap with backer rod or insulation and cover the insulation with caulk (remember—most insulation doesn't stop air leaks—it just serves as a filter).

Step 4: After interior and exterior trim is installed, seal the gap between the trim and the interior or exterior finish with long-life caulk.

Figure 6-7
Window Flashing Details



Doors

Exterior wood doors have low insulating values, typically R-2.2. Storm doors increase the R-value only to about R-3.0 and are not good energy investments. The best energy-conserving alternative is a metal or fiberglass insulated door. Metal doors have a foam insulation core which can increase the insulating value to above R-7. They usually cost no more than conventional exterior doors and come in decorative styles, complete with raised panels and insulated window panes.

Insulated metal or fiberglass doors usually have excellent weatherstripping and long lifetimes. They will not warp, and offer increased security; however, they are difficult to trim, so careful installation is required. As with windows, it is important to seal the rough openings. Thresholds should seal tightly against the bottom of the door and must be caulked underneath. After the door is installed, check it carefully when closed to see if there are any air leaks.

Accessible Design

Almost one out of ten people will suffer from physical disabilities during their lifetime. Designing homes to ensure accessibility for the physically impaired adds little to the cost of a home. One important feature is to ensure that both exterior and interior door openings and hallways are 3'-0" wide to allow passage of a wheelchair or walker. Ensuring that baths and kitchens have adequate room for wheelchairs is another feature that adds little to construction costs but is expensive to retrofit.

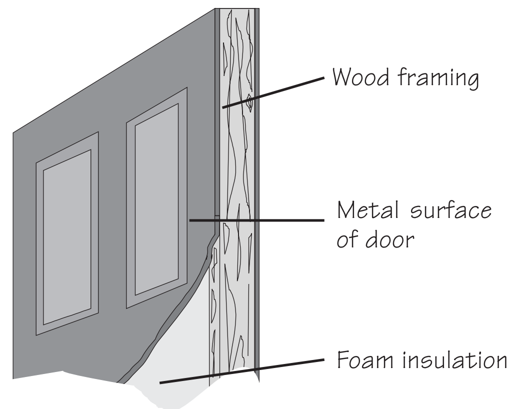
Windows and Ventilation

Natural Ventilation

A primary purpose of windows is to provide for ventilation. With Alabama's mild climate, natural ventilation can maintain comfort for much of the spring and fall. The size and placement of the window openings affect ventilation. Casement windows open fully for ventilation, while double-hung and slider windows open only 50 percent of their total area. In addition, casement windows can be used to channel breezes into the home.

The optimum placement of windows for ventilation would be on each side of the house to take advantage of breezes from any direction. However, the ventilation benefits of east and west windows are overshadowed by the problems they pose by allowing summer sunlight into the home. In general, it is best to avoid east and west windows. Place the major glass areas on the south and a moderate number of windows on the north for cross ventilation.

Figure 6-8
Insulated Metal Door



Each room should have a window to allow air to enter (ideally located on the south or north wall) and a separate opening to enable air to exit. The outlet may be a doorway leading into another area of the home. The inlet and outlet should be located so that they create breezes in the areas most frequently occupied.

In addition to providing for cross ventilation, windows can be used to create ventilation between low and high areas. For example, in a two-story house, as air inside warms it rises and exits through upper level windows. As the air rises, it draws outside air through the lower windows into the house. This process is known as the *stack effect*. However, the force of the rising air is weak, so it is not practical to provide special design features in a house to encourage this type of ventilation.

In fact, natural ventilation of any type is unpredictable. While having some operable windows is desirable, it is not usually worthwhile to increase construction costs solely to increase the window area for ventilation. Mechanical ventilation provided by fans is economical and much more reliable.

Mechanical Ventilation

Mechanical ventilation—using fans or blowers— provides an inexpensive means of creating a cooling air flow. Internal air movement created by portable fans or ceiling fans can provide comfort inexpensively. Use fans even when the air conditioning is operating. For each degree that the thermostat is raised, air conditioning costs drop 3 to 8 percent. By setting the thermostat between 80 and 85°F and using fans, homeowners can save 20 to 50 percent on cooling bills.

Whole house fans, also called attic fans, blow hot room air from inside up into the attic and pull supply air into the home from outside. Be sure to construct an insulated cover for the whole house fan and place it in the attic.

The primary disadvantage of whole house fans is that they bring in outside air containing dust and, at times, pollen and other allergens. They also pull in moisture. However, for most people, whole house fans can save considerably on cooling bills. In fact, some homes without air conditioning rely solely on whole house fans to maintain comfort.

Whole house fans can be coupled with ceiling fans to reduce cooling costs 50 to 70 percent as follows:

- When it is hotter than 85°F outside, set the air conditioner thermostat at 85°F and run ceiling and portable fans. Do not use whole house fan when air conditioning.
- When it is cooler than 85°F outside and not excessively humid, turn the air conditioner off, open the windows, and run the whole house fan.
- On days when temperatures do not rise above 85°F until mid- or late afternoon, try ventilating during the cooler morning hours. As temperatures increase, close windows and pull shades to keep the heat outside. Use interior fans to create a breeze. As temperatures cool in the evening, open the house and ventilate.

Windows and Shading

Shading Coefficients

An important characteristic of windows is the *shading coefficient* (SC), which measures how much sunlight is transmitted through a window compared to that transmitted through clear, single-glazed glass. The more layers of glass, coatings, or tints that a window has, the more sunlight it impedes and hence, the lower the shading coefficient. Typical values are shown in Table 6-3.

In sections of Alabama with hotter summers and warmer winters, tinted glass may be recommended for windows that face east, west and south. These windows have lower shading coefficients and block sunlight in summer so as to reduce cooling bills.

Table 6-3
Window Treatment Shading Coefficients

Treatment	Window Type	Shading Coefficient*
Single-glazed window	1/8-inch glass	1.00
	1/4-inch glass	.94
	tinted (1/4-inch)	.78
Double-glazed window	1/8-inch glass	.88
	1/4-inch glass	.81
	tinted (1/4-inch)	.67
Venetian blinds	1/4-inch single glass	.60
	1/4-inch double glass	.54
Roller blinds (white)	1/4-inch single glass	.25
	1/4-inch double glass	.25
Light, airy drapes	1/4-inch single glass	.70
	1/4-inch double glass	.58
Heavy drapes	1/4-inch single glass	.45
	1/4-inch double glass	.42
Exterior shade screen/louvered sun screen	1/4-inch single glass	.38
	1/4-inch double glass	.42

*Fraction of sunlight that passes through glass and window treatment. Assumes sunlight strikes perpendicular to glass. SHGC ≃ 0.89 x SC

Window Shading Options

Most windows in Alabama require shading devices other than window tinting. Options include:

- Overhangs
- Blinds
- Shutters
- Landscaping and trees

The effectiveness of different window shading options depends on the composition of the incoming sunlight. Sunlight reaches the home in three forms: *direct, diffuse*, and *ground reflected*. On a clear day, most sunlight is direct, traveling as a beam without obstruction from the sun to a home's windows. In winter, most of the direct sunlight striking a window is transmitted; however, in summer, the sun strikes south windows at a much steeper angle, and much of the direct sunlight is reflected.

The majority of the sunlight entering south-facing windows in the summer is either diffuse—bounced between the particles in the sky until it arrives as a bright haze—or is reflected off the ground.

In developing a strategy for effectively shading windows, both direct and indirect sources of sunlight must be considered. Overhangs, long thought to be totally effective for shading south-facing windows, are best at blocking direct sunlight and are therefore only a partial solution.

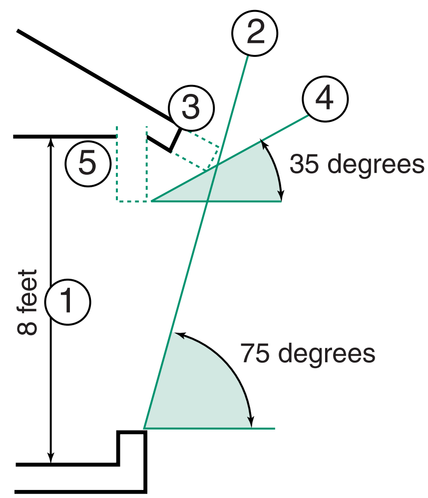
Overhangs

Overhangs shade direct sunlight on windows facing within about 30 degrees of south. Overhangs on east and west windows are ineffective unless they are as long as the window is high.

Overhangs above south-facing windows should provide complete shade for the glazing in midsummer—around July 21—yet still allow access to winter sunlight. For a standard 8-foot wall with windows, the overhang should be 2 to 2½ feet in length. Make certain that there is a gap between the bottom of the overhang and the top of the glazing to prevent shading the upper portion of the glass in winter. Figure 6-9 illustrates a method for sizing overhangs above south-facing windows.

Retractable awnings allow full winter sunlight, yet provide effective summer shading. They should have open sides or vents to prevent accumulation of hot air underneath. Awnings may be more expensive than other shading options, but they serve as an attractive design feature.

Figure 6-9
Guidelines for Overhangs



Size south overhangs using the diagram above and these rules:

1. Draw to scale the wall to be shaded by the overhang.
2. Draw the summer sun angle upward from the bottom of the glazing.
3. Draw the overhang until it intersects the summer sun angle line.
4. Draw the line at the winter sun angle from the bottom edge of the overhang to the wall.
5. Use a solid wall above the line where the winter sun hits. The portion of the wall below that line should be glazed.

Summer and Winter Sun Angles
(Degrees from horizon at noon)

	July 21	January 21
Huntsville	73	33
Birmingham	74	34
Montgomery	75	35
Mobile	76	36

External shades and shutters

Exterior window shading treatments are effective cooling measures because they block both direct and indirect sunlight before it enters windows. Solar shade screens are an excellent exterior shading product with a thick weave that blocks up to 70 percent of all incoming sunlight before it enters the windows. The screens absorb sunlight so they should be used on the outside of the windows. From the outside, they look slightly darker than regular screening, and provide greater privacy. From the inside many people do not detect a difference. Most products also serve as insect screening and come in several colors. They should be removed in winter to allow full sunlight through the windows. A more expensive alternative to the fiberglass product is a thin, louvered metal screen that blocks sunlight, but still allows a view from inside to outside.

Hinged decorative exterior shutters which close over the windows are also excellent shading options. However, they obscure the view, block daylight, can be expensive, are subject to wear and tear, and can be difficult to operate on a daily basis.

Interior shades and shutters

Shutters and shades located inside the house include curtains, roll-down shades, and Venetian blinds. More sophisticated devices, such as shutters that slide over the windows on a track and interior movable insulation, are also available.

Interior shutters and shades are generally the least effective shading measures because they try to block sunlight that has already entered the room. However, if east-, south-, or west-facing windows do not have exterior shading, interior measures are needed. The most effective interior treatments are solid shades with a reflective surface facing outside. In fact, simple white roller blinds keep the house cooler than more expensive louvered blinds, which do not provide a solid surface and allow trapped heat to migrate between the blinds into the house.

Reflective films and tints

Reflective film, which adheres to glass and is found often in commercial buildings, can block up to 85% of incoming sunlight. The film blocks sunlight all year, so it is inappropriate on south windows in passive solar homes. However, it may be practical for unshaded east and west windows. It is not recommended for windows that experience partial shading because as the film absorbs sunlight it may heat the glass unevenly. The uneven heating of windows may break the glass or ruin the seal between double-glazed units.

Table 6-4
Shading Coefficients for
Window Coverings

Type of Covering	Shading Coefficient*
None	0.88
Medium-colored venetian blinds	0.57
Opaque dark shades	0.60
Opaque white shades	0.25
Translucent light shades	0.37
Open weave dark draperies	0.62
Close weave light draperies	0.45

*Lower numbers shade better. The table assumes windows are double-glazed. Source: *ASHRAE Handbook of Fundamentals, 1985.*

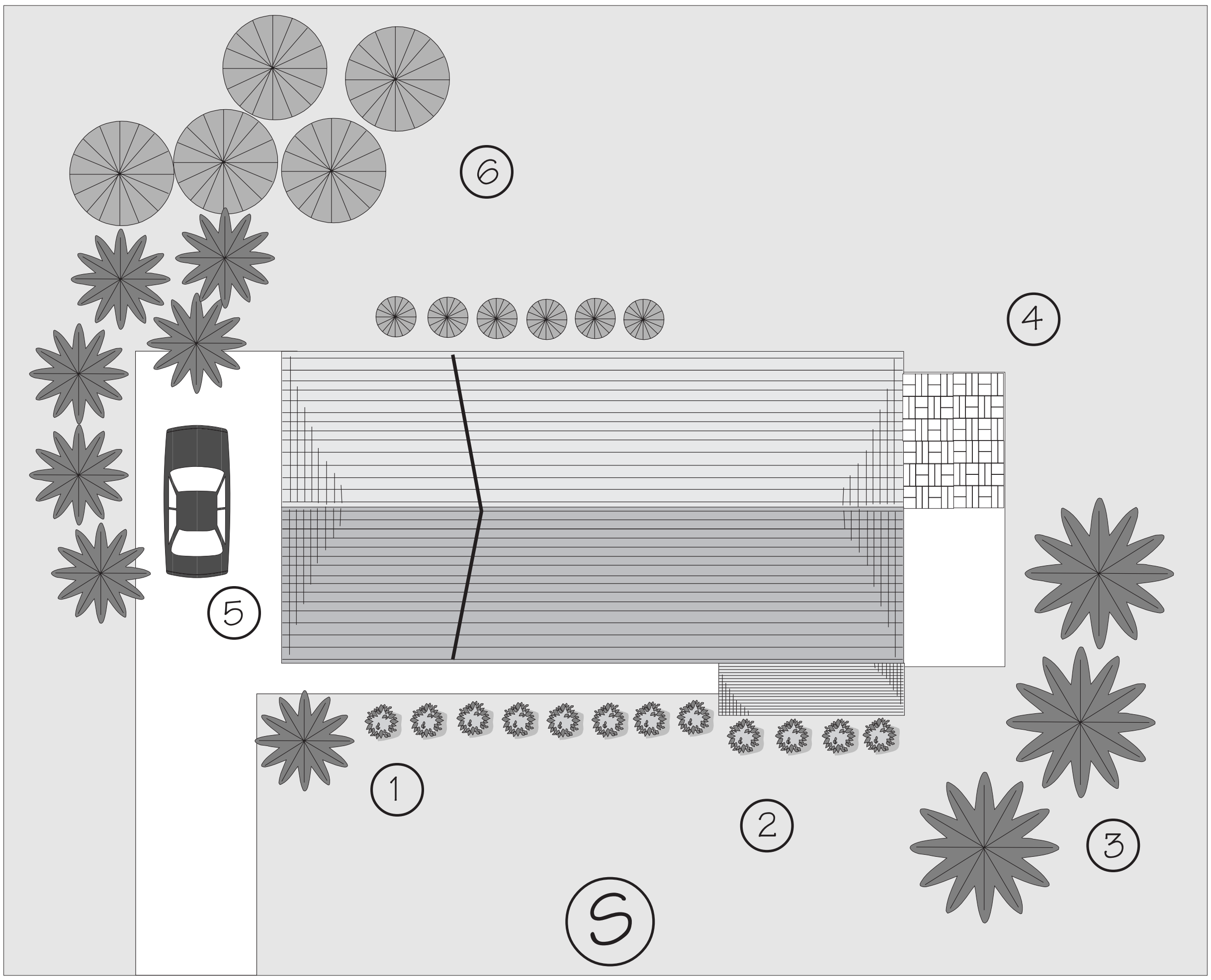
The installed cost of reflective films ranges from $1 to $4 per square foot. Price should not be the sole criterion when selecting an installer—quality is a vital consideration affecting the appearance of the house and the beauty of the view to the outside.

Most window manufacturers offer tinted windows, which block sunlight all year. They can have shading coefficients under .30. The window tints can add color, such as green, amber, rose, or blue to the window. In some cases, the window can have a reflective finish to block additional sunlight. These tints are often inexpensive, costing only $3 to $10 extra per window for many units. However, don't forget that the tint is permanent, so incoming sunlight will be blocked in both summer and winter.

Landscaping and trees

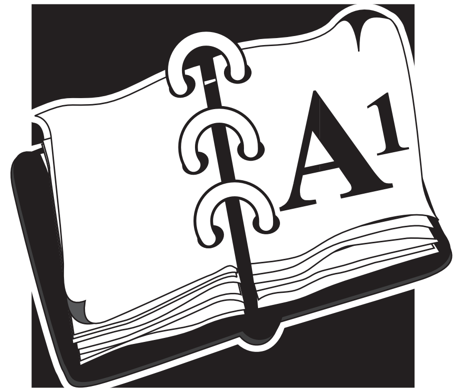
Alabama's abundant trees are wonderful for natural shading, but they must be located appropriately so as to provide shade in summer and not block the winter sun coming from the south. Even deciduous trees that lose their leaves during cold weather block some winter sunlight—a few bare trees can block over 50 percent of the available solar energy. Some guidelines for energy efficient landscaping are shown in Figure 6-10.

Figure 6-10
Landscaping Guidelines



1. Major glass areas are oriented within 20 degrees of south and have overhangs for summer shading.
2. Ground cover reduces reflected sunlight.
3. Deciduous trees shade east, west, southeast, and southwest sides in summer.
4. Trellis with deciduous vine shades east wall.
5. Garage on west blocks summer sun and winter winds.
6. Windbreak of evergreen trees and shrubs to the north buffers winter winds.

Notes:



Appendix 1

Mortgage Rate Tables

The following tables show the monthly payment for principal and interest for a $1,000 loan at various interest rates and amortization periods. For example, a $50,000 loan at 15% with a 25-year amortization period will have monthly payments of $12.81 x 50 = $640.42. This table is useful in comparing different methods of financing construction loans and permanent mortgages and their effect on the economics of energy efficient construction techniques.

Interest Rate

Years of Amortization	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00
1	85.61	85.72	85.84	85.95	86.07	86.18	86.30	86.41	86.53	86.64	86.76	86.87	86.99
2	43.87	43.98	44.10	44.21	44.32	44.43	44.55	44.66	44.77	44.89	45.00	45.11	45.23
3	29.97	30.08	30.20	30.31	30.42	30.54	30.65	30.76	30.88	30.99	31.11	31.22	31.34
4	23.03	23.14	23.26	23.37	23.49	23.60	23.71	23.83	23.95	24.06	24.18	24.30	24.41
5	18.87	18.99	19.10	19.22	19.33	19.45	19.57	19.68	19.80	19.92	20.04	20.16	20.28
6	16.10	16.22	16.34	16.46	16.57	16.69	16.81	16.93	17.05	17.17	17.29	17.41	17.53
7	14.13	14.25	14.37	14.49	14.61	14.73	14.85	14.97	15.09	15.22	15.34	15.46	15.59
8	12.66	12.78	12.90	13.02	13.14	13.26	13.39	13.51	13.63	13.76	13.88	14.01	14.14
9	11.52	11.64	11.76	11.88	12.01	12.13	12.25	12.38	12.51	12.63	12.76	12.89	13.02
10	10.61	10.73	10.85	10.98	11.10	11.23	11.35	11.48	11.61	11.74	11.87	12.00	12.13
11	9.86	9.99	10.11	10.24	10.37	10.49	10.62	10.75	10.88	11.02	11.15	11.28	11.42
12	9.25	9.37	9.50	9.63	9.76	9.89	10.02	10.15	10.28	10.42	10.55	10.69	10.82
13	8.73	8.86	8.99	9.12	9.25	9.38	9.51	9.65	9.78	9.92	10.05	10.19	10.33
14	8.29	8.42	8.55	8.68	8.81	8.95	9.08	9.22	9.35	9.49	9.63	9.77	9.91
15	7.91	8.04	8.17	8.30	8.44	8.57	8.71	8.85	8.99	9.13	9.27	9.41	9.56
17	7.29	7.42	7.56	7.69	7.83	7.97	8.11	8.25	8.40	8.54	8.69	8.83	8.98
20	6.60	6.74	6.88	7.02	7.16	7.31	7.46	7.60	7.75	7.90	8.06	8.21	8.36
25	5.85	5.99	6.14	6.29	6.44	6.60	6.75	6.91	7.07	7.23	7.39	7.55	7.72
30	5.37	5.52	5.68	5.84	6.00	6.16	6.32	6.49	6.65	6.82	6.99	7.16	7.34

Interest Rate

Years of Amortization	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25
1	87.10	87.22	87.34	87.45	87.57	87.68	87.80	87.92	88.03	88.15	88.27	88.38	88.50
2	45.34	45.46	45.57	45.68	45.80	45.91	46.03	46.14	46.26	46.38	46.49	46.61	46.72
3	31.45	31.57	31.68	31.80	31.92	32.03	32.15	32.27	32.38	32.50	32.62	32.74	32.86
4	24.53	24.65	24.77	24.89	25.00	25.12	25.24	25.36	25.48	25.60	25.72	25.85	25.97
5	20.40	20.52	20.64	20.76	20.88	21.00	21.12	21.25	21.37	21.49	21.62	21.74	21.87
6	17.66	17.78	17.90	18.03	18.15	18.27	18.40	18.53	18.65	18.78	18.91	19.03	19.16
7	15.71	15.84	15.96	16.09	16.22	16.34	16.47	16.60	16.73	16.86	16.99	17.12	17.25
8	14.26	14.39	14.52	14.65	14.78	14.91	15.04	15.17	15.31	15.44	15.57	15.71	15.84
9	13.15	13.28	13.41	13.54	13.68	13.81	13.94	14.08	14.21	14.35	14.49	14.63	14.76
10	12.27	12.40	12.53	12.67	12.80	12.94	13.08	13.22	13.35	13.49	13.63	13.78	13.92
11	11.55	11.69	11.82	11.96	12.10	12.24	12.38	12.52	12.66	12.80	12.95	13.09	13.24
12	10.96	11.10	11.24	11.38	11.52	11.66	11.81	11.95	12.10	12.24	12.39	12.54	12.68
13	10.47	10.61	10.75	10.90	11.04	11.19	11.33	11.48	11.63	11.78	11.92	12.08	12.23
14	10.06	10.20	10.34	10.49	10.64	10.78	10.93	11.08	11.23	11.38	11.54	11.69	11.85
15	9.70	9.85	9.99	10.14	10.29	10.44	10.59	10.75	10.90	11.05	11.21	11.37	11.52
17	9.13	9.28	9.43	9.59	9.74	9.90	10.05	10.21	10.37	10.53	10.69	10.85	11.02
20	8.52	8.68	8.84	9.00	9.16	9.32	9.49	9.65	9.82	9.98	10.15	10.32	10.49
25	7.88	8.05	8.22	8.39	8.56	8.74	8.91	9.09	9.26	9.44	9.62	9.80	9.98
30	7.51	7.69	7.87	8.05	8.23	8.41	8.59	8.78	8.96	9.15	9.33	9.52	9.71

Interest Rate

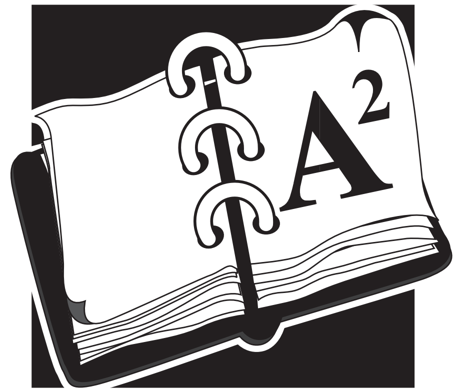
Years of Amortization	11.50	11.75	12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50
1	88.62	88.73	88.85	88.97	89.08	89.20	89.32	89.43	89.55	89.67	89.79	89.90	90.02
2	46.84	46.96	47.07	47.19	47.31	47.42	47.54	47.66	47.78	47.89	48.01	48.13	48.25
3	32.98	33.10	33.21	33.33	33.45	33.57	33.69	33.81	33.94	34.06	34.18	34.30	34.42
4	26.09	26.21	26.33	26.46	26.58	26.70	26.83	26.95	27.08	27.20	27.33	27.45	27.58
5	21.99	22.12	22.24	22.37	22.50	22.63	22.75	22.88	23.01	23.14	23.27	23.40	23.53
6	19.29	19.42	19.55	19.68	19.81	19.94	20.07	20.21	20.34	20.47	20.61	20.74	20.87
7	17.39	17.52	17.65	17.79	17.92	18.06	18.19	18.33	18.46	18.60	18.74	18.88	19.02
8	15.98	16.12	16.25	16.39	16.53	16.67	16.81	16.95	17.09	17.23	17.37	17.51	17.66
9	14.90	15.04	15.18	15.33	15.47	15.61	15.75	15.90	16.04	16.19	16.33	16.48	16.63
10	14.06	14.20	14.35	14.49	14.64	14.78	14.93	15.08	15.23	15.38	15.53	15.68	15.83
11	13.38	13.53	13.68	13.83	13.98	14.13	14.28	14.43	14.58	14.73	14.89	15.04	15.20
12	12.83	12.98	13.13	13.29	13.44	13.59	13.75	13.90	14.06	14.21	14.37	14.53	14.69
13	12.38	12.53	12.69	12.84	13.00	13.15	13.31	13.47	13.63	13.79	13.95	14.11	14.28
14	12.00	12.16	12.31	12.47	12.63	12.79	12.95	13.11	13.28	13.44	13.60	13.77	13.94
15	11.68	11.84	12.00	12.16	12.33	12.49	12.65	12.82	12.98	13.15	13.32	13.49	13.66
17	11.18	11.35	11.51	11.68	11.85	12.02	12.19	12.36	12.53	12.70	12.87	13.05	13.22
20	10.66	10.84	11.01	11.19	11.36	11.54	11.72	11.89	12.07	12.25	12.44	12.62	12.80
25	10.16	10.35	10.53	10.72	10.90	11.09	11.28	11.47	11.66	11.85	12.04	12.23	12.42
30	9.90	10.09	10.29	10.48	10.67	10.87	11.06	11.26	11.45	11.65	11.85	12.05	12.25

Interest Rate

Years of Amortization	14.75	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75	17.00	17.25	17.50	17.75
1	90.14	90.26	90.38	90.49	90.61	90.73	90.85	90.97	91.09	91.20	91.32	91.44	91.56
2	48.37	48.49	48.61	48.72	48.84	48.96	49.08	49.20	49.32	49.44	49.56	49.68	49.80
3	34.54	34.67	34.79	34.91	35.03	35.16	35.28	35.40	35.53	35.65	35.78	35.90	36.03
4	27.70	27.83	27.96	28.08	28.21	28.34	28.47	28.60	28.73	28.86	28.98	29.11	29.24
5	23.66	23.79	23.92	24.05	24.19	24.32	24.45	24.58	24.72	24.85	24.99	25.12	25.26
6	21.01	21.15	21.28	21.42	21.55	21.69	21.83	21.97	22.11	22.25	22.39	22.53	22.67
7	19.16	19.30	19.44	19.58	19.72	19.86	20.00	20.15	20.29	20.44	20.58	20.73	20.87
8	17.80	17.95	18.09	18.24	18.38	18.53	18.68	18.82	18.97	19.12	19.27	19.42	19.57
9	16.78	16.92	17.07	17.22	17.37	17.53	17.68	17.83	17.98	18.14	18.29	18.45	18.60
10	15.98	16.13	16.29	16.44	16.60	16.75	16.91	17.06	17.22	17.38	17.54	17.70	17.86
11	15.35	15.51	15.67	15.82	15.98	16.14	16.30	16.46	16.63	16.79	16.95	17.11	17.28
12	14.85	15.01	15.17	15.33	15.49	15.66	15.82	15.99	16.15	16.32	16.49	16.65	16.82
13	14.44	14.60	14.77	14.93	15.10	15.27	15.43	15.60	15.77	15.94	16.11	16.29	16.46
14	14.10	14.27	14.44	14.61	14.78	14.95	15.12	15.29	15.46	15.64	15.81	15.99	16.16
15	13.83	14.00	14.17	14.34	14.51	14.69	14.86	15.04	15.21	15.39	15.57	15.75	15.92
17	13.40	13.58	13.75	13.93	14.11	14.29	14.47	14.65	14.84	15.02	15.20	15.39	15.57
20	12.98	13.17	13.35	13.54	13.73	13.91	14.10	14.29	14.48	14.67	14.86	15.05	15.24
25	12.61	12.81	13.00	13.20	13.39	13.59	13.79	13.98	14.18	14.38	14.58	14.78	14.97
30	12.44	12.64	12.84	13.05	13.25	13.45	13.65	13.85	14.05	14.26	14.46	14.66	14.8

Years of Amortization	16.50	16.75	17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50
	Interest Rate												
1	90.97	91.09	91.20	91.32	91.44	91.56	91.68	91.80	91.92	92.04	92.16	92.28	92.40
2	49.20	49.32	49.44	49.56	49.68	49.80	49.92	50.04	50.17	50.29	50.41	50.53	50.65
3	35.40	35.53	35.65	35.78	35.90	36.03	36.15	36.28	36.40	36.53	36.66	36.78	36.91
4	28.60	28.73	28.86	28.98	29.11	29.24	29.37	29.51	29.64	29.77	29.90	30.03	30.16
5	24.58	24.72	24.85	24.99	25.12	25.26	25.39	25.53	25.67	25.80	25.94	26.08	26.22
6	21.97	22.11	22.25	22.39	22.53	22.67	22.81	22.95	23.09	23.23	23.38	23.52	23.66
7	20.15	20.29	20.44	20.58	20.73	20.87	21.02	21.16	21.31	21.46	21.61	21.76	21.91
8	18.82	18.97	19.12	19.27	19.42	19.57	19.72	19.88	20.03	20.18	20.33	20.49	20.64
9	17.83	17.98	18.14	18.29	18.45	18.60	18.76	18.91	19.07	19.23	19.39	19.55	19.71
10	17.06	17.22	17.38	17.54	17.70	17.86	18.02	18.18	18.34	18.50	18.67	18.83	19.00
11	16.46	16.63	16.79	16.95	17.11	17.28	17.44	17.61	17.78	17.94	18.11	18.28	18.45
12	15.99	16.15	16.32	16.49	16.65	16.82	16.99	17.16	17.33	17.50	17.67	17.85	18.02
13	15.60	15.77	15.94	16.11	16.29	16.46	16.63	16.80	16.98	17.15	17.33	17.50	17.68
14	15.29	15.46	15.64	15.81	15.99	16.16	16.34	16.52	16.69	16.87	17.05	17.23	17.41
15	15.04	15.21	15.39	15.57	15.75	15.92	16.10	16.28	16.47	16.65	16.83	17.01	17.19
17	14.65	14.84	15.02	15.20	15.39	15.57	15.76	15.94	16.13	16.32	16.50	16.69	16.88
20	14.29	14.48	14.67	14.86	15.05	15.24	15.43	15.63	15.82	16.01	16.21	16.40	16.60
25	13.98	14.18	14.38	14.58	14.78	14.97	15.17	15.37	15.57	15.78	15.98	16.18	16.38
30	13.85	14.05	14.26	14.46	14.66	14.87	15.07	15.28	15.48	15.68	15.89	16.09	16.30

Years of Amortization	19.75	20.00	20.25	20.50	20.75	21.00	21.25	21.50	21.75	22.00	22.25	22.50	22.75
	Interest Rate												
1	92.51	92.63	92.75	92.87	92.99	93.11	93.23	93.35	93.47	93.59	93.71	93.84	93.96
2	50.77	50.90	51.02	51.14	51.26	51.39	51.51	51.63	51.75	51.88	52.00	52.13	52.25
3	37.04	37.16	37.29	37.42	37.55	37.68	37.80	37.93	38.06	38.19	38.32	38.45	38.58
4	30.30	30.43	30.56	30.70	30.83	30.97	31.10	31.24	31.37	31.51	31.64	31.78	31.91
5	26.35	26.49	26.63	26.77	26.91	27.05	27.19	27.34	27.48	27.62	27.76	27.90	28.05
6	23.81	23.95	24.10	24.24	24.39	24.54	24.68	24.83	24.98	25.13	25.27	25.42	25.57
7	22.06	22.21	22.36	22.51	22.66	22.81	22.96	23.12	23.27	23.43	23.58	23.74	23.89
8	20.80	20.95	21.11	21.27	21.42	21.58	21.74	21.90	22.06	22.22	22.38	22.54	22.70
9	19.87	20.03	20.19	20.35	20.51	20.67	20.84	21.00	21.17	21.33	21.50	21.66	21.83
10	19.16	19.33	19.49	19.66	19.83	19.99	20.16	20.33	20.50	20.67	20.84	21.01	21.18
11	18.62	18.79	18.96	19.13	19.30	19.47	19.64	19.82	19.99	20.17	20.34	20.52	20.69
12	18.19	18.37	18.54	18.72	18.89	19.07	19.24	19.42	19.60	19.78	19.96	20.14	20.32
13	17.86	18.04	18.21	18.39	18.57	18.75	18.93	19.11	19.30	19.48	19.66	19.84	20.03
14	17.59	17.77	17.95	18.14	18.32	18.50	18.69	18.87	19.06	19.24	19.43	19.62	19.80
15	17.38	17.56	17.75	17.93	18.12	18.31	18.49	18.68	18.87	19.06	19.25	19.44	19.63
17	17.07	17.26	17.45	17.64	17.83	18.02	18.22	18.41	18.60	18.80	18.99	19.18	19.38
20	16.79	16.99	17.18	17.38	17.58	17.78	17.97	18.17	18.37	18.57	18.77	18.97	19.17
25	16.58	16.78	16.99	17.19	17.39	17.60	17.80	18.00	18.21	18.41	18.62	18.82	19.03
30	16.50	16.71	16.92	17.12	17.33	17.53	17.74	17.95	18.15	18.36	18.57	18.77	18.98



Appendix 2
Fingertip Facts

This section contains statistical energy information—conversion factors, R-values, fuel prices, energy efficiency recommendations, and climatic data for Alabama. It serves as a reference guide for those seeking a quick answer to an energy question.

Abbreviations

Btu	British Thermal Unit, the amount of heat needed to increase the temperature of one pound of water one degree Fahrenheit (about the amount of heat released when a kitchen match burns)
1° F	one degree Fahrenheit
MMBtu	million Btu
kWh	kilowatt-hour
kW	kilowatt
cf	cubic foot
cfm	cubic foot per minute
bbl	barrel
gal	gallon

Energy and Fuel Data

Energy Units

1 kWh = 3,412 Btu
1 MMBtu = 293 kwh
1 Btu = 252 calories
1 Btu = 1,055 joules

Power Units

1 watt = 3.412 Btu/hour
1 kW = 3,412 Btu/hour
1 horsepower = 746 watts
1 ton of cooling = 12,000 Btu/hour

Fuel Units

1 cf of natural gas $\simeq$ 1,000 Btu
1 therm = 100,000 Btu
1 bbl fuel oil = 42 gallons
1 bbl fuel oil = 5.8 MMBtu
1 ton fuel oil = 6.8 bbl
1 gallon fuel oil = 136,000 Btu
1 gallon propane = 91,500 Btu
1 ton bituminous (Eastern) coal = 21–26 MMBtu
1 ton sub-bituminous (Western) coal = 14–18 MMBtu
1 cord wood = 128 cubic feet (4 ft x 4 ft x 8 ft)
1 cord dried oak = 23.9 MMBtu
1 cord dried pine = 14.2 MMBtu

Heating Degree Days and Cooling Hours

Heating Degree Days (HDD) are a measure of how cold a location is in winter.

Cooling Degree Days (CDD) are a measure of how hot a climate is in summer.

HVAC Equipment Efficiencies

Annual Fuel Utilization Efficiency (AFUE)
shows the average annual efficiency at which fuel-burning furnaces operate.

Coefficient of Performance (COP)
measures how many units of heating or cooling are delivered for every unit of electricity used in a heat pump or air conditioner.

Heating Season Performance Factor (HSPF)
measures the average number of Btu of heating delivered for every watt-hour of electricity used by a heat pump.

Seasonal Energy Efficiency Ratio (SEER)
measures how readily air conditioners convert electricity into cooling—a SEER of 10 means the unit provides 10 Btu's of cooling per watt-hour of electricity.

Insulating Values

The R-value is the measure of resistance to heat flow via conduction. R-values vary according to specific materials and installation.

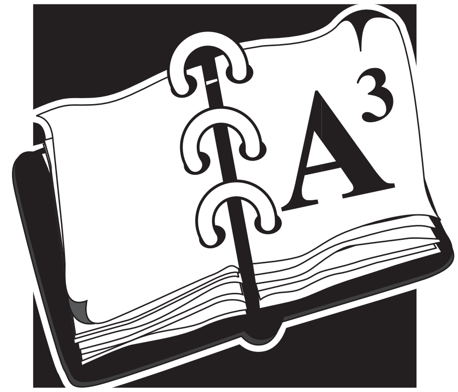
Insulation	R-value per inch
Fiberglass batts/rolls	3.2
Fiberglass loose-fill	2.2
Rockwool loose-fill	2.6
Cellulose	3.7
Vermiculite	2.1
Perlite	3.3

Rigid Insulation Boards	R-value per inch
Fiberboard sheathing (noninsulating blackboard)	2.6
Expanded polystyrene (beadboard)	4.0
Extruded polystyrene	5.0
Polyisocyanurate and polyurethane	7.2

Building Materials	R-value per inch
Drywall	.9
Wood siding	.9 to 1.2
Common brick	.2
Lumber and siding	
Hardwood	.8 to .94
Softwood	.9 to 1.5
Plywood	1.3
Particle Board (medium density)	1.1
Asbestos-cement (entire shingle)	.21

Building Materials	Total R-value
Concrete block (entire block)	
Unfilled	1.1
Filled with vermiculite/perlite	4.6
Filled with cement mortar	1.8

Dead Air Spaces	R-value of air space
1/2-inch	.75
3/4-inch	.77
3–1/2-inch	.80
3–1/2-inch, reflecting surface on one side	1.6
3–1/2-inch, reflecting surface both sides	2.2



Appendix 3

Resources

Resources

Sustainable Building

- American Council for an Energy Efficient Economy (ACE[3])
  1001 Connecticut Avenue, NW, Suite 801
  Washington, DC 20036
  Research and Conferences: 202-429-8873
  Publications: 202-429-0063
  www.aceee.org
- Center for Resourceful Building Technology
  P.O. Box 100
  Missoula, MT 59806
  406-549-7678
  www.crbt.org
- Efficient Windows Collaborative
  Alliance to Save Energy
  1200 18th Street N.W., Suite 900
  Washington, DC 20036
  202-857-0666
  www.efficientwindows.org/
- *Energy Design Update*
  Cutter Information Corp.
  37 Broadway, Suite 1
  Arlington, MA 02174-5539
  800-964-5125
  www.cutter.com
- Energy and Environmental Building Association (EEBA)
  490 Concordia Avenue
  St. Paul, MN 55103-2441
  651-268-7585
  www.eeba.org
- Energy Efficient Lighting Association
  P.O. Box 727
  Princeton Junction, NJ 08550
  609-799-4900
- ENERGY STAR Program
  U.S. Environmental Protection Agency
  Atmospheric Pollution Program Division
  401 M St, SW (6202J)
  Washington, DC 20460
  202-564-9190 or 888-STAR-YES
  www.epa.gov/homes (residential)
  www.epa.gov/buildings (commercial)
  www.energystar.gov
- *Environmental Building News*
  E Build, Inc.
  122 Birge St., Suite 30
  Brattleboro, VT 05301
  802-257-7300
  www.buildinggreen.org
- *Home Energy*
  Energy Auditor and Retrofitter, Inc.
  2124 Kittredge Street #95
  Berkley, CA 94704
  510-524-5405
  www.homeenergy.org
- *Journal of Light Construction*
  Builderburg Partners, Ltd.
  932 West Main St.
  Richmond, VT 05477
  802-434-4747
  www.jlconline.com
- Lighting Research Center
  Rensselaer Polytechnic Institute
  110 8th Street
  Watervliet Facility
  Troy, NY 12180
  518-276-8716
- National Association of Home Builders Research Center
  400 Prince George's Boulevard
  Upper Marlboro, MD 20774
  301-249-4000
  www.nahbrc.com
- National Fenestration Rating Council (NFRC)
  1300 Spring St., Suite 500
  Silver Spring, MD 20910
  301-589-NFRC
  www.nfrc.org

- Oak Ridge National Laboratory
  Buildings Technology Center, Building Envelope Research
  P. O. Box 2008, MS 6070
  Oak Ridge, TN 37831-6070
  423-574-0022
  www.ornl.gov/roofs + walls/
- Southface Energy Institute, Inc.
  241 Pine Street
  Atlanta, GA 30308
  404-872-3549
  www.southface.org
- Sustainable Building Industry Council
  (formerly Passive Solar Industries Council)
  1331 H Street, Suite 1000
  Washington, DC 20005
  202-628-7400
  www.sbicouncil.org
- U.S. Department of Energy
  Energy Efficiency and Renewable Energy Clearinghouse (EREC)
  P.O. Box 3048
  Merrifield, VA 22116
  800-363-3732
  www.eren.doe.gov
- U.S. Department of Energy Office of Codes and Standards
  (energy efficient appliances)
  www.eren.doe.gov/buildings/consumer_information/index.html

Energy Codes

- U.S. DOE
  Building Standards & Guidelines Program (BSGP)
  1-800-270-CODE (2633)
  www.energycodes.org
- Alabama Department of Economic and Community Affairs
  Science, Technology and Energy Division
  334-242-5290
  www.adeca.alabama.gov

Home Energy Rating Systems (HERS) and Energy Efficient Mortgages

In April 1995, the National Association of State Energy Officials and Energy Rated Homes of America founded the Residential Energy Services Network (RESNET) to develop a national market for home energy rating systems and energy efficient mortgages. RESNET's activities are guided by a mortgage industry steering committee composed of the leading national mortgage executives.

Go to www.natresnet.org to view information on:

- Home energy ratings
  www.natresnet.org/herseems/default.htm
- Energy efficient mortages www.natresnet.org/herseems/default.htm
- List of Alabama certified home energy raters
  www.natresnet.org/dir/raters/Alabama.htm
- List of Alabama financing programs
  www.natresnet.org/dir/lenders/Alabama.htm

Radon

- U.S. EPA National Safety Council
  (call for test kits and general information)
  1-800-767-7236
- NEHA-certified Radon Testers and Mitigators
  1-800-269-4174
  www.radongas.org

Notes:

Alabama Department of Economic and Community Affairs
Science, Technology and Energy Division
401 Adams Avenue
P.O. Box 5690
Montgomery, AL 36103-5690
(334)242-5290
www.adeca.alabama.gov