CHAPTER 31

Thermal & Acoustical Insulation

Section 31.1
Thermal Insulation

Section 31.2
Acoustical Insulation

Chapter Objectives

After completing this chapter, you will be able to:

- **Identify** several types and forms of insulation.
- **Describe** how an insulator's R-value determines its effectiveness as insulation.
- **Define** the main function of insulation.
- **Identify** the best uses for common types of insulating materials.
- **Explain** the importance of vapor retarders and ventilation.
- **Describe** several types of wall construction that reduce noise transmission.

Discuss the Photo

Insulation The individual in the photo is installing insulation. *What purposes can you think of for installing insulation?*

Writing Activity: Write a Letter

New methods are being designed to reduce heating and cooling costs. Write a one-page letter to a local builder asking about the newest techniques for insulating new homes. In your letter, introduce yourself and be clear about what information you are requesting. Proofread your letter to correct any errors.

Dana Neely/Getty Images

Chapter 31 Reading Guide

Before You Read Preview

Different regions require different types of insulation. Before reading this chapter, write down which U.S. regions you would expect to place a high priority on insulation. After you have read the chapter carefully, revisit your answers and correct them if necessary.

Content Vocabulary

- thermal insulation
- R-value
- building envelope
- batt
- condensation
- vapor retarder
- radiant heat
- emissivity
- acoustic insulation
- Sound Transmission Class (STC)
- Impact Noise Rating (INR)

Academic Vocabulary

You will find these words in your reading and on your tests. Use the academic vocabulary glossary to look up their definitions if necessary.

- byproduct
- expands
- flexible

Graphic Organizer

As you read, use a chart like the one shown to identify issues and their solutions.

Issues	Solutions
How do I determine the right type of insulation for a home in a given location?	Consider the climate, the R-value of the insulation, and how the house is constructed.

Go to **glencoe.com** for this book's OLC for a downloadable version of this graphic organizer.

Academic Standards

Mathematics

Number and Operations: Understand meanings of operations and how they relate to one another (NCTM)

Algebra: Represent and analyze mathematical situations and structures using algebraic symbols (NCTM)

English Language Arts

Use written language to communicate effectively (NCTE 4)

Science

Physical Science: Structure and properties of matter (NSES)

Physical Science: Interactions of energy and matter (NSES)

Earth and Space Science: Energy in the earth system (NSES)

Industry Standards

Insulation and Ventilation

Moisture and Thermal Protection

NCTE National Council of Teachers of English
NCTM National Council of Teachers of Mathematics
NSES National Science Education Standards

Section 31.1

Thermal Insulation

Insulation Basics

Why do U.S. building codes divide the country into zones?

Insulation is any material that slows the transmission of heat, sound, or electricity. Different uses require specific types of material. For example, the material that insulates electrical wires would not be suitable for insulating walls. Sound insulation is not necessarily effective at slowing heat loss.

This chapter will cover primarily thermal insulation. **Thermal insulation** slows the transmission of heat through walls, floors, and ceilings. Acoustical (sound) insulation is discussed in Section 31.2.

Properties of Thermal Insulation

Thermal insulation increases the comfort of home occupants. It also reduces the cost of utilities by heating or cooling climate.

Heating Climate Smaller, less expensive furnaces are required and less energy or fuel is needed to maintain a certain temperature level.

Cooling Climate A properly insulated house can be served by smaller, less expensive cooling equipment. In addition, less electricity is needed to maintain a house at comfortable temperature levels.

Most building materials and even the air space between studs have some insulating properties, as shown in **Table 31-1**. However, to meet current standards for energy efficiency, additional insulation is needed. The amount of thermal insulation required in a house varies greatly by region. Houses in mild climates need less insulation, while houses in severe climates need more.

Materials are rated according to their insulating abilities. The most common method is to rate materials according to R-value.

R-value is a measure of a material's ability to resist heat transmission. R-value varies according to a material's thickness, but it is cumulative. For example, one type of insulation might have a value of R-5 per inch. Two inches would have a total R-value of R-10. This is why R-value figures are often given per inch of material thickness.

When choosing the type and amount of insulation, climate is the primary factor to consider. The map in **Figure 31-1** shows the lowest temperatures throughout the continental United States during an average winter. Such information is useful in figuring the amount of insulation needed for walls, ceilings, and floors. Generally, local codes specify the minimum amount of insulation required.

Reading Check

Explain *What does R-value measure?*

Table 31-1: Thermal Properties of Various Building Materials per Inch of Thickness

Material	Thermal Resistance (R)
Wood	1.25
Air space[a]	0.97
Cinder block	0.28
Common brick	0.20
Face brick	0.11
Concrete (sand and gravel)	0.08
Stone (lime or sand)	0.08
Steel	0.0031
Aluminum	0.00070

[a] Thermal properties apply to air spaces ranging from ¾ inch to 4 inches in thickness.

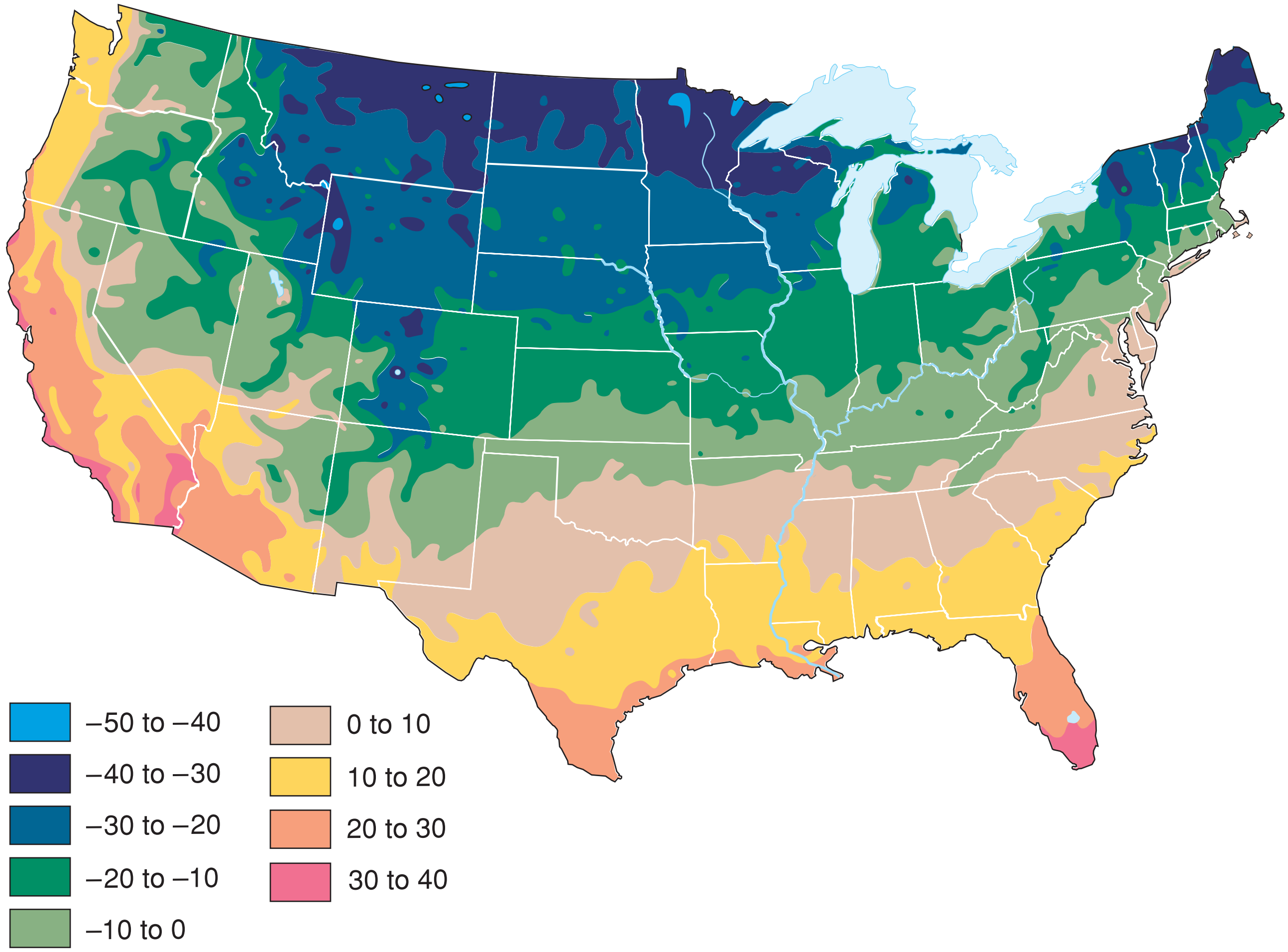


Figure 31-1 Lowest Temperatures

Coldest Regions This map of the continental United States indicates the lowest temperature (°F) occurring in each zone during an average winter.

The IRC identifies different climate zones as a way of identifying the amount of insulation various areas need. The 2006 IRC divides the United States into eight climate zones, as shown in **Figure 31-2** on page 896. The edges of the zones are defined by county lines. The map also identifies four climate types: Marine, Dry, Moist, and Warm-Humid. These regions influence the way insulation and related building components are installed. Compare Figure 31-1 to Figure 31-2 to see how the climate of an area relates to the zone map.

In each of the new zones, a minimum amount of insulation is required, as shown in **Table 31-2** on page 896. It is important to understand that the code identifies the *minimum* amount of insulation required in a house. A builder can increase insulation levels above the minimum amounts required. In fact, many builders participate in national, local, and state programs that certify above-code homes. These homes are especially energy-efficient.

Where to Insulate

To reduce heat loss during cold weather in most climates, all walls, ceilings, roofs, and floors that separate heated from unheated spaces should be insulated. This continuous layer of insulation is referred to as the **building envelope**. Everything inside the building envelope will be heated and/or cooled. Everything outside the envelope is exposed to outdoor temperatures.

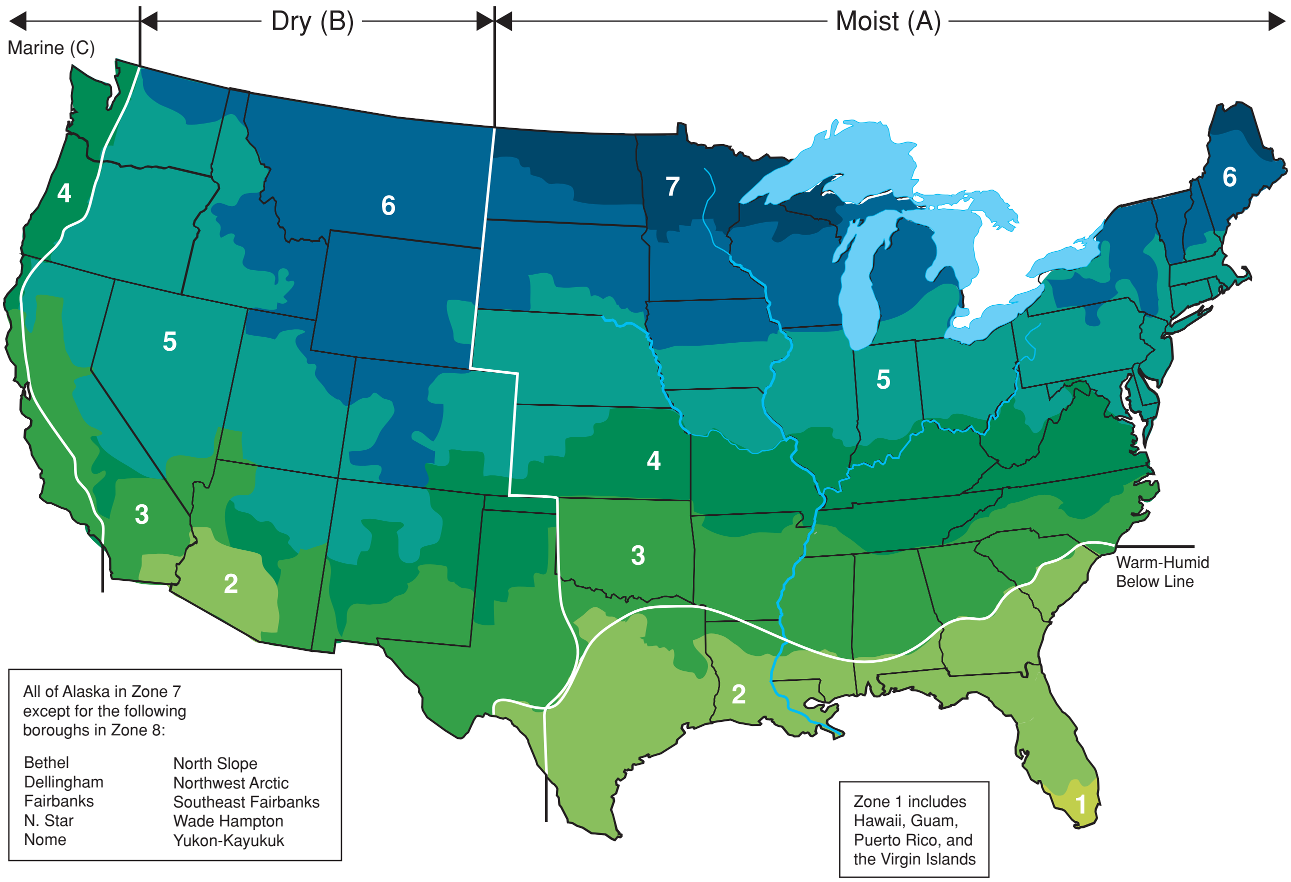


Figure 31-2 Climate Zone Map

Eight Zones The 2006 IRC climate zone map. Each zone requires a certain minimum amount of thermal insulation.

Table 31-2: Insulation and Fenestration Requirements by Component [a]

Climate Zone	Ceiling R-Value	Wood Frame Wall R-Value	Floor R-Value	Basement[b] Wall R-Value	Slab[c] R-Value and Depth
1	30	13	13	0	0
2	30	13	13	0	0
3	30	13	19	0	0
4 except Marine	38	13	19	10/13	10, 2ft
5 and Marine 4	38	19 or 13 + 5[e]	30[d]	10/13	10, 2ft
6	49	19 or 13 + 5[e]	30[d]	10/13	10, 4ft
7 and 8	49	21	30[d]	10/13	10, 4ft

[a] R-values are minimums. R-19 insulation shall be permitted to be compressed into a 2×6 cavity.
[b] The first R-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.
[c] R-5 shall be added to the required slab edge R-values for heated slabs.
[d] Or insulation sufficient to fill the framing cavity. R-19 minimum.
[e] "13 + 5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25% or less of the exterior, R-5 sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25% of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.

Types of Insulation

What types of insulation would be hardest to seal against wall studs?

Insulation is manufactured in a variety of types. Each type has advantages for specific uses. The basic types are batts and loose-fill, rigid sheet, and spray-foam insulation. There are also hybrid insulation systems that use materials and installation techniques that do not fit neatly into any single category.

Batts and Blankets

The most common type of insulation used in houses comes in the form of a batt. A **batt** is any thick insulation material that comes in precut widths designed to fit between framing members. Extra-wide batts designed to cover large areas of an attic are sometimes called *blankets*. Batts and blankets are packaged in compressed bundles or rolls. Each product must be cut to length on site. Batts and blankets come in different thicknesses and widths. Material intended for a standard 2×4 wall, for example, will be 15" wide and 3½" thick. This allows it to fit the wall cavity formed by studs spaced 16" OC. The cavities are actually 14½" wide, but batt insulation is slightly wider than this to make up for slight variations in stud position. The extra width also ensures a snug fit against the sides of the studs. Batts are also available for other OC spacings and wall thicknesses.

Materials The most common material for batts and blankets is fiberglass. Fiberglass insulation is made of natural ingredients such as sand and recycled glass. The materials are melted and formed into thin strands. When matted together, the strands are sometimes referred to as *glass wool.* Fiberglass insulation sometimes has a kraft paper facing on one side, as shown in **Figure 31-3**. Continuous tabs on the sides of the facing allow the batts to be stapled to studs or joists. The facing also serves as a vapor retarder, which will be discussed later in this section. Batts and blankets are also available without a kraft paper facing. *Unfaced insulation,* sometimes referred to as *friction-fit insulation,* is simply pressed into the wall cavities and not stapled. If this is done, 4-mil thick plastic film must be stapled over the walls to serve as a vapor retarder. As an alternative to fiberglass, batts can be made from recycled cotton, natural wool, and rock wool (a fibrous material made from molten stone and slag, a **byproduct** of steel making). Cotton and natural wool must be chemically treated to improve resistance to fire, mold, and rodents.

Figure 31-3 Batt Insulation

Common Choice Fiberglass insulation in blankets and batts is the most common type used in residential construction.

R-Value Fiberglass insulation has a value of about R-3 per inch. Low-density batts intended to insulate 2×4 walls, for example, are usually rated R-11; high-density batts are rated R-15. Low-density batts intended for 2×6 walls are rated R-19; high-density batts are rated R-21. Blankets intended for floors and ceilings may be rated as high as R-38. The R-value of cotton and natural wool insulation is similar to fiberglass. The R-value of rock wool is slightly higher than fiberglass. The higher the R-value, the better a material insulates.

Loose-Fill Insulation

Loose-fill insulation consists of materials that are usually supplied in bags or bales. Depending on where it will be installed, the material can be poured into place manually or blown into place using specialized pumping equipment. In an attic, blowing insulation over the joists covers a large area quickly. Loose-fill insulation is often used in attic floors where HVAC pipes and wiring make it difficult to install blanket insulation. It can also be pumped into the walls of older houses that were not insulated during construction. This involves drilling holes through the siding. In new construction, loose-fill can also be installed into open wall cavities. The technique calls for installing a special membrane over the studs. The loose fill can be blown through the membrane and into the wall cavities.

Materials and R-Value Materials used include shredded fiberglass, rock wool, and cellulose-based products. Cellulose-based products are made primarily from recycled paper, and must be treated with chemicals to make them insect and fire resistant. Because loose-fill materials can be applied in various thicknesses, their R-value is typically given per inch. Multiply the R-value per inch by the thickness of the installation to get an overall R-value. The approximate R-values for each material are:

- Fiberglass: R-2.5 per inch
- Rock wool: R-3.2 per inch
- Cellulose: R-3.5 per inch.

Rigid Insulation

Rigid insulation is manufactured in various sizes and thicknesses of solid panels. They are often 4 ft. by 8 ft. in size. Panels often have a reflective surface on one side. These thin panels pack more R-value into a smaller space than most other types of insulation. Rigid insulation is sometimes used as a nonstructural sheathing on walls during construction, as shown in **Figure 31-4**. It also serves as a substrate for other materials. Some types of rigid insulation are suitable for use below grade for the exterior surfaces of basement walls.

Figure 31-4 Rigid Insulation
Insulating Layer Rigid insulation can be applied to the outside of a house prior to the installation of the siding. All seams should be sealed with aluminized tape.

Jim West/Photoedit

Materials and R-Value Rigid insulation is made from one of the following materials:

Expanded Polystyrene (EPS) Polystyrene is formed into beads that puff up when exposed to steam. The beads are then molded into blocks of insulation and sliced into sheets. EPS is rated from R-3.6 to R-4.2 per inch.

Extruded Expanded Polystyrene (XEPS, sometimes called XPS) This material is similar to EPS but has greater compressive strength for use as foundation insulation below grade. It is rated at R-5 per inch.

Polyurethane and Polyisocyanurate These materials are often faced with foil to slow the loss of the blowing agent used in their manufacture. They are rated at R-5.6 per inch.

Spray-Foam Insulation

Spray-foam insulation is made from material that **expands** as it is installed. It is sprayed into open wall and ceiling cavities as a wet material, as shown in **Figure 31-5**. Once exposed to air, the material foams rapidly to fill the cavity. The amount of expansion can be a hundredfold or more. After the material expands, it typically solidifies within an hour. The exact amount of expansion is difficult to control, so excess material must be sliced off flush with the surface of the framing once the insulation hardens. The shavings are then collected and recycled. Because spray-foam insulation is applied as a liquid and then expands, it seals and fills small gaps and seals cavities much better than other types of insulation.

Materials and R-Value Spray foam is available in various formulations. Slow-curing types are designed to flow over and around obstructions before curing. Open-cell foam allows moisture to pass through the cured material. Closed-cell foam allows very little moisture to pass through the cured material. Materials used for foam include polyisocyanurate, polyurethane, and cementitious products made from minerals extracted from seawater. R-values range from approximately R-3.9 per inch for cementitious products to as much as R-8 for the other types.

Hybrid Insulation Systems

The importance of thermal insulation increases as the cost of electricity and heating fuels rises. Some insulation materials and methods combine aspects of the four basic insulation types noted above.

Wet-Spray Insulation Loose-fill materials such as cellulose or fiberglass can be mixed with water and sprayed into wall cavities. An adhesive is sometimes mixed in to help the material stick to surfaces. Once the moisture content of the insulation drops to less than 19 percent, it can be covered with drywall. Drying takes at least 24 hours.

Combined Insulation Some builders spray a 1"-thick layer of spray-foam insulation over wall cavities to fill gaps, then install fiberglass batt insulation in the cavities once the foam cures.

Figure 31-5 Spray-Foam Insulation
Superb Sealer Spray-foam insulation expands to fill gaps and seals the areas between framing members.

Controlling Moisture

Where might you see condensation on a hot, humid day?

Insulation is used to maintain comfortable temperatures within a house. However, a great deal of moisture vapor is generated inside a typical house. It comes from the breath of people as well as activities such as cooking, dishwashing, laundering, and bathing. If the insulation is not installed properly, moisture-vapor can become trapped inside the walls. This can eventually:

- Reduce the effectiveness of the insulation.
- Encourage decay in wood materials.
- Promote the formation of mold.
- Attract wood-destroying insects.

Most building materials allow water vapor to pass through them. In cold weather, the warm vapor from inside the house will eventually reach a part of the wall that is cold. This might be the inside surface of the wall sheathing, or it might even be somewhere inside the insulation itself. Cold air cannot hold as much moisture as warm air, so when warm air cools, it releases some of the moisture it carries. The moisture forms on surfaces as a liquid. The process by which a vapor turns into a liquid is called **condensation**. For example, on a cold day, water droplets often appear on the inside surface of windows. This occurs because warm, moist indoor air is cooled when it contacts the glass, and has to unload some of its moisture. This moisture is deposited on the cold surface. The liquid water formed by the process is also called condensation.

There are various ways to solve this problem. One way would be to eliminate all sources of moisture inside a house, but this is not realistic. A second method is to prevent moisture vapor from getting into the walls. Builders can do this by placing a barrier between the insulation and the moisture.

Science: Energy & Matter

Conduction Most insulation is used to prevent the conduction of heat. Generally speaking, metals are considered to be good conductors, while wood products are poor conductors. Which type of material is a better insulator? Why?

Starting Hint Poor conductors make good insulators.

Vapor Retarders

A **vapor retarder** is a material that reduces the rate at which water vapor can move through a material. An older term for this is *vapor barrier.* However, the term is not quite accurate because it implies that moisture transfer is stopped completely. This is not true. Every material allows some moisture to pass through it.

Among the effective vapor retarder materials are asphalt laminated papers, aluminum foil, and plastic films. The kraft paper facing on batt insulation also acts as a vapor retarder.

The effectiveness of a vapor retarder is rated by its *perm value*. Perm value is a measure of water vapor transmission through a material. Low perm values indicate vapor retarders with high resistance to vapor transmission. A value of 0.50 perm is adequate. However, it is good practice to use barriers that have values less than 0.25 perm.

One common method for installing a vapor retarder is to staple wide rolls of plastic film over studs, plates, and window and door headers after insulating the walls. This is called *enveloping* and is used over insulation that does not already include a vapor retarder, such as unfaced batts. The plastic should fit tightly around outlet boxes and seams should be sealed. A ribbon of sealing compound around an outlet or switch box limits vapor transmission at this area.

It is extremely important to install a vapor retarder with great care. If the installer leaves gaps and untaped seams, moisture vapor will get into the wall cavities at these points.

No vapor retarder resists all vapor. Some leakage into the wall can be expected. Therefore, the flow of vapor to the outside should not be slowed by materials of high resistance on the cold side of the barrier. For example, sheathing paper should be waterproof but not highly vapor resistant.

Attic Ventilation

A third approach to controlling moisture is to provide ventilation. This approach cannot be used in wall cavities, but it is very important in attics and roof framing. Ventilation removes water vapor but it also reduces ice-damming problems and helps to keep temperatures inside the house cooler in the summer.

Removing Water Vapor Water vapor in air leaking from heated sections of the house will condense when it comes in contact with cold surfaces in the attic. Even when vapor retarders have been installed, some vapor will work through spaces around pipes and other poorly sealed areas. Some vapor will also work through the vapor retarder itself. Although the amount of water vapor may be unimportant if it is evenly distributed, water vapor can cause damage if concentrated in cold spots. Moisture vapor can escape through wood shingle and wood shake roofing systems. However, it cannot escape through roofing systems topped with asphalt, fiberglass, metal and other impervious materials. This is why attic spaces and roof systems should be ventilated. Air flow carries away excess moisture vapor.

Preventing Ice Dams Another reason to ventilate an attic or roof is to reduce the formation of ice at the eaves. An attic that is poorly ventilated and poorly insulated tends to be warmer than outside air in the winter. The warmth melts snow on the roof. Water running down the roof freezes when it reaches the colder surfaces of the eaves, often forming into ice at the gutter. This ice dam may cause water to back up at the eaves and into the wall and ceiling cavities. With a well-insulated ceiling and enough ventilation, attic temperatures are low. This greatly reduces the melting of snow on the roof.

Reducing Temperatures In hot weather, ventilation of attic and roof spaces allows hot air to escape. This lowers the attic temperature and helps the house to stay cooler.

Build It Green In regions where a house must be cooled for much of the year, thermal insulation helps the house to stay cool. But shade trees are also important in such climates. By shading walls and roof surfaces, trees can reduce a home's annual heating and cooling bill by 20 percent or more. Shading the west side of a house is particularly effective in reducing cooling needs. This is because the west side catches the afternoon sun.

It was once a common practice to install louvered ventilation openings in the end walls of gable roofs. However, air movement through this system varies and is often inefficient. A much more efficient approach is to provide openings in the soffit as well as a ridge vent at the top of the roof, as shown in **Figure 31-6**. As heated air rises in the attic, it is exhausted through the ridge vent. This process draws cooler air

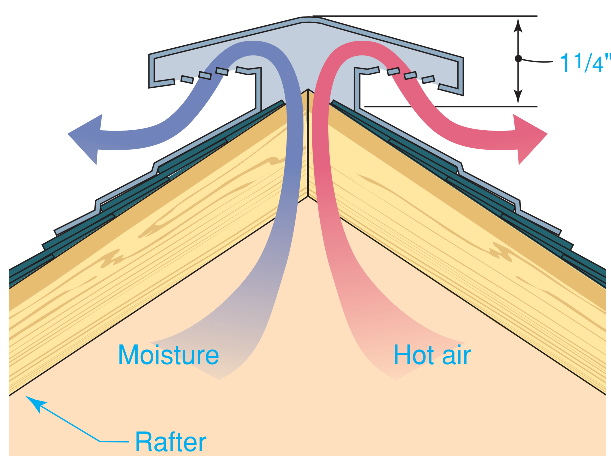


Figure 31-6 Ridge Venting
Effective Ventilation A continuous ridge vent can be capped with shingles to help blend the vent with the roof. *Why is ridge venting becoming more common?*

in through the soffit vents. Where a sloped ceiling is insulated, there should be a free opening of at least 1½" between the sheathing and the insulation to encourage air movement. (For more on ventilating roofs, see Chapter 19 and Chapter 22).

Crawl-Space Ventilation

Many houses are built on a crawl space foundation. Moisture rising through the soil can turn to vapor, which can move through the flooring system and into the house.

Soil Cover Crawl spaces must be protected from ground moisture by a vapor retarder, sometimes called a *soil cover,* as shown in **Figure 31-7**. The vapor retarder is often a 6-mil or 8-mil thick plastic film. Any joints must be lapped at least 6" and be sealed with appropriate tape or by some other method. Such protection helps to prevent decay of wood framing members. It also prevents floor insulation from becoming saturated with moisture.

Vents Just as with an attic, a crawl space should be vented to remove any moisture vapor that gets through the soil cover. The minimum net area of ventilation for a crawl space is 1 sq. ft. of venting for each 150 sq. ft. of crawl-space area. *Net area* refers to the amount of air that actually gets through a screened vent. The net area rating is typically stamped on the vent itself. For a house with an area of 1,500 sq. ft., for example, this would be 10 sq. ft. This area should be distributed evenly between vents located around the crawl space. At least one vent must be located within 3 ft. of each corner of the foundation. Vents should be covered with a corrosion-resistant screen to keep insects out.

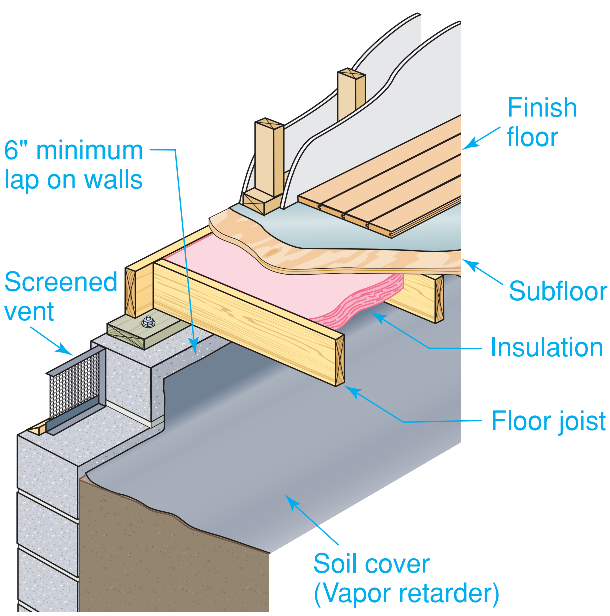


Figure 31-7 Crawl-Space Vapor Retarder
Moisture Removal A ventilated crawl space that has a vapor barrier and soil cover.

Unvented Crawl Spaces In some cases, there are advantages to eliminating vents in a crawl space. The 2006 IRC allows this type of construction but with some restrictions. Exposed earth must be covered with a continuous vapor retarder. The crawl space area must also be mechanically ventilated with a fan or supplied with conditioned air.

Radiant-Heat Barriers

What materials would make poor radiant heat barriers?

In the summer, outside surfaces exposed to direct sunlight may reach temperatures of 50°F (10°C) or more above shade temperatures. These surfaces tend to transfer this heat toward the inside of the house. Insulation in the attic slows the flow of heat, improving summer comfort and reducing the need for air conditioning. However, additional steps are sometimes taken to reduce radiant heat gain. **Radiant heat** travels in a straight line away from a hot surface and heats anything solid it meets. If radiant heat gain is reduced, the air-conditioning system does not have to work as hard to maintain a comfortable temperature in the house. Installing a radiant-heat barrier in the attic is one way to stop radiant heat gain.

A radiant-heat barrier is a thin, **flexible** sheet material with at least one reflective surface, usually of aluminum, as shown in **Figure 31-8**. Some radiant-heat barriers have a reflective coating on both sides. Installed properly, a radiant-heat barrier can reduce heat transfer into the attic by about

Figure 31-8 Radiant-Heat Barrier
Heat Blocker A radiant-heat barrier reduces heat gain in a house.

95 percent. In climates where saving heating energy is the main concern, however, radiant-heat barriers are rarely cost-effective.

Reading Check

Explain *What is the relationship between radiant heat and the air-conditioning system in a home?*

How Radiant-Heat Barriers Work

All materials emit energy by thermal radiation. The amount emitted depends on the surface temperature and the material's emissivity. **Emissivity** is a measure of radiation that is expressed as a number between 0 and 1. The higher the emissivity, the greater the emitted radiation. Another important property is *reflectivity*. Reflectivity measures how much radiant heat is reflected by a material. It is expressed as a number between 0 and 1 or as a percentage between 0 and 100. A material with high reflectivity has low emissivity, and vice versa. To perform properly, radiant-barrier materials must have high reflectivity (usually 0.9 or 90 percent, or more), low emissivity (usually 0.1 or less), and face an open air space.

For example, on a sunny day, a roof absorbs solar energy. This heats the roof sheathing, which causes the underside of the sheathing and the roof framing to radiate heat downward toward the attic floor. Placing a radiant-heat barrier on the underside of the rafters reflects much of the heat back toward the roof. Thus the top surface of the attic insulation stays cooler and so do the rooms below.

Radiant-heat barriers may be installed in attics in two ways. One method is to attach the barrier to the underside of the rafter framing. Another method is to drape the barrier loosely over the rafters just before the roof sheathing is applied. In this method, the barrier should droop so that there is at least 1" of air space between it and the underside of the sheathing. The air space makes the barrier more effective. It also creates an air channel that allows the soffit and ridge vents to work more effectively. Do not install a radiant-heat barrier by spreading it over attic insulation. Dust accumulating on the barrier can reduce its effectiveness. Also, the barrier might trap moisture vapor rising through the ceiling.

Figure 31-9 Installation Gap
How Not to Install Insulation This shows a poor insulation job. *Why should gaps be avoided between insulation and framing?*

Installing Insulation

What factors can make insulation difficult to install in a wall?

Installation of insulation is a job in which good craftsmanship pays off in money saved for the homeowner. When installing any insulation, it must fill all the wall and ceiling cavities completely. There should be no gaps between the insulation and the framing or around other objects. As shown in **Figure 31-9**, gaps form a ready passage through which heat and moisture vapor can escape.

Where to Insulate

The proper placement of insulation is important. The basic concept is to insulate all portions of the building envelope.

Walls All walls that separate living space from outdoor air must be insulated. In a one-and-a-half-story house, however, it is sometimes difficult to establish the building envelope. In such cases, second floor *knee walls* should be treated just as if they were exterior walls, as shown in **Figure 31-10**. Knee walls are half-height walls often found in attics.

Floor Systems In houses with unheated crawl spaces, insulation should be placed between the floor joists as shown in **Figure 31-11**.

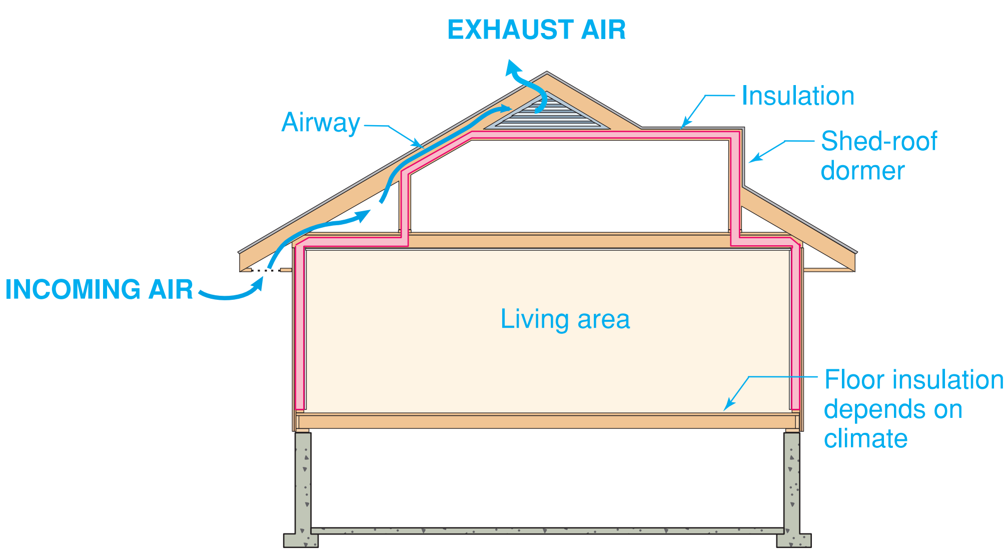


Figure 31-10 The Building Envelope
Surrounding Living Spaces Insulating a one-and-a-half-story house. In some climates, the floor system might also be insulated.

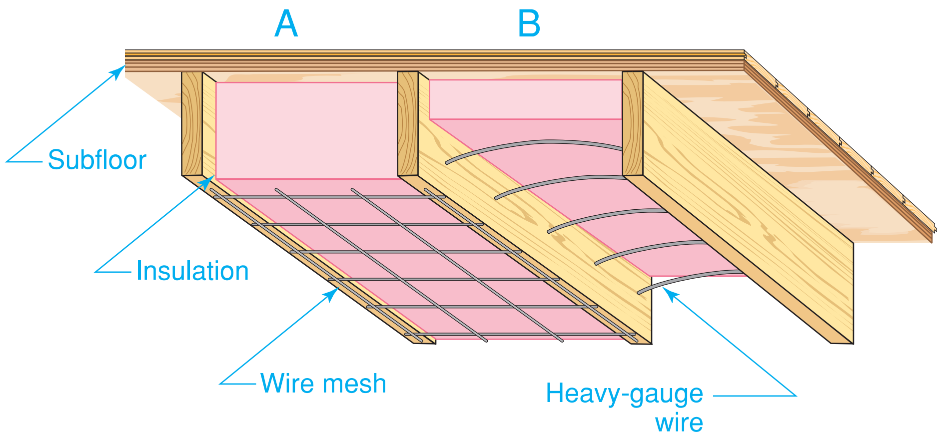


Figure 31-11 Supporting Batt Insulation
Two Methods Methods of installing insulation between floor joists. **A.** Wire mesh stapled to the joists. **B.** Heavy-gauge wire pointed at each end and sprung into place.

If batt insulation is used, it should be well supported by a galvanized wire mesh or a rigid board. The vapor barrier should be installed toward the subflooring. Press-fit or friction insulation fits tightly between joists and requires only a small amount of support to hold it in place.

Attics and Cathedral Ceilings Heat rises, so it is important to slow down heat loss during cold weather by insulating the attic. Where attic space is unheated and a stairway leads to the attic, insulation should be installed around the stairway as well as in the first-floor ceiling. The door or hatchway leading to the attic should be weatherstripped and insulated to prevent heat loss. Walls adjoining a garage or unheated porch should also be insulated. Vaulted ceilings above conditioned space must be insulated as much as possible. It is often necessary to provide an air space above the insulation. This would allow any moisture vapor to be exhausted. Ventilation is not necessary, however, if the ceiling cavities are insulated with spray-foam insulation. Check with local codes.

Foundation Walls and Slabs In Zones 4 and higher, these surfaces must be insulated if they form part of the building envelope. Slabs are typically insulated by a layer of rigid insulation that is installed just before the slab is placed.

Installing Batt Insulation

Blanket or batt insulation with a vapor retarder should be placed between framing members so that the tabs of the facing lap the edges of the studs as well as the top and bottom plates, as shown in **Figure 31-12**. This is generally preferred to stapling the tabs to the sides of the studs. A hand stapler or hammer tacker is commonly used to fasten the insulation and the barriers in place.

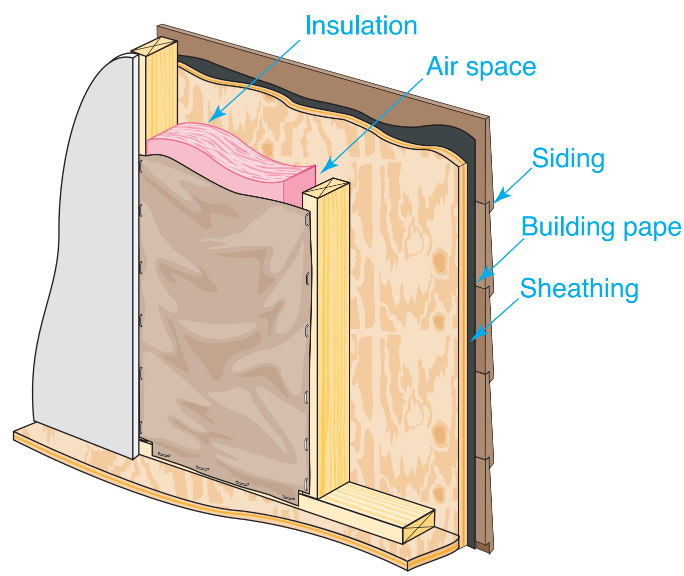


Figure 31-12 Installing Faced Batts
A Good Seal The insulation tabs should be stapled to the edge of each stud.

Figure 31-13 Cutting Batts

Straight Cuts To cut insulation, place it on a piece of scrap plywood. Compress the material with a wood scrap and cut it with a utility knife.

JOB SAFETY

HANDLING FIBERGLASS Fiberglass is a skin and lung irritant. Always wear protective clothing, including a long-sleeve shirt, gloves, long pants, high-top work boots, and a cap, when working with fiberglass. In addition, wear a suitable dust mask or respirator and eye protection. Follow all safety precautions suggested by the insulation manufacturer.

Go to **glencoe.com** for this book's OLC for more on job safety.

Batt insulation can be cut with a utility knife as shown in **Figure 31-13**. Batts and blankets should always be compressed while being cut. This ensures that cut edges will be smooth, improves cutting accuracy, and prevents too many fiberglass fibers from escaping into the air. Something as simple as a 2×6 board or some other wood scrap can be used to compress the insulation near the cutting area. It can also serve as a straightedge for guiding the utility knife.

When friction-fit batt insulation is installed, a plastic-film vapor retarder such as 4-mil polyethylene is commonly used to envelop the entire exposed wall and ceiling. It covers the openings as well as window and door headers and edge studs. This system is one of the best for blocking vapor movement. After the drywall has been installed or plastering has been completed, the film can be trimmed around the window and door openings.

Blanket insulation is often used in ceilings. The vapor retarder should be placed against the back of the ceiling finish. Unfaced blankets may be layered to provide a suitable thickness. In this case, place one layer of insulation at 90° to the first. This also insulates the ceiling framing.

Insulation should be placed behind electrical outlet boxes and other utility connections in exposed walls to limit condensation. It is important to understand that some types of recessed light fixtures require a specific amount of clearance between the fixture and the insulation. This allows heat generated within the fixture to escape. A recessed fixture that overheats is a fire hazard.

Narrow gaps around doors and windows also require insulation. This is best done by spraying expanding foam sealant into the gaps. However, be sure that the foam does not push window and door jambs out of position. To minimize this problem, use low-expansion foam designed for this purpose.

Estimating and Planning

CERTIFICATION PREP

This estimating and planning exercise will prepare you for national competitive events with organizations such as SkillsUSA and the Home Builder's Institute.

Batt Insulation

Materials

To estimate the amount of insulation required, you must first figure the square footage of the wall or ceiling to be insulated. Refer to the house plan below.

Round off the outside dimensions of the heated portion of the home to a width of 28' and a length of 52'. The perimeter of the house is thus 160'.

$$(2 \times 28) + (2 \times 52) = 160$$

If the wall height is 8', the walls will have an area of 1,280 sq. ft.

$$8 \times 160 = 1{,}280$$

Subtract the area of the window and door openings, which equals about 150 sq. ft., from the total area.

$$1{,}280 - 150 = 1{,}130$$

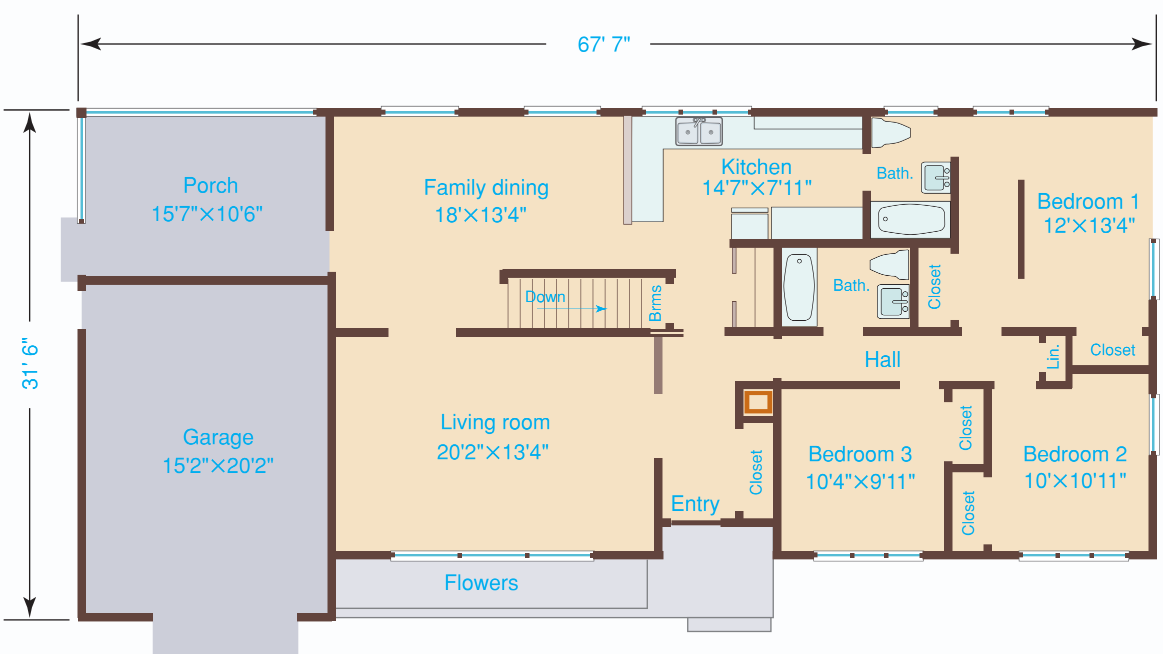
The total wall area to be insulated is 1,130 sq. ft.

Using figures supplied by the insulation manufacturer, determine how many square feet each roll or bundle of insulation will cover. Divide the area to be covered by the coverage per roll or bundle. The answer will be the number of rolls or bundles required. Add approximately 5 percent to this figure to allow for waste.

Estimating on the Job

The ceiling of a home must also be insulated. Figure the area of the ceilings by multiplying the width times the length. Divide the number by the number of square feet in each roll. Add approximately 5 percent to this figure to allow for waste.

1. If one roll of insulation covers 100 square feet, how many rolls of insulation will be needed for the ceilings in this house?



Section 31.1 Assessment

After You Read: Self-Check

1. What type of insulation is the most common?
2. What is the typical R-value for low-density batt insulation for 2×4 and 2×6 walls?
3. What is the building envelope?
4. Define *emissivity*.

Academic Integration: Science

5. **Condensation** You may have noticed the concentration of moisture on the inside of a window on a cold day. This moisture appears through the process of condensation. Write one or two sentences describing the process of condensation.

Go to glencoe.com for this book's OLC to check your answers.

Section 31.2 Acoustical Insulation

Understanding Acoustics

How do windows affect sound transmission?

Acoustical insulation is insulation that slows the transmission of sound. Acoustical insulation has always been important in apartments, motels, and hotels. However, the use of household appliances, television, radio, and stereo systems has increased the noise levels in single-family homes. Today, sound insulation between the active areas (such as recreation rooms and home theaters) and sleeping areas is often desirable. Insulation against outdoor sounds is also important where houses are close together or where they are near highways. As a result, sound control has become an important part of house design and construction.

How Sound Travels

Sound is transmitted by waves. It travels readily through the air and also through some materials. A noise inside a house, such as music, a loud conversation, or a barking dog, creates sound waves. These radiate outward until they strike a wall, floor, or ceiling. The surface vibrates as a result of the pressure of the sound waves. When airborne sound strikes a conventional wall, the studs act as sound conductors unless they are separated in some way from the covering material.

The resistance of a building element, such as a wall, to the passage of airborne sound is described by its **Sound Transmission Class (STC)** number. Sound Transmission Class is a numerical rating that indicates the ability of a material or combination of materials to reduce sound transmission. The higher the STC number, the better a material is as a sound barrier.

Flanking Paths Faulty construction, such as poorly fitted doors, can allow sound to pass around a material without actually going through it. This type of sound transmission follows what is called a *flanking path*. Heating ducts, wiring chases, and plumbing runs can also allow sound to travel freely through the air within wall and ceiling assemblies. In fact, a hole as small as 1 square inch in a wall rated at STC 50 can reduce that wall's performance to STC 30. Plumbers, electricians, and others who regularly cut holes in framing should keep this fact in mind as they work.

Sound Absorption

To reduce sound levels in a house, sound-absorbing materials can be added. Sound-absorbing materials do not necessarily resist airborne sounds. However, they can reduce noise by preventing sound from being reflected back into a room. Perhaps the most commonly used sound-absorbing material is acoustical ceiling tile or panels, as shown in **Figure 31-14**. Numerous holes or fissures on the surface, or a combination of both, trap the sound. Acoustical tile and panels are most often used where they are not subject to too much mechanical damage, such as in the ceiling. Paint or other finishes that fill or cover the tiny holes or fissures greatly reduce their efficiency.

Sound Insulation Techniques

What types of wall construction might affect the work of other trades?

The addition of sound-absorbing materials is only one way to reduce sound levels in a house. The most effective methods usually involve the structure of a house. For this reason, they must be decided upon at the earliest stages of house design. Many of the materials will be difficult or impossible to add later.

Acoustical Walls

Thick walls of dense materials such as masonry can stop sound quite effectively. In a wood-frame house, however, an interior masonry wall results in increased costs. A less expensive system is to combine sound-deadening insulating board and gypsum board outer covering. This provides good sound control at only slight additional cost. A number of combinations, providing different STC ratings, are possible with this system.

Good STC ratings can be obtained in a wood-frame wall by using the combination of materials and techniques shown in **Figure 31-15** on page 910.

A double wall, which may consist of 2×6 or wider plate and staggered 2×4 studs, is sometimes constructed for sound control as shown in Figure 31-15D. However, the extra effort and planning required for

Figure 31-14 Acoustical Ceiling Panels

Absorbing Sound A suspended ceiling system with acoustical panel inserts will absorb some sound.

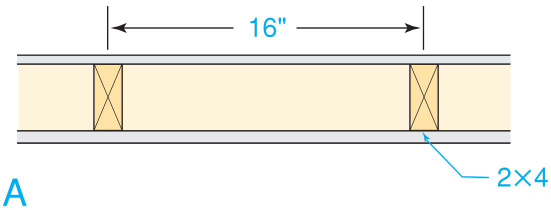
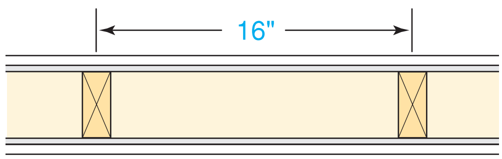
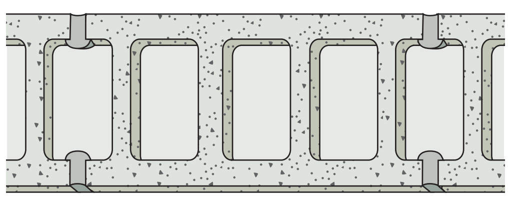
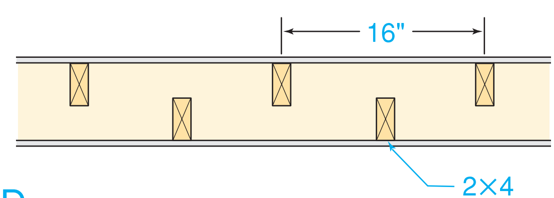
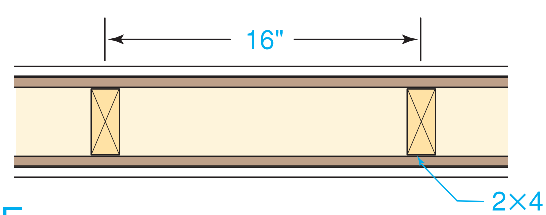
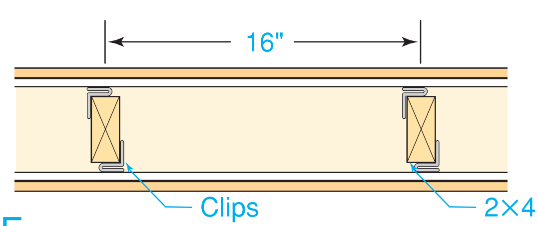
WALL DETAIL	DESCRIPTION	STC RATING
 A	1/2" gypsum wallboard 5/8" gypsum wallboard	32 37
 B	3/8" gypsum lath (nailed) plus 1/2" gypsum plaster with whitecoat finish (each side)	39
 C	8" concrete block	45
 D	1/2" gypsum wallboard (each side)	45
 E	1/2" sound-deadening board nailed 1/2" gypsum wallboard laminated (each side)	46
 F	Resilient clips to 3/8" gypsum backer board 1/2" fiberboard laminated (each side)	52

Figure 31-15 Acoustical Performance of Walls

Quiet Options A standard wall is shown in **A**. The STC rating of a wall can be improved in various ways (**B**–**F**).

double-wall construction does not necessarily warrant its expense.

Acoustical Floors and Ceilings

Sound insulation between an upper floor and the ceiling of a lower story involves not only resistance to airborne sounds but also to impact noises. *Impact noise* results when an object strikes or slides along a wall or floor. Footsteps, dropped objects, and furniture being moved all cause impact noise. It may also be caused by the vibration of a dishwasher, food disposal, or other equipment. In all instances, the floor is set into vibration by the impact or contact, and sound is radiated from both sides of the floor.

The impact noise resistance of a floor system is described by its Impact Noise Rating. The **Impact Noise Rating (INR)** is a measure of the resistance of a floor system based on decibels (dB), a measure of sound intensity. The higher the INR, the better the impact sound reduction. Another rating, the *Impact Insulation Class (IIC)*, is sometimes used instead because IIC figures are easier to determine. Like the INR, it measures the resistance to sound transmission due to impact. The higher the IIC number, the better the impact insulation.

Builder's Tip

UNDERSTANDING DB The softest sounds humans can hear range from 0 to 1 decibel (dB). Except for thunder and erupting volcanoes, no sound that is found in nature exceeds 100 dB. Noise levels produced by saws, routers, and other tools and equipment range from 87 to 108 dB.

Section 31.2 Assessment

After You Read: Self-Check

1. One wall assembly has an STC rating of 40, while another has an STC rating of 55. Which wall would be best at reducing sound transmission?
2. What is a flanking path?
3. Why is it important to limit the number and size of holes in a wall?
4. On what unit is the INR rating based?

Academic Integration: Science

5. **The Velocity of Sound** The velocity of sound is the product of wavelength and frequency (velocity = wavelength × frequency). In air, sound travels at a constant speed of 1,100 feet per second. If the value of the frequency is large, the value of the wavelength is small. For example, if the frequency is 1,100 hertz, then the wavelength would be 1 foot. What is the frequency of a sound wave whose wavelength is 0.5 feet?

   Starting Hint: If a product is constant and one of two factors is doubled, the other factor is halved.

   Step 1: Write an equation to represent the situation in the problem: (Velocity = frequency × wavelength).

   Step 2: Plug in the known values (velocity and wavelength).

   Step 3: Solve for the unknown value (frequency). Express your answer in hertz.

Go to glencoe.com for this book's OLC to check your answers.

CHAPTER 31

Review and Assessment

Chapter Summary

Section 31.1

Thermal insulation is available as flexible batts and blankets, rigid board, loose fill, and spray foam. Insulation helps to reduce heat gain as well as cooling loss. R-value is the measure of an insulator's effectiveness. A vapor retarder limits water vapor penetration.

Section 31.2

Acoustic insulation slows the transmission of sound. The amount of sound transmitted through a house can be reduced with the proper wall and ceiling construction. The STC and INR ratings measure a material's resistance to sound transmission.

Review Content Vocabulary and Academic Vocabulary

1. Use each of these content vocabulary and academic vocabulary words in a sentence or diagram.

Content Vocabulary

- thermal insulation (p. 894)
- R-value (p. 894)
- building envelope (p. 895)
- batt (p. 897)
- condensation (p. 900)
- vapor retarder (p. 900)
- radiant heat (p. 902)
- emissivity (p. 903)
- acoustical insulation (p. 908)
- Sound Transmission Class (STC) (p. 908)
- Impact Noise Rating (INR) (p. 911)

Academic Vocabulary

- byproduct (p. 897)
- expands (p. 899)
- flexible (p. 902)

Speak Like a Pro

Technical Terms

2. Work with a classmate to define the following terms used in the chapter: *blankets* (p. 897), *glass wool* (p. 897), *unfaced insulation* (p. 897), *friction-fit insulation* (p. 897), *vapor barrier* (p. 900), *perm value* (p. 900), *enveloping* (p. 900), *soil cover* (p. 902), *net area* (p. 902), *reflectivity* (p. 903), *knee walls* (p. 904), *flanking path* (p. 909), *impact noise* (p. 911), *Impact Insulation Class (IIC)* (p. 911).

Review Key Concepts

3. **Name** the types and forms of insulation.

4. **Explain** how effectiveness as insulation is determined by the R-value.

5. **Discuss** the primary purpose of insulation.

6. **Describe** the basic types of insulation.

7. **Describe** how vapor retarders and ventilation control moisture.

8. **Explain** the types of wall construction that will reduce noise transmission.

Critical Thinking

9. Explain How can tradesmen such as plumbers and electricians affect the STC rating of a wall?

Academic and Workplace Applications

STEM Mathematics

10. Estimating Batt Insulation A rectangular house with outside dimensions of 26' × 44' is to be insulated. For the 8' exterior walls, 4" thick batts measuring 15" × 48" are to be used. Assume that the area of the doors and windows is 15 percent of the floor area. How many batts will be needed?

Math Concept Perimeter is the distance around a shape. The perimeter of a house is usually measured in feet. Area is the space covered by a shape. The area of exterior walls and floors is usually measured in square feet.

Step 1: Calculate the area of the exterior. Multiply the perimeter times the height. Subtract the area of the doors and windows.

Step 2: Calculate the area of one batt. Divide to find the number of batts required.

Step 3: Add a waste allowance of 5 percent.

STEM Engineering

11. Moisture and Ventilation Roofing plans play an important role in the ventilation of a house. Wood shingle and wood shake roofs do not resist vapor movement, but asphalt shingles are highly resistant to vapor movement. In this case, the most practical method of removing moisture is by ventilating the attic or roof. Discuss some of the reasons to ventilate a roof or attic in a two-paragraph summary. Explain some potential problems that may arise if a roof or attic is not properly ventilated.

21st Century Skills

12. Productivity and Accountability Your health has an impact on the work you do. Some illnesses are not preventable, but there are things you can do to prevent illness. Discuss some ways in which poor health can affect your productivity as an employee. Then name some things you can do to maintain excellent health and productivity on the job.

Standardized TEST Practice

CERTIFICATION PREP

Multiple Choice

Directions Choose the word or phrase that best completes the following statements.

13. A measure of a material's ability to resist heat transmission is called _______ .

a. STC-value
b. H-value
c. R-value
d. INR-value

14. The insulation commonly used in ceiling areas is called _______ .

a. flexible insulation
b. loose-fill insulation
c. friction-fit insulation
d. non-flexible insulation

15. _______ is a measure of water vapor transmission through a material.

a. Vapor value
b. Perm value
c. R-value
d. P-value

TEST-TAKING TIP

Do not just stop working during a test if you get stuck on a question. Take a 30-second break. If you are still stuck, move on to another question.

*These questions will help you practice for national certification assessment.