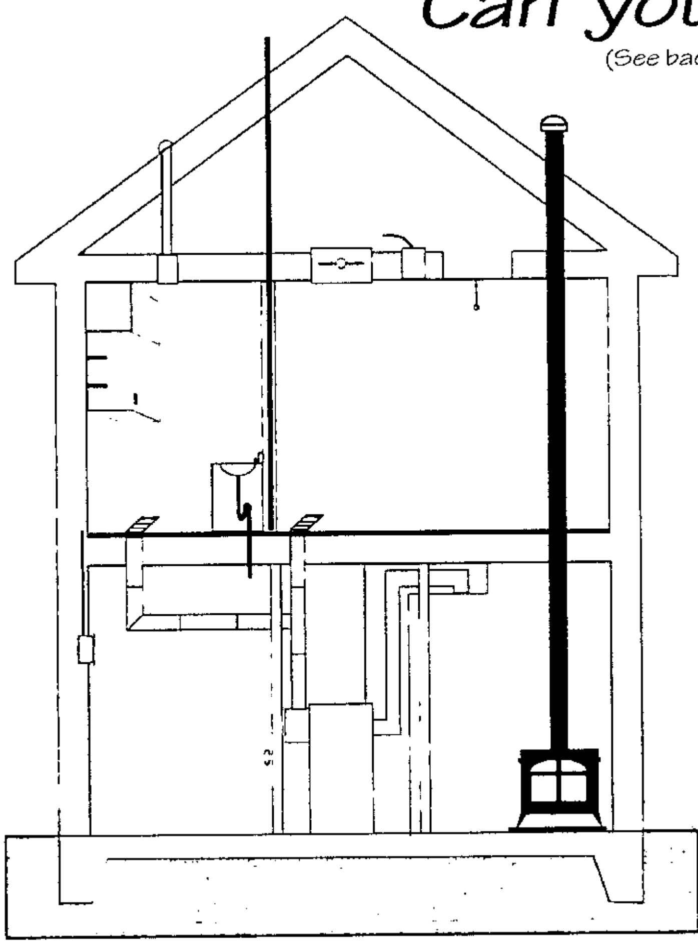
Technical Publication # 107 UF

Energy Efficient Building Construction in Florida

Air leakage is a common cause of building energy inefficiency.
This drawing illustrates 19 sites of potential air leakage.

Can you find them?

(See back cover to check your answers.)



UNIVERSITY OF FLORIDA

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Development of Energy Efficient Building Construction in Florida is the result of a collaborative effort between the M. E. Rinker, Sr. School of Building Construction and Florida Energy Extension Service, both of the University of Florida. This project was tremendously facilitated by the generosity of the Georgia Environmental Facilities Authority - Division of Energy Resources and Southface Energy Institute in allowing us to use materials directly from A Builder's Guide to Energy Efficient Homes in Georgia (even to the extent of sharing electronic text and graphics files). Likewise, the Building Codes and Standards Office in the Florida Department of Community Affairs was extremely helpful and provided electronic files for Energy Code Excerpts: A Study Guide for Florida's Energy Efficiency Code for Building Construction. Finally, the Building Construction Industry Advisory Committee helped make this project possible by providing funding and review oversight to ensure the handbook's quality.

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Energy Efficient Building Construction in Florida

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Development of the ***Energy Efficient Building Construction in Florida*** handbook involved many people at the University of Florida. The following listing identifies personnel working on the project and briefly describes their specific contributions.

Annette Cannon – Graphics Designer, Florida Energy Extension Service. Ms. Cannon was responsible for the graphic design of the handbook's cover.

Gary Cook – Assistant Instructor, M.E. Rinker, Sr. School of Building Construction. He was the primary reviewer of the *Energy Efficient Building Construction in Florida* handbook.

Barbara Haldeman – Technical Editor and Layout Specialist, Florida Energy Extension Service. Barbara was responsible for developing and implementing styles for all Florida Energy Extension Service publications.

Jennifer Jones – Project Assistant, Florida Energy Extension Service. Ms. Jones coordinated the review, update, layout and duplication of the handbook. She was also responsible for the review and updating of all three Appendices and the Resources section.

Craig Miller – Coordinator Educational Media/Communications, Florida Energy Extension Service. Mr. Miller served as overall coordinator for the *Energy Efficient Building Construction in Florida* handbook development project. He was specifically responsible for development of Chapter 4 (*Air Leakage – Materials and Techniques*), Chapter 5 (*Insulation Materials and Techniques*), Chapter 10 (*Appliances and Lighting*) and Chapter 11 (*Siting and Passive Design Features*).

Wendell Porter – Assistant Instructor, Agricultural and Biological Engineering. Mr. Porter originated the concept of developing the *Energy Efficient Building Construction in Florida* handbook and was specifically responsible for development of Chapter 7 (*Heating, Ventilation, Air Conditioning (HVAC)*), Chapter 8 (*Duct Design and Sealing*) and Chapter 10 (*Appliances and Lighting*).

Kathleen Ruppert – Assistant Extension Scientist, Agricultural and Biological Engineering. Dr. Ruppert was specifically responsible for development of Chapter 9 (*Domestic Hot Water*) and a major contributor to Chapter 10 (*Appliances and Lighting*). She has also made major revisions to Chapter 5 (*Insulation Materials and Techniques*), which appear in this edition of the handbook.

Arlene Stewart – Educational Materials Designer, Florida Energy Extension Service. Ms. Stewart was specifically responsible for development of Chapter 6 (*Windows and Doors*) and supported development of Chapter 10 (*Appliances and Lighting*).

Leon Wetherington – Assistant Professor, M. E. Rinker, Sr. School of Building Construction. Dr. Wetherington was specifically responsible for development of Chapter 1 (*Step–by–Step Energy Efficient Construction*), Chapter 2 (*Why Build Efficiently?*), and Chapter 3 (*The Building as a System*).

Contents

Introduction

When used together, the phrases *energy efficiency* and *building construction* are often assumed to mean greater costs with no incentives. But actually, energy efficient building construction practices can mean greater profits. *Energy Efficient Building Construction in Florida* is an adaptation for Florida conditions and code requirements of *A Builder's Guide to Energy Efficient Homes in Georgia.* The handbook includes excerpts from Florida's energy efficiency code for building construction to aid builders in understanding and complying with the code. (The relevant sections of the Florida Energy Code that include specific code requirements are listed under the appropriate chapter title.) Just as importantly, it is designed to bridge the gap between energy efficient building practices and greater profitability.

Greater profits can be realized around four key concepts: increased sales, improved energy efficiency, reduced system costs, and improved products.

❐ Increased Sales – Increase sales volume by offering more value for less total monthly cost. Typically energy efficient construction costs more to build, but will be less expensive for owners to operate, where monthly energy savings exceed any small increase in the monthly mortgage. Builders can profit by selling extra energy features, attracting more buyers looking for energy efficient buildings, and reducing expensive call-backs where buildings are more comfortable and well-built.

❐ Improved Energy Efficiency – Increase spending on critical features that provide a wide range of owner benefits in addition to impressively lower utility bills. In particular, builders can look for significant energy savings with high-efficiency building envelopes; heating, cooling and ventilation (HVAC) systems; lighting; and appliances.

❐ Reduced System Costs – Realize significant construction cost savings with an integrated approach to mechanical system design. Opportunities to reduce initial construction costs are based on more efficient building envelopes, which require smaller HVAC equipment and distribution systems.

❐ Improved Products – Use the benefits offered by energy efficient features to differentiate your buildings. In addition to significantly lower utility bills, you can look to offer improved comfort, quieter interiors, better indoor air quality, high quality construction, positioning for high resale value, and an environmentally friendly building.

With special mortgage considerations and allowances available to purchasers of energy-efficient buildings, *Energy Efficient Building Construction in Florida* makes both cents and sense.

Chapter 1: Step-by-Step Energy Efficient Construction

This quick reference guide shows the key elements of energy efficient construction. These features save money, improve indoor air quality, enhance comfort, prevent moisture problems, and increase the long term durability of the building.

Energy Efficient Buildings: The Key Features

Air barrier system

- ❐ Eliminate leakage between conditioned and unconditioned spaces, in particular between:
  - living areas
  - attics
  - crawl spaces
  - garages

Continuous insulation system

- ❐ Install insulation as continuously as possible between conditioned and unconditioned spaces, including:
  - exterior walls
  - floor systems over unconditioned or exterior spaces
  - ceilings below unconditioned or exterior spaces
  - wall areas adjacent to attic space—such as knee walls and attic stairways

Select and install energy efficient windows

- ❐ Design buildings with minimal glass, especially on the southeast and southwest sides
- ❐ Use double-glazed windows with U-values under 0.70 (R-values of at least 1.65)
- ❐ Consider low-emissivity coatings and other high performance features
- ❐ Shade windows in summertime

Design cooling and heating system for efficiency

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

Seal ductwork

- Size ductwork to meet the heating and cooling load of each room
- Place ductwork to supply proper airflow; measure airflow to guarantee comfort
- Seal all potential duct leaks—except those in removable components—with mastic or mastic plus fiber mesh
- Seal leaks around removable components with aluminum tape
- Provide for return air duct system where appropriate

Minimize hot water costs

Choose energy efficient appliances and lighting

Carefully consider the placement of the building on the property to provide maximum shade in the summer and sunlight in the winter

Figure 1-1
Building Section

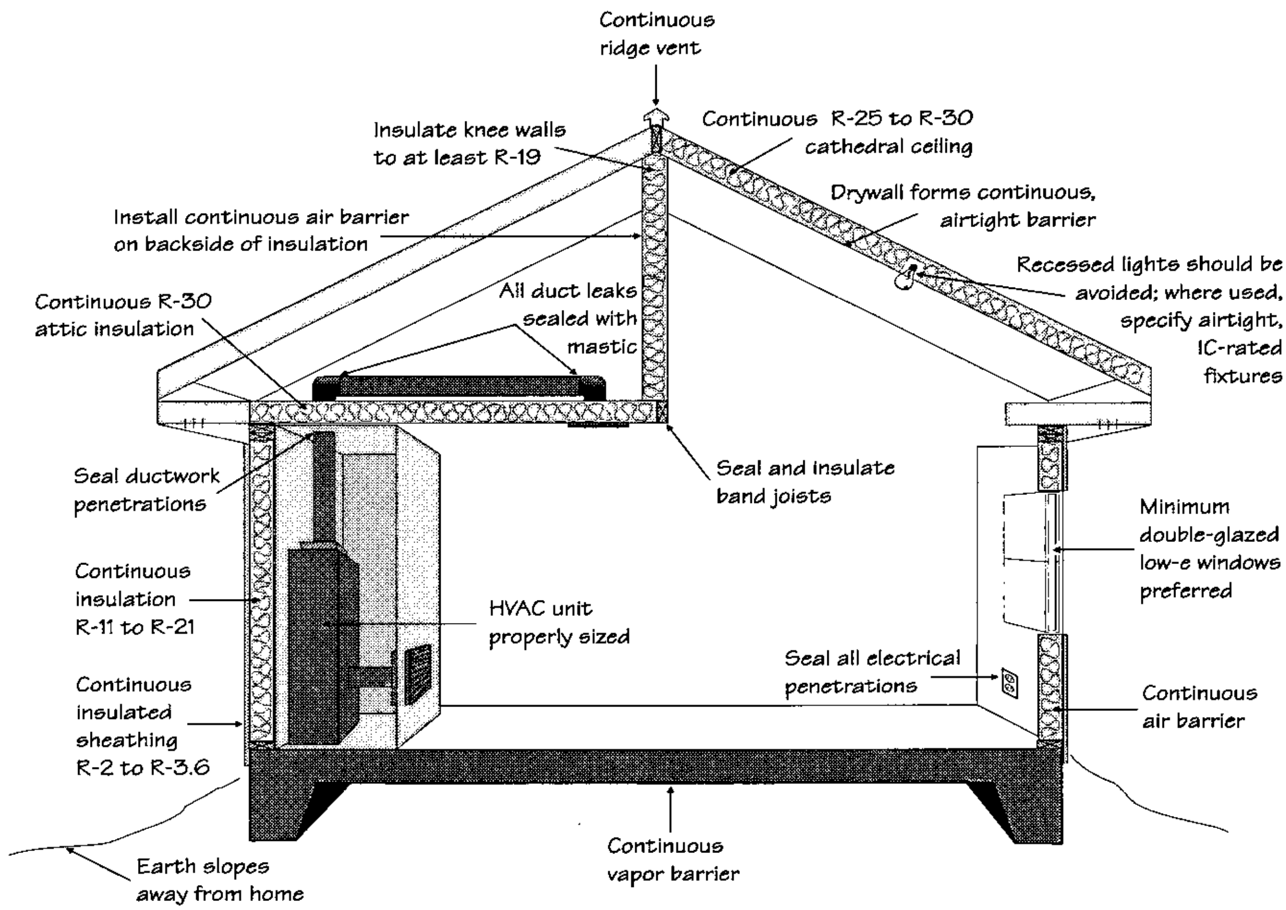


Figure 1-2
Site Planning

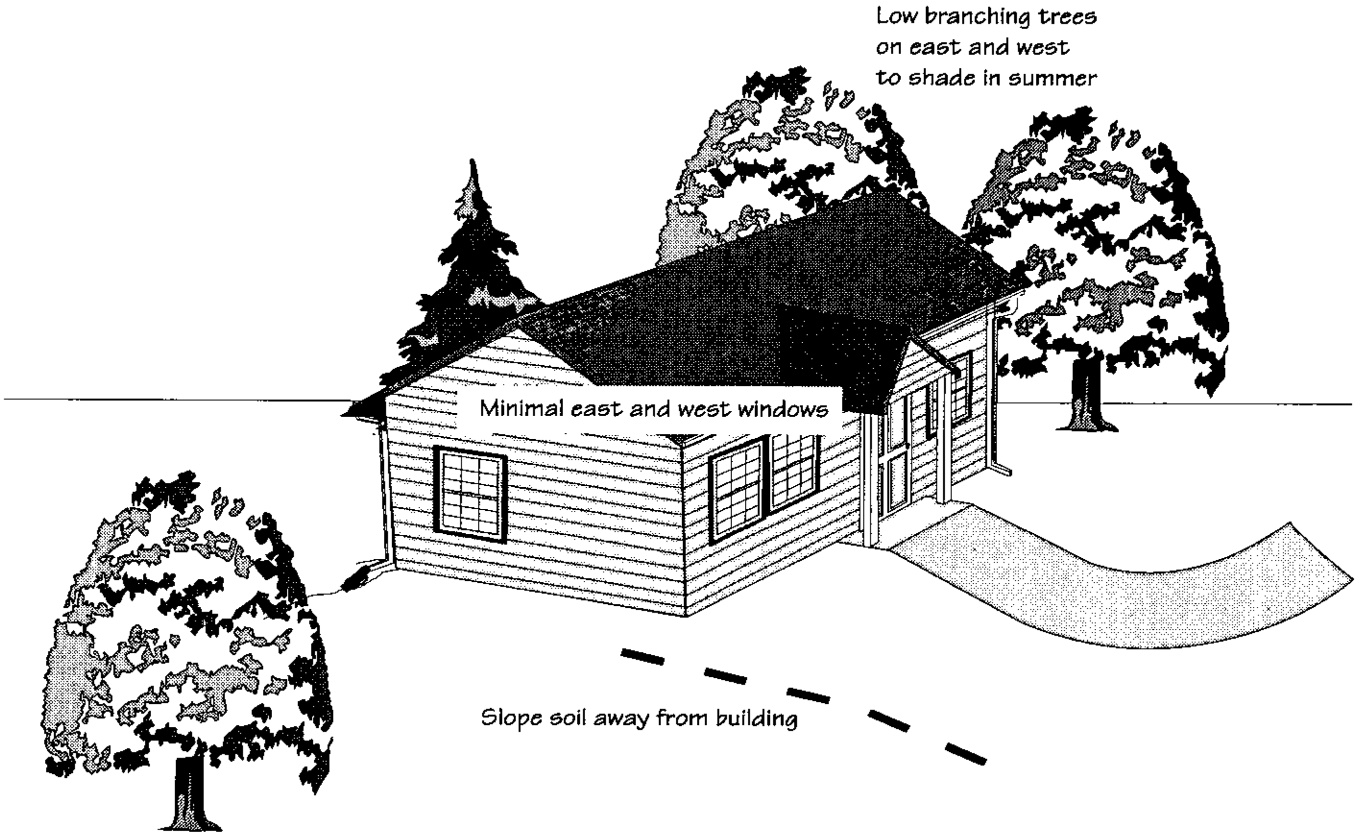
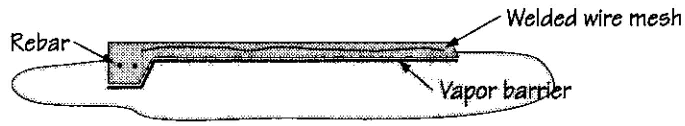
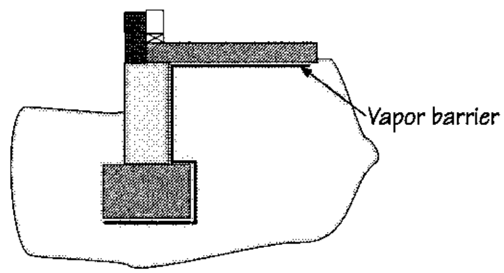


Figure 1-3
Foundation Alternatives



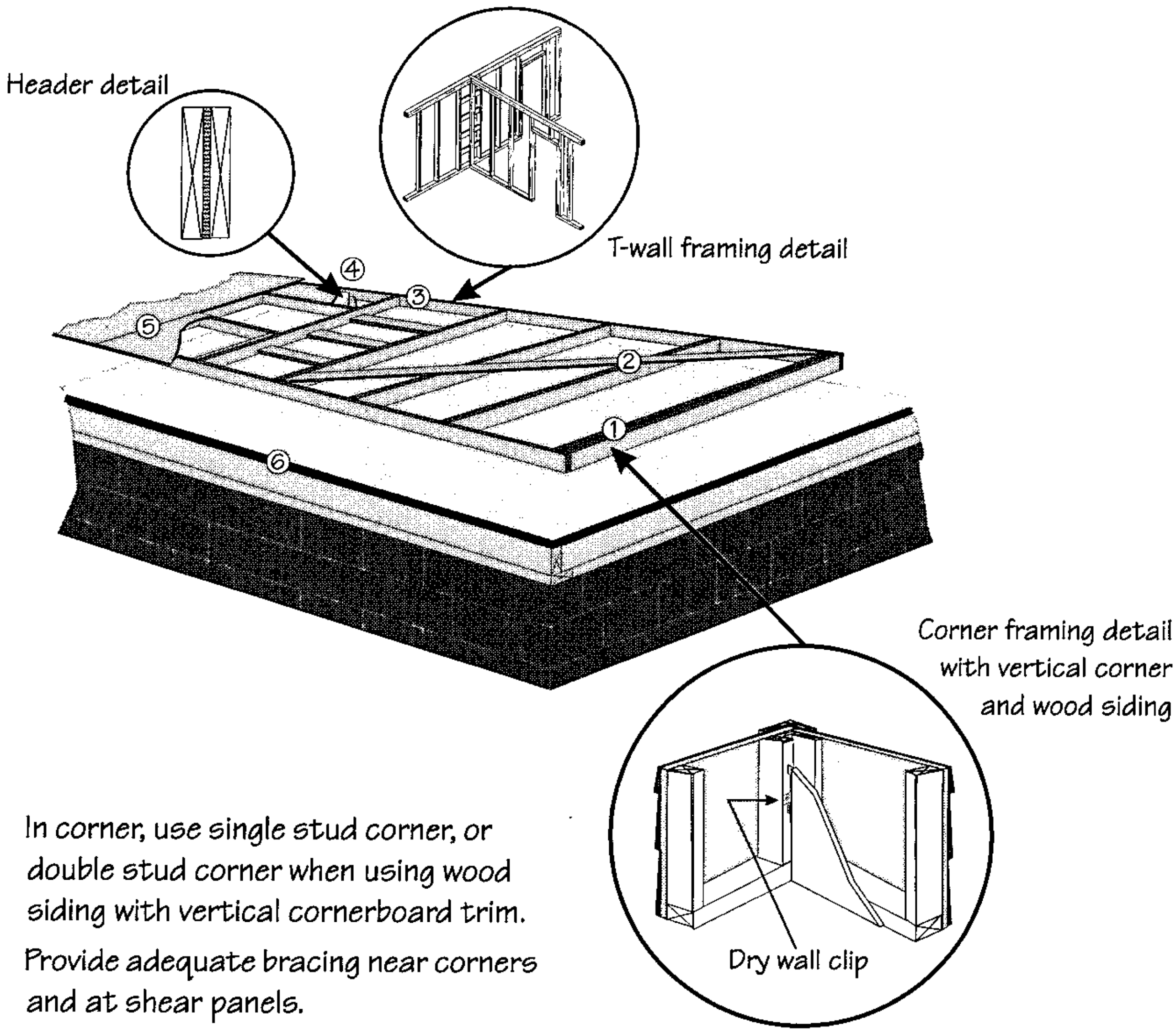
Monolithic Concrete Slab



Stem Wall

For slab-on-grade construction, design footing and foundation wall or monolithic slab and footing according to local code requirements. If building a suspended floor system, place a vapor barrier under the footing and over the ground under the floor.

Figure 1-4
Wall Framing



1. In corner, use single stud corner, or double stud corner when using wood siding with vertical cornerboard trim.
2. Provide adequate bracing near corners and at shear panels.
3. At partition wall (T-wall) intersection, eliminate additional studs for nailing drywall; use "ladder" instead. A ladder consists of 2 x 4 blocking turned on edge and nailed flush with the inside face of the studs 16 inches on center. This will provide nailing for the first stud of the partition while allowing insulation in the exterior wall (see inset).
4. Add 1/2" foam to structural headers.
5. Cover entire wall with 1/2" foam sheathing, including band joists and second top plates.
6. Before lifting wall in place, attach sill sealant material to subfloor.

Figure 1-5
Ceiling Details

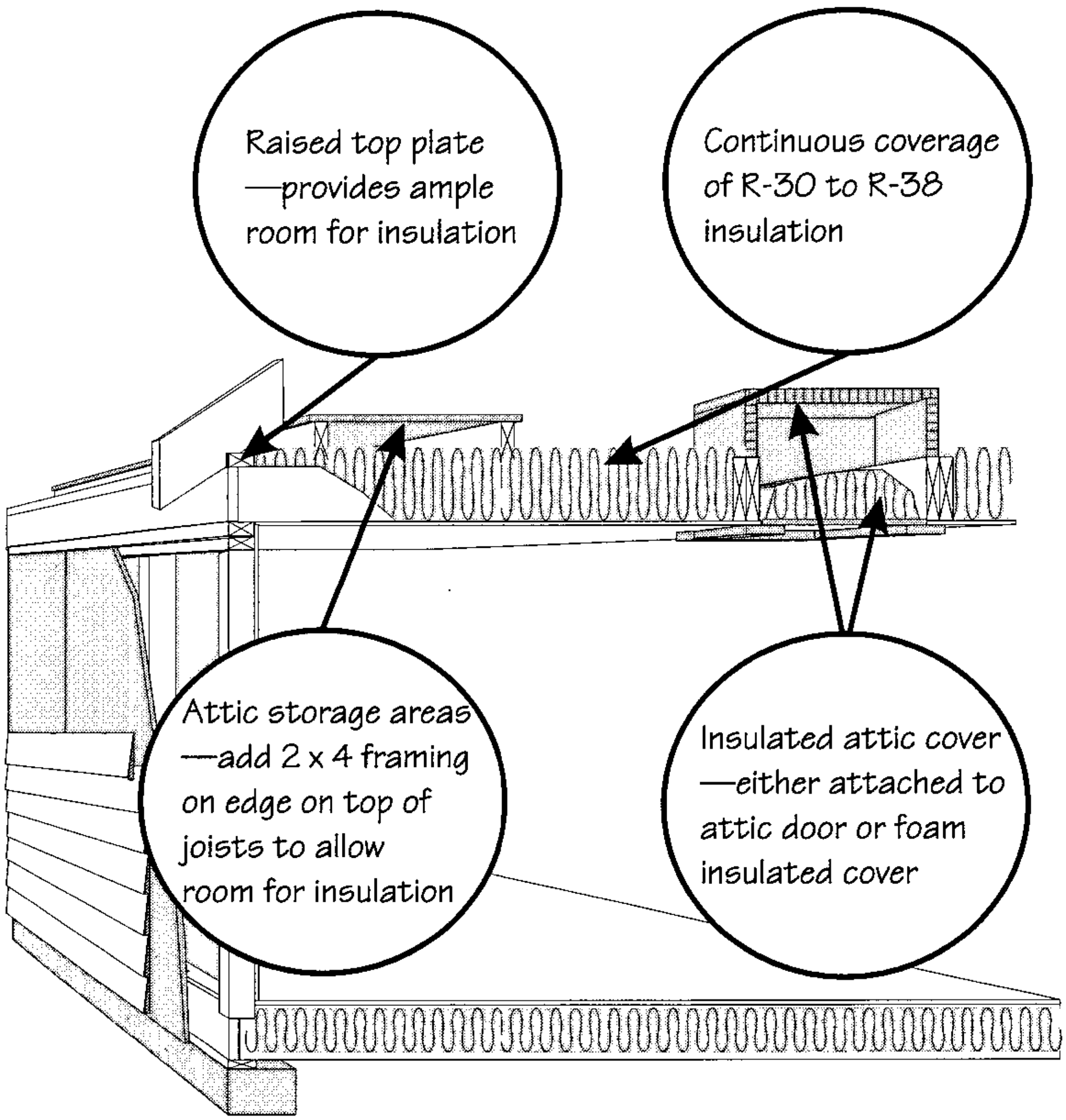


Figure 1-6
Seal Plumbing Penetrations

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.

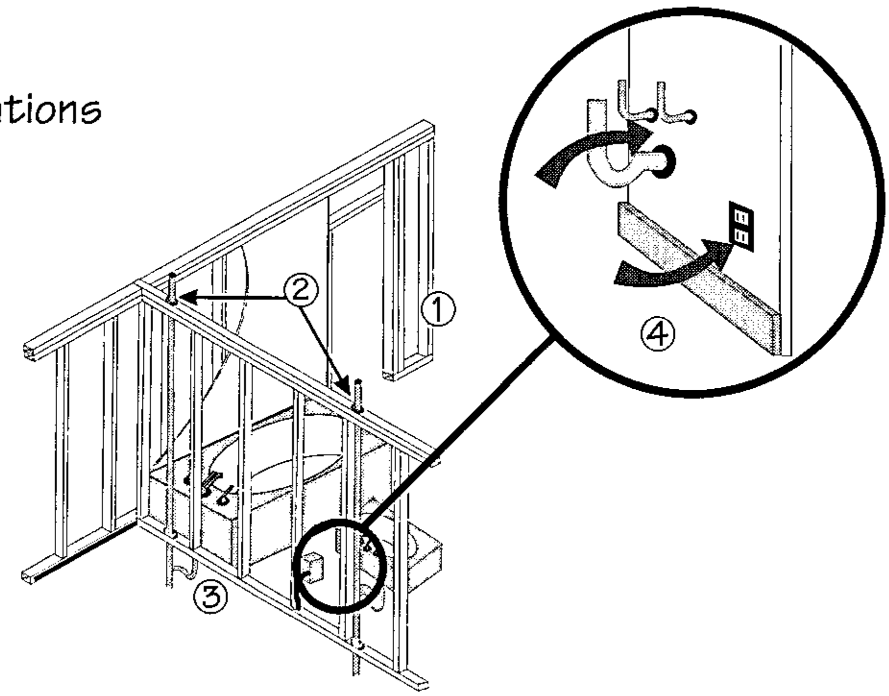


Figure 1-7
Seal electrical penetrations

Seal electrical penetrations

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

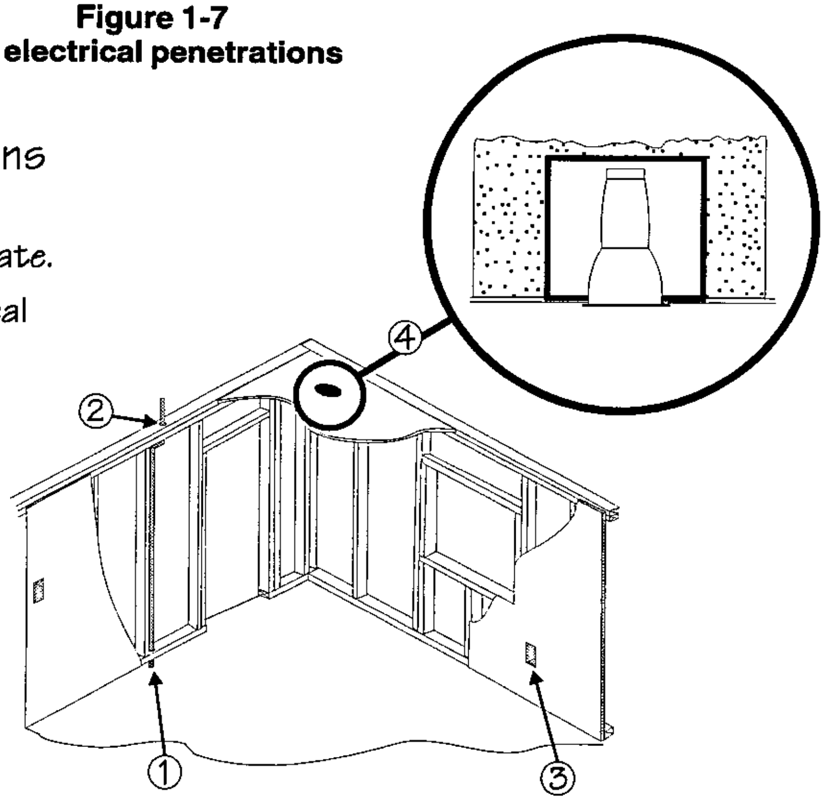
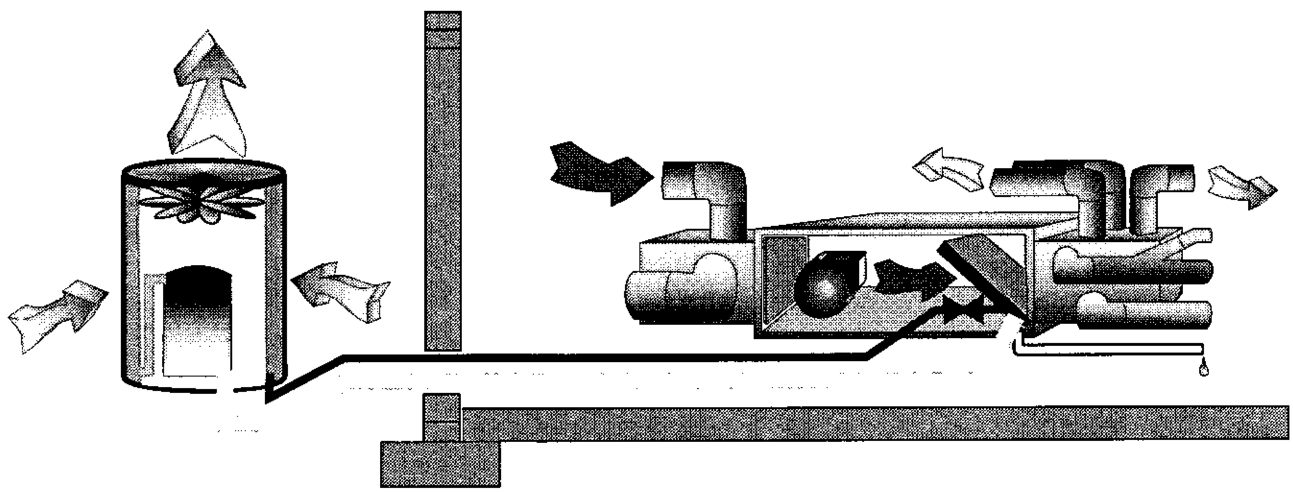
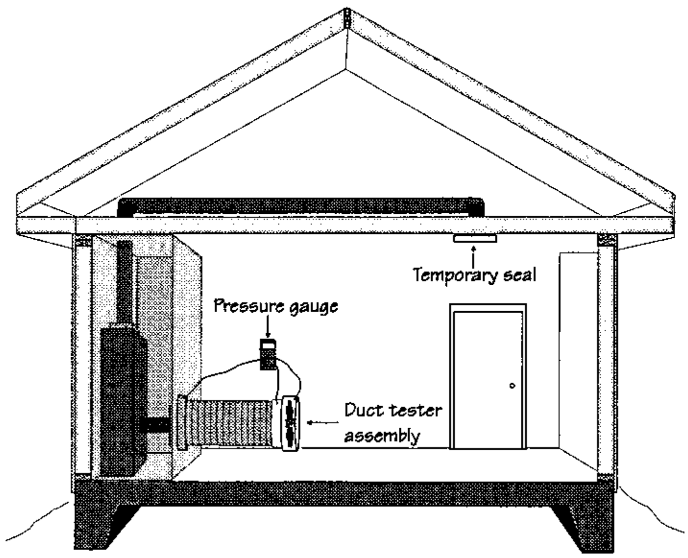


Figure 1-8
HVAC Systems



1. Size for heating and cooling load using Manual J techniques (see Chapter 7).
2. Size latent (dehumidification) load for cooling system.
3. Compare cost and projected energy savings of at least 3 HVAC contractor bids and 3 equipment options:
   a. Minimum efficiency: SEER 10 cooling, AFUE .78 furnace, HSPF 6.8 heat pump
   b. Moderate efficiency: SEER 11 cooling, AFUE .80 furnace, HSPF 7.2 heat pump
   c. High efficiency: SEER 13 cooling, AFUE .90 furnace, HSPF 7.8 heat pump (make sure the Sensible Heating Ratio (SHR) can address the latent loads)
4. Consider automatic zoned system instead of multiple separate systems.
5. When selecting a contractor, do not just go by price, but consider the following:
   a. reputation for quality
   b. type of duct system
   c. number of returns
   d. sound-muffling components
   e. willingness to ensure and test for airtight ductwork

Figure 1-9
Duct Testing System

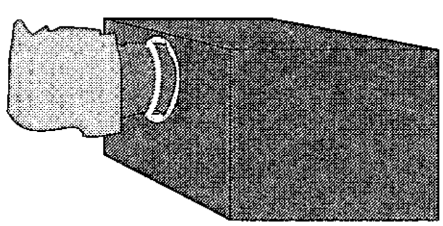


An example of a duct testing system

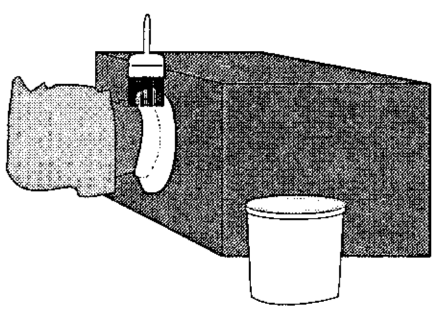
Ductwork

1. Design using Manual D Concepts.
2. Install returns in each room with a closeable door and more than one supply.
3. Seal all duct leaks with mastic or mastic and fiber mesh—use guidelines in Chapter 8.
4. Test ducts for air tightness.
5. Test home for pressure imbalance problems.

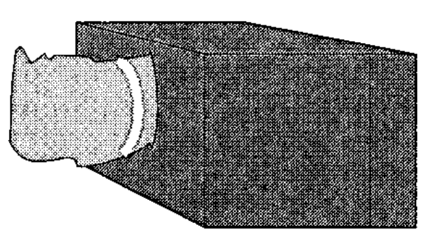
Figure 1-10
Step-by-Step Duct Sealing



Attach flex-duct to take-off collar with strap

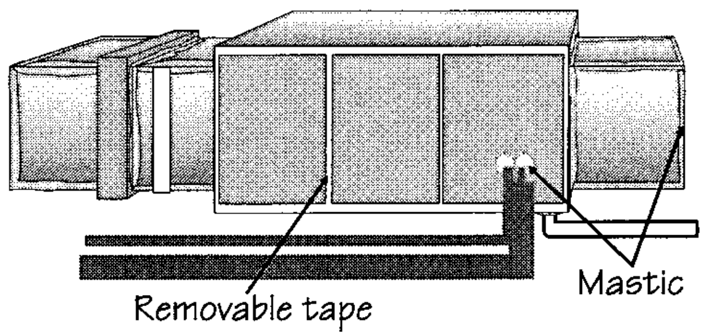


Apply mastic to seal flex-duct to collar and collar to plenum



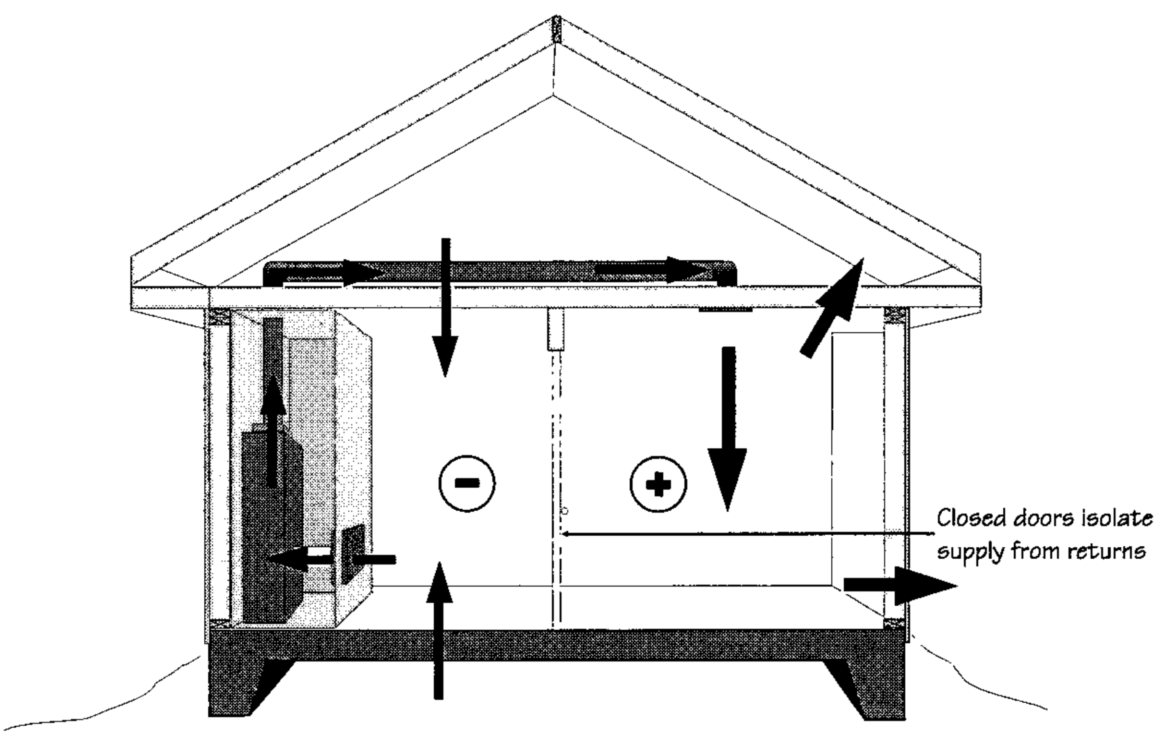
Pull insulation and outer liner over sealed take-off; strap outer liner in place

Figure 1-11
Properly Seal Air Handler



Many air handler cabinets come from the factory with leaks. They should be sealed with duct-sealing mastic. Removable panels should be sealed with cloth or metal duct tape.

Figure 1-12
Prevent Pressure Imbalance Problems



Chapter 2: Why Build Efficiently? 19

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 and make additional profit from the extra construction costs.
- Heating and cooling contractors have fewer call-backs.
- Real estate licensees receive additional fees from the value added features and enhance their reputation by selling higher quality homes that consumers appreciate.
- Bankers receive 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.
- ENERGY STAR® home buyers qualify for more attractive mortgages. Environmental Protective Agency (EPA) Energy Star Homes must be at least 20% more energy efficient than the Florida Energy Code. This is verified through a third-party site energy rating and a performance test. A Home Energy Rating System (HERS) score of 86 or better must be achieved.
- 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.

Achieving Efficiency

Energy efficient buildings 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 result is that buildings fall far short of being efficient, with energy bills higher than necessary, comfort and moisture problems, and owners who are thoroughly dissatisfied—hardly a positive customer relations situation.

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

Building an energy efficient structure does not require 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 areas with potential air leaks.
- ❒ Design and installation of the heating and cooling equipment.
- ❒ Effectiveness of sealing ducts.

Successful builders of energy efficient homes realize the importance of quality. They also know that achieving low energy costs and greater comfort in today's competitive marketplace requires careful planning throughout the design and construction process.

Table 2-1 shows the savings available for a "typical energy efficient home" (i.e., annual energy cost is approximately 30 percent less than a standard 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 2-1
Savings from an Energy Efficient Home

Standard Home		Energy Efficient Home			
Year	Annual Energy Cost	Extra Mortgage Cost	Annual Energy Cost	Total Cost	Cumulative 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.

The Florida Energy Code

The Florida Energy Efficiency Code for Building Construction was first enacted in 1980 and has been revised and updated several times since. Florida's code establishes a minimum standard of energy efficiency. However, because it is a performance code it does not prescribe how to meet that standard. This allows the builder or designer flexibility in deciding how to build an efficient building. Prescriptive methods of meeting the code may be used in some cases, if the builder prefers.

The code establishes a budget of base points for each building using certain optimized "baseline" features (exterior walls, ceilings, and floors, etc.) and the building's actual areas and configuration. The base points are compared to the designed or "as-built" building using multipliers that reflect energy transfer through the same wall, ceiling and floor areas, and equipment efficiencies of the components actually designed for that building.

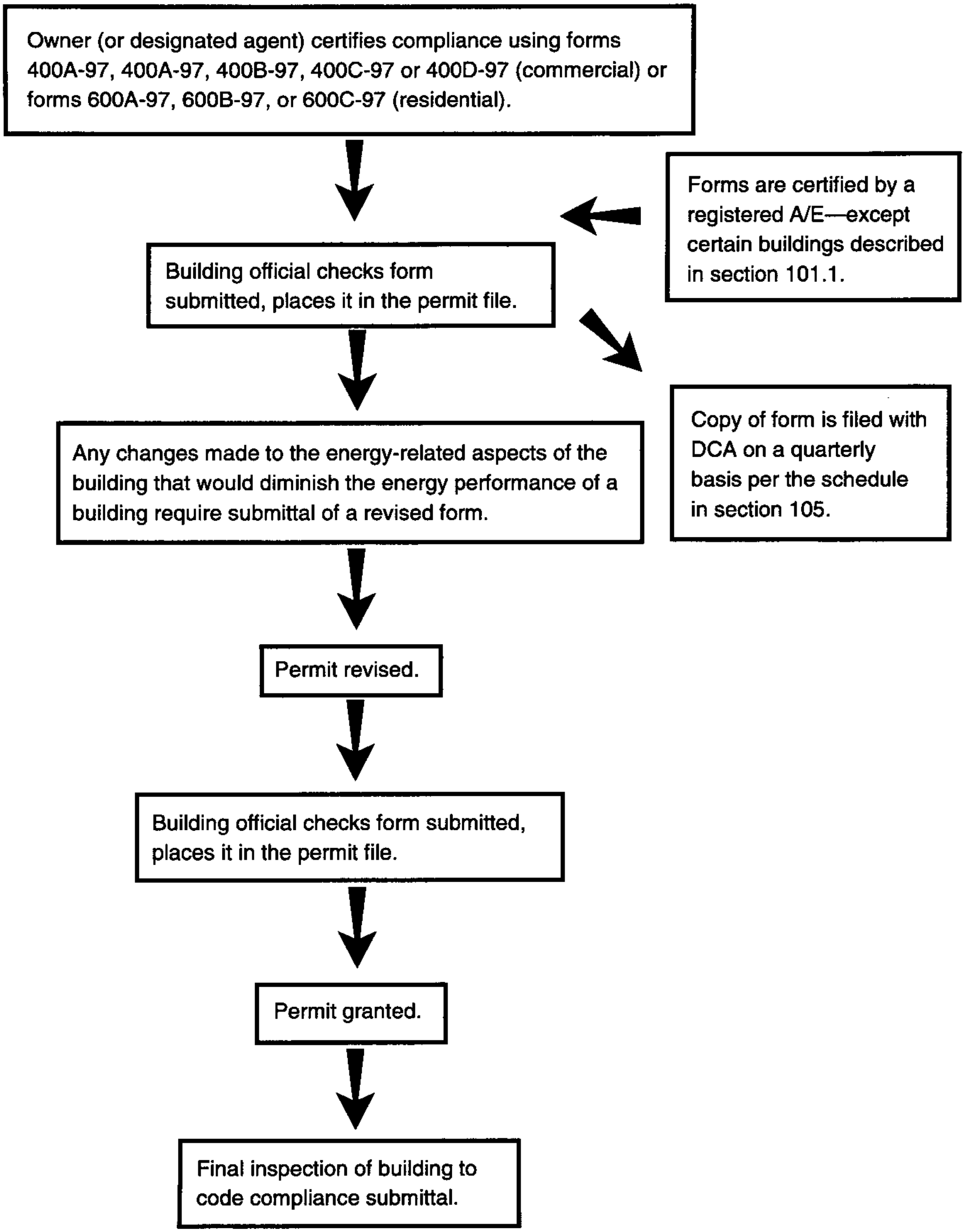
This allows the builder or designer considerable versatility. For example, a more efficient heating and cooling system could be chosen instead of double pane windows, or more windows on the north side of the building and less on the south or west side of the building.

Code Compliance and Permitting

A building's compliance with the Florida Energy Efficiency Code (see Appendix III) should be based on the climate zone where it is located. Once the climate-specific compliance method is chosen, certification is indicated by the forms approved for that method. Figure 2-1 provides an overview of compliance methods.

Refer to the Code to determine who is authorized to prepare and submit Code compliance forms, as well as jurisdictional and climate zone data. The only software approved for determining compliance with the Code is the EnergyGauge software, available from the Florida Solar Energy Center (see p. 22 for address).

Figure 2-1
Code Compliance Flow Chart



Florida Building Energy-Efficiency Rating System

The Florida Building Energy-Efficiency Rating Act, as amended in 1998, provides for a statewide uniform system for rating the energy efficiency of buildings. This rating system is based on the building's annual energy usage and costs with consideration to local climate conditions, construction practices, and building use.

The energy rating for new and existing *residential* buildings shall be determined using the Florida Residential Building Energy Rating System software (EnergyGauge/ResFREE, Version 2). The energy rating for new *public* and new and existing *commercial* buildings shall be determined using the Florida Commercial Building Energy Rating System software (EnergyGauge/ComFREE 97, Version 2.2). The EnergyGauge software is developed and maintained by the Department of Community Affairs, which produces the Florida Building Rating Guide forms. Figure 2-2 illustrates how all compliance and rating elements are organized within the EnergyGauge program.

The rating system software can be obtained from:

Florida EnergyGauge Program
Florida Solar Energy Center
1679 Clearlake Road
Cocoa, Florida 32922-5703
Phone: (321) 638-1492
email: energygauge@fsec.ucf.edu
Web site: http://www.fsec.ucf.edu

Financing Energy Efficiency

A useful tool is now available in Florida 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 help make it easier for homebuyers to qualify for energy efficient homes or to afford a more costly home at a given income.

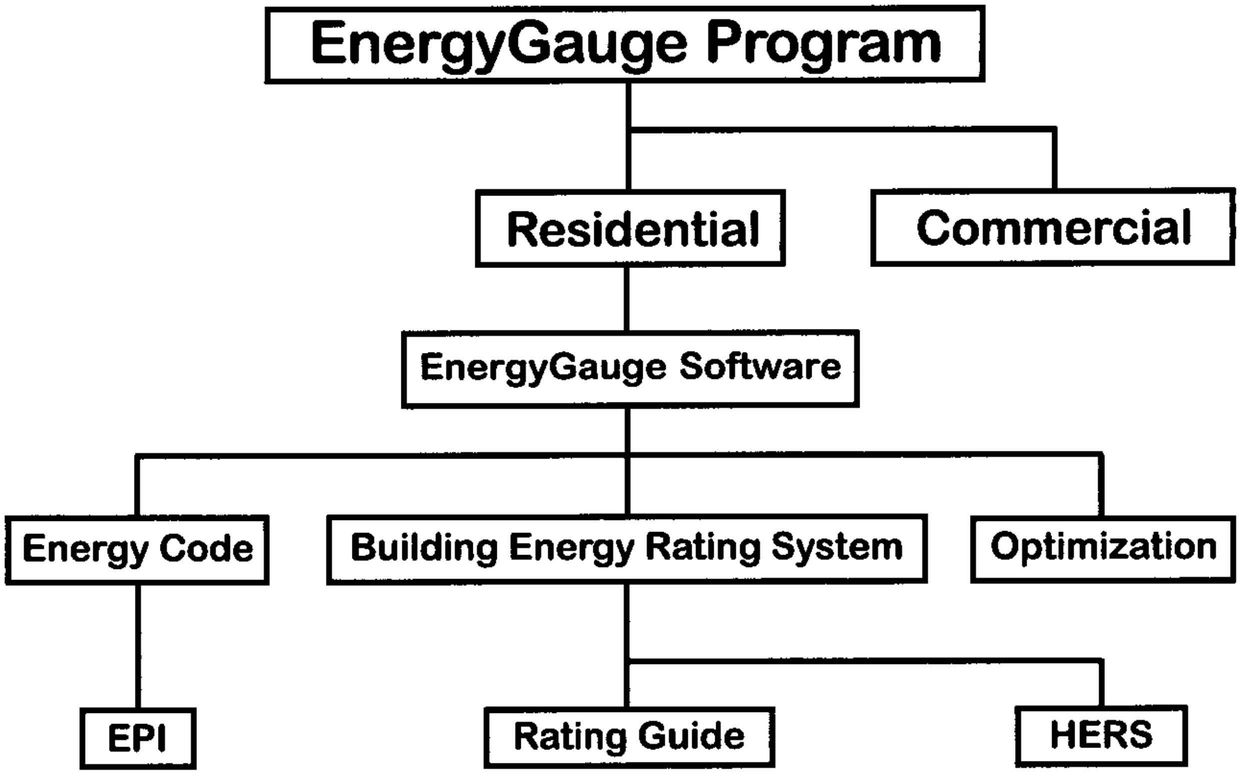
For example, preferred terms for homebuyers purchasing ENERGY STAR® Homes through an ENERGY STAR® Mortgage can include:

- ❐ 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 Florida, contact your lending institution.

Figure 2-2
EnergyGauge Program Organization



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 are 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)

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

Lifetime of Energy Investments (Years)

Payback (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.

Chapter 3: The Building as a System

We sometimes think of buildings as independent structures, placed on an attractive lot, and lived in without regard to the world around. Yet, most buildings have problems—some simply minor nuisances, others life-threatening:

- ❒ Mold on walls, ceilings, and furnishings
- ❒ Mysterious odors
- ❒ Excessive cooling and heating 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 building to properly react to the outdoor or indoor environment. The building 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 building 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 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 building. Higher velocities make occupants more comfortable in summer, but less comfortable in winter.
- Structural integrity—the ability of the materials that make up the building to create a long-term barrier between the exterior and inside.

Concepts

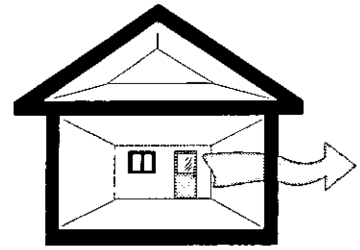
Heat Flows in Buildings

Health and comfort factors are determined considerably by how readily heat moves through a building and its exterior envelope. The next page explains the three primary modes of heat transfer.

HOW HEAT MOVES

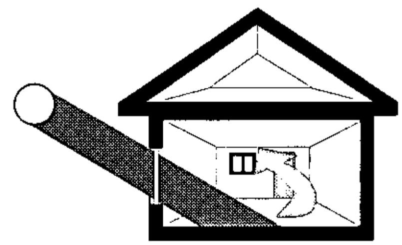
CONDUCTION

Figure 3-1
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.

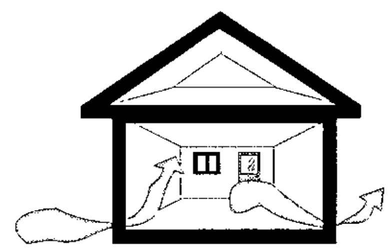
Figure 3-2
Convection



CONVECTION

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

Figure 3-3
Air Leakage



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

RADIATION

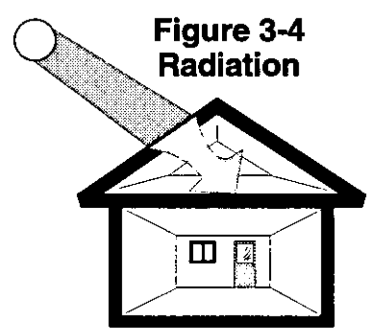


Figure 3-4
Radiation

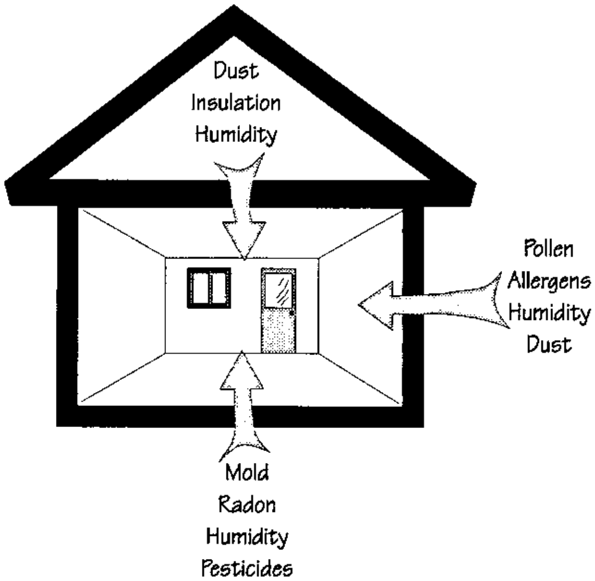
- The net movement of radiant energy from warmer to cooler objects across empty spaces (like warmth from a fireplace).
- Examples include radiant heat traveling from:
  - inner panes of glass to outer panes in double-glazed windows in winter
  - roof deck to attic insulation during hot, sunny days
- Radiant energy exchange can be minimized by installing reflective barriers; examples include radiant heat barriers in attics and low-emissivity coatings for windows.

Air Leaks and Indoor Air Quality

Both building professionals and building occupants have concerns about indoor air quality. It is important to understand that few studies on the subject have shown a strong relationship between indoor air quality and the air tightness of a building.

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

Figure 3-5
Air Quality Problems from "Fresh" Air



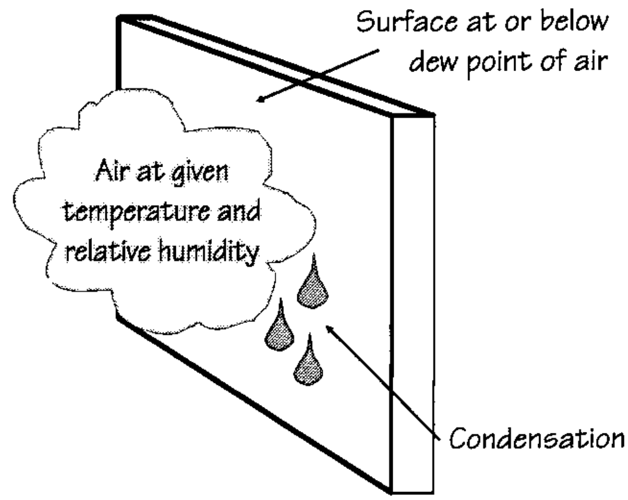
Air leaks often bring in air quality problems from attics, the outside, and crawl spaces (Figure 3-5), such as:

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

The best solution to air quality problems is to construct a building as tightly as possible and install an effective ventilation system that can bring in fresh outside air (not crawl space or attic air). Ventilation system design options and indoor air quality are described in greater detail in Chapter 7.

Relative Humidity and Water Condensation

Figure 3-6
Conditions for Condensation



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 holds more vapor than cold air. The amount of water vapor in the air is measured by its relative humidity (RH). At 100% RH, water vapor condenses into a liquid. The temperature at which water vapor condenses is its dew point.

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 (see next page). Preventing condensation involves reducing the RH of the air or increasing the temperatures of surfaces exposed to the air.

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

Effect of Relative Humidity

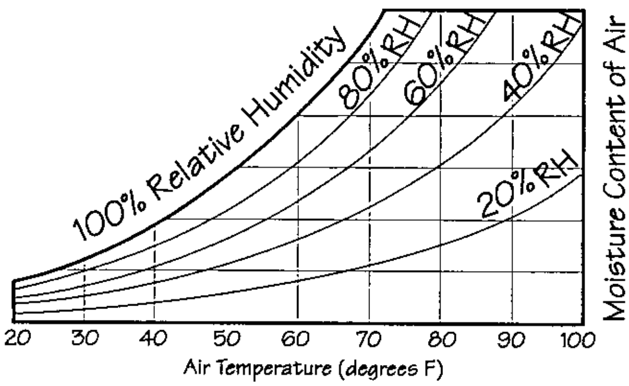
People respond dramatically to changes in relative humidity:

- ❑ 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°.
- ❑ Dry air can often aggravate respiratory problems.
- ❑ Molds grow in air over 70% RH.
- ❑ Dust mites prosper at over 50% RH.
- ❑ Wood decays when the RH is near or at 100%.
- ❑ People are most comfortable at 30% to 50% RH.

MOISTURE AND RELATIVE HUMIDITY

A psychrometric chart aids in understanding the dynamics of moisture control. A simplified chart shown in Figure 3-7 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.

Figure 3-7
Psychrometric Chart



Winter Condensation in Walls

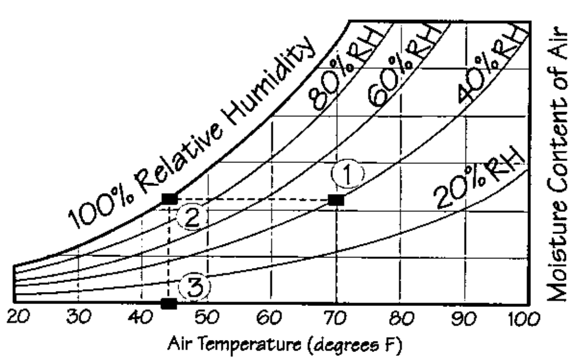
In a well built wall, the temperature of the inside surface of the sheathing will depend on the insulating value of the sheathing, and the indoor and outdoor temperatures. When it is 35°F outside, and 70°F at 40% relative humidity inside:

- 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 3-8, find the point representing the indoor air conditions (70°F).
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.

Fig 3-8
Winter Dewpoint Temperature Inside Walls

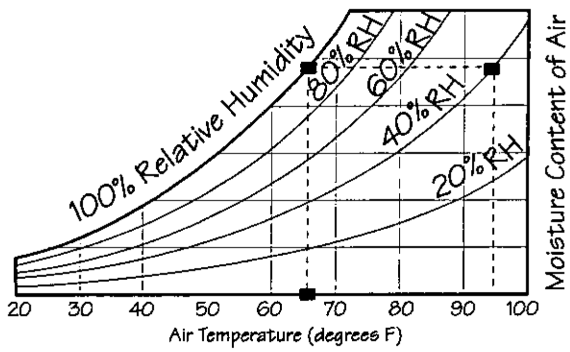


In the example, condensation would occur if the temperature of the inside surface of the sheathing were at 44°F. Thus, under the temperature conditions in this example, water droplets may form on the plywood sheathing, but not on the insulated sheathing.

SUMMER CONDENSATION IN WALLS

Figure 3-9 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 3-9
Summer Dewpoint Temperature Inside Walls



Systems in a Building

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

- ❑ Structural system
- ❑ Moisture control system
- ❑ Air barrier system
- ❑ Thermal insulation system
- ❑ HVAC system

STRUCTURAL SYSTEM

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

- ❑ 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 designer and builder should:

- ❑ Ensure the roof is watertight to prevent rainwater intrusion. Provide diverters or gutters and downspouts to direct water away from entries and walkways. If gutters are used, make sure that they are properly designed to handle Florida's frequent and heavy rainfall. (The owner should clean them regularly.) Gutters should be attached so that water cannot enter the fascia or spike penetrations, which should be carefully sealed. Good use of diverters and overhangs can eliminate the need for gutters.

- ❐ Divert ground water away from the building through proper grading and install effective gutters and downspouts.
- ❐ 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.

Moisture Control System

Buildings 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.

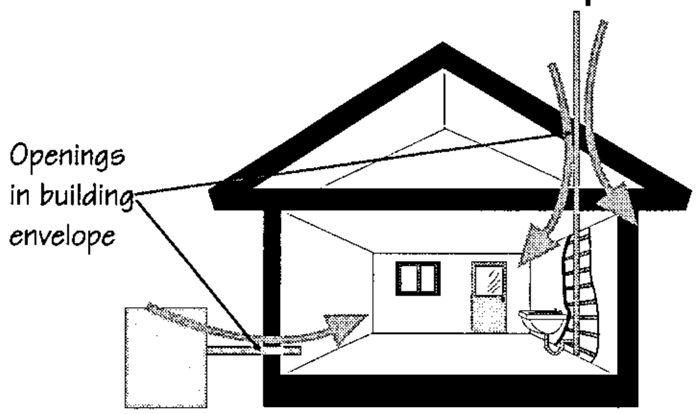
The moisture control system includes quality construction to shed water from the building and its foundation, vapor and air barrier systems that hinder the flow of air infiltration and water vapor, and cooling and heating systems designed to provide comfort throughout the year.

There are four primary modes of moisture migration into buildings. 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 (Figure 3-10)
- ❒ 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

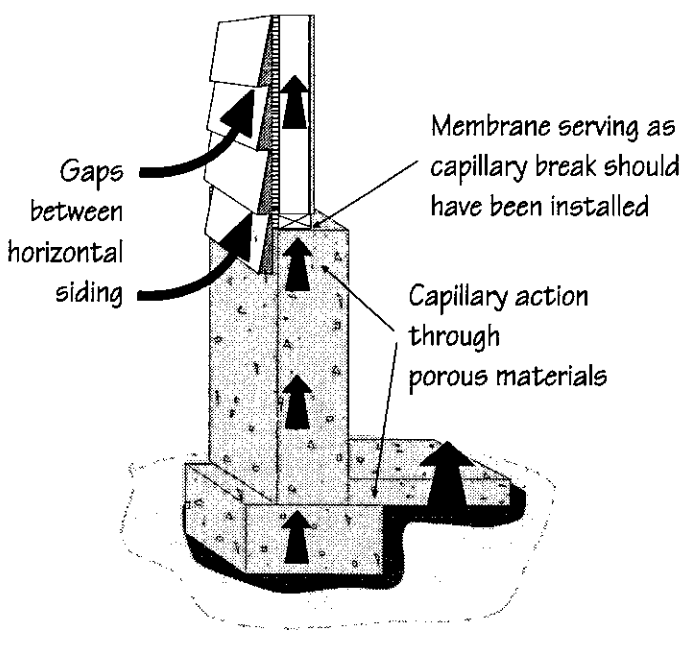
Figure 3-10
Bulk Moisture Transport



Capillary action (Figure 3-11)

- ❒ 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 waterproof, vapor barrier material to form a capillary break

Figure 3-11
Capillary Action



Air transport

- ❒ Unsealed penetrations and joints between conditioned and unconditioned areas allow air containing water vapor to flow into enclosed areas. 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

Vapor diffusion

- ❒ Water vapor in air moves through permeable materials (those having Perm ratings over 1, see Table 3-1)
- ❒ Primary source is water vapor in the air
- ❒ Causes:
  - exterior moisture moving into the building in summer
  - interior moisture permeating wall and ceiling finish materials
  - moist crawl space air migrating into the building
- ❒ Least important of the four modes of moisture migration

Table 3-1
Perm Ratings of Different Materials

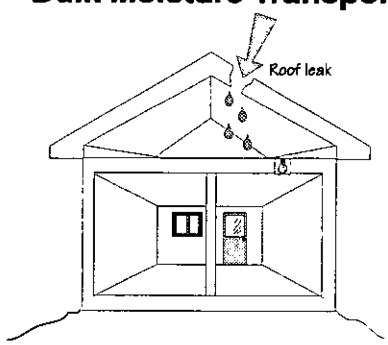
Aluminum foil (.35 mil)	0.05
Polyethylene plastic (6 mil)	0.06
Plastic-coated insulated foam sheathing	under 0.30
Asphalt-coated paper backing on insulation	0.40
Vapor barrier paint or primer	0.45
Plywood with exterior glue	0.70
Drywall (unpainted)	50.0

MOISTURE PROBLEM EXAMPLE

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

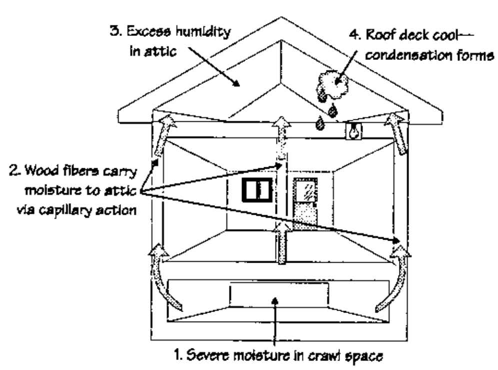
What type of moisture problem may be causing the mildew growth, which requires relative humidities over 70%? In reality, any of the forms of moisture transport could cause the problem:

Figure 3-12
Bulk Moisture Transport



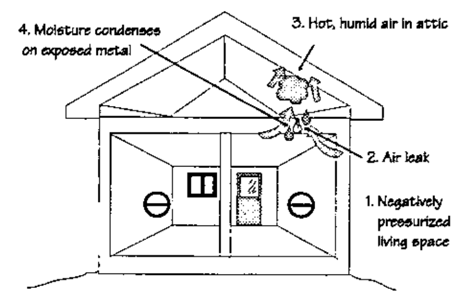
Bulk moisture transport—the home may have roof leaks above the recessed lamps.

Figure 3-13
Capillary Action



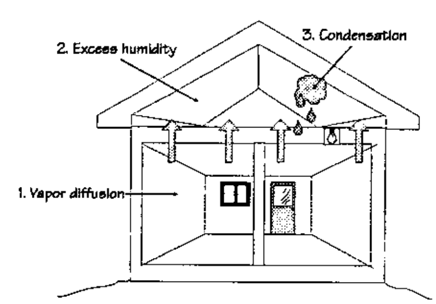
Capillary action—the home may have a severe moisture problem in its crawl space or under the slab. Moisture travels up the slab via capillary action into the framing lumber, and all the way into the attic. If the attic air becomes sufficiently moist, it may condense on the surface of the cool roof deck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

Figure 3-14
Air Transport



Air transport—most recessed lamps are quite leaky; if the living space is negatively pressurized, hot humid air can be drawn from the attic to the living space. As the air come into contact with the metal can lip that is in air-condtioned space, water vapor condenses on the exposed surface. This is the most likely explanation.

Figure 3-15
Vapor Diffusion



Vapor diffusion—the least likely explanation.

AIR BARRIER SYSTEM

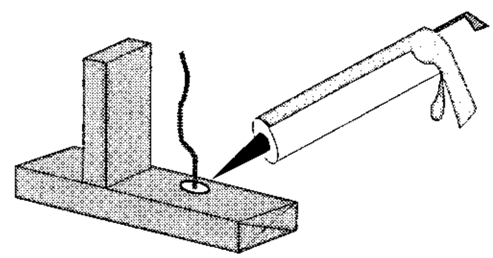
Air leakage can be detrimental to the long term durability of buildings. It can also cause a substantial number of other problems, including:

- 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

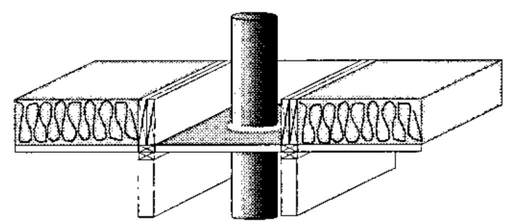
An air barrier system may sound formidable (Figure 3-16), but it is actually a simple concept—seal all leaks between conditioned and unconditioned spaces with durable materials. Achieving success can be difficult without diligent efforts, particularly in buildings with multiple stories and changing roof lines.

Air barriers may also help a building 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.

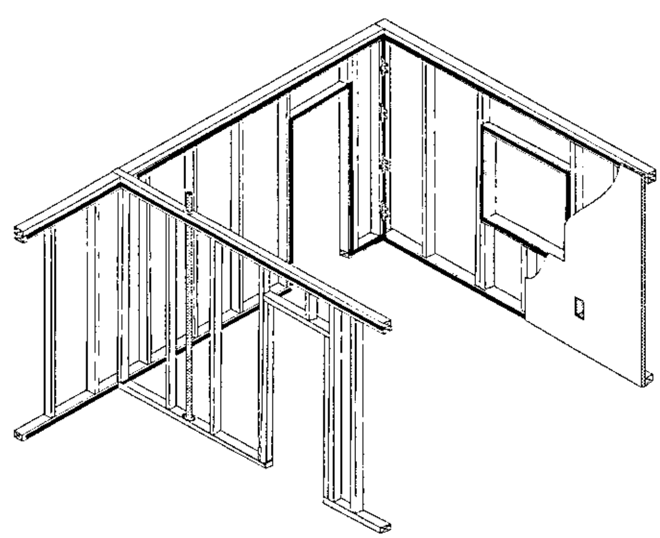
Figure 3-16
Air Barrier System Requirements



Seal all penetrations



Seal all penetrations through ceilings, walls, and floors



Install continuous air barrier system

Chapter 4 describes air barrier systems—which can be effective with proper installation. They are one of the key features of an energy efficient building. 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 building.
- ❒ Install a continuous air barrier material such as the airtight drywall approach or continuous air barrier system.

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 building 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 the Florida Energy Efficiency Code.
- ❑ 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.
- ❑ 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 summer and winter. Energy efficient buildings, particularly passive solar designs, can reduce the number of hours during the year when the HVAC system is needed.

These systems are often not well designed and may not be installed to perform as intended. As a consequence, buildings often suffer higher heating and cooling bills and have 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 building. The side-bar 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. (See "Carbon Monoxide Disaster, pp. 46–47, for more detail.)

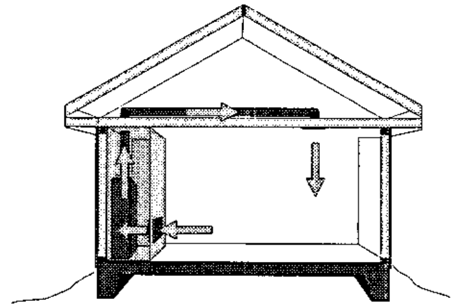
Pressure imbalances can increase air leakage, which may draw additional moisture into the building. Proper duct design and installation helps prevent pressure imbalances from occurring.

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.

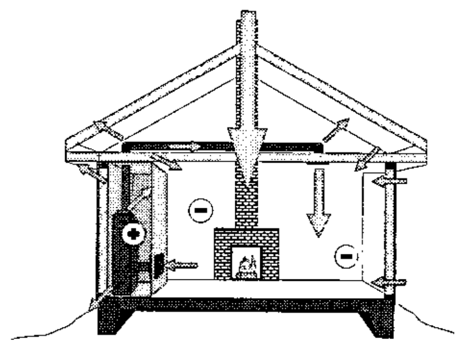
Figure 3-17
Balanced Air Distribution



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 building, so the pressure inside the building 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.

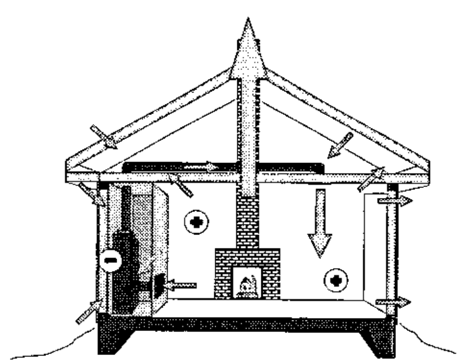
Figure 3-18
Air Leaks in Supply Ducts



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 system ducts 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.

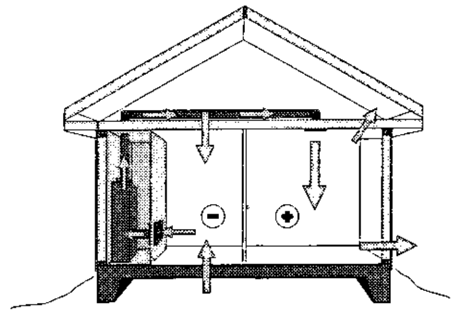
Figure 3-19
Air Leaks in Return System



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.

Figure 3-20
Return Blocked by Door



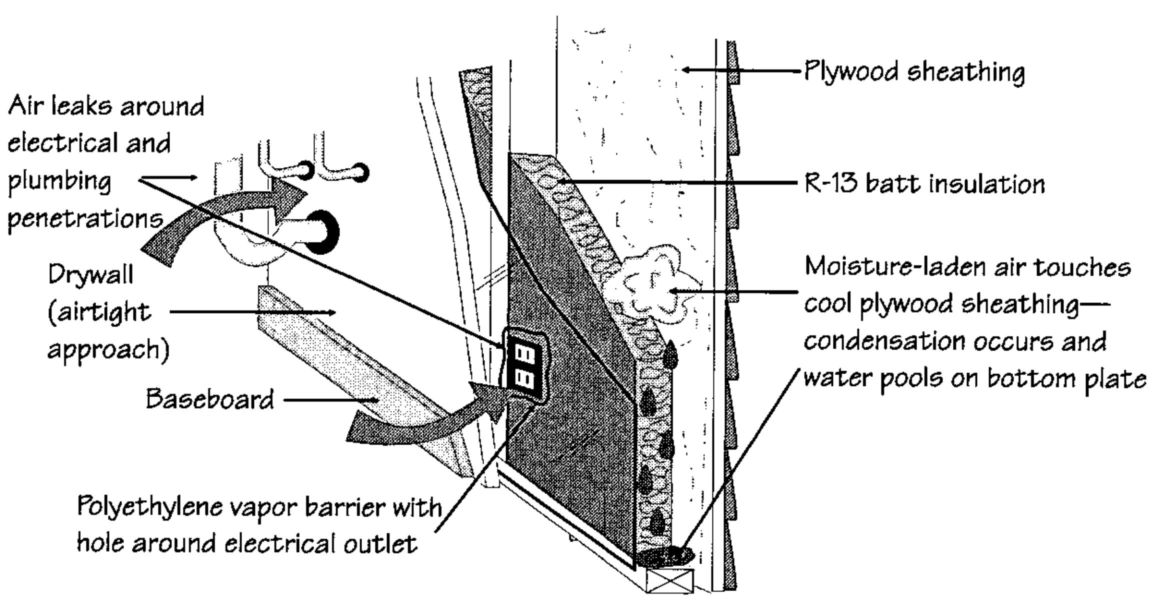
WALL MOISTURE EXAMPLE

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 bathroom has no return air duct, its door is usually closed and is not undercut at the bottom. Therefore, when the heating and cooling system operates the room becomes pressurized. This is an 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 barrier, which was installed by a builder using Northern building construction techniques. The exterior wall has CDX plywood sheathing, which also can serve as a vapor barrier.

Figure 3-21
Wall Moisture Example



6. When the air leaks carry water vapor into the wall cavity, the two vapor barriers 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 worsen.

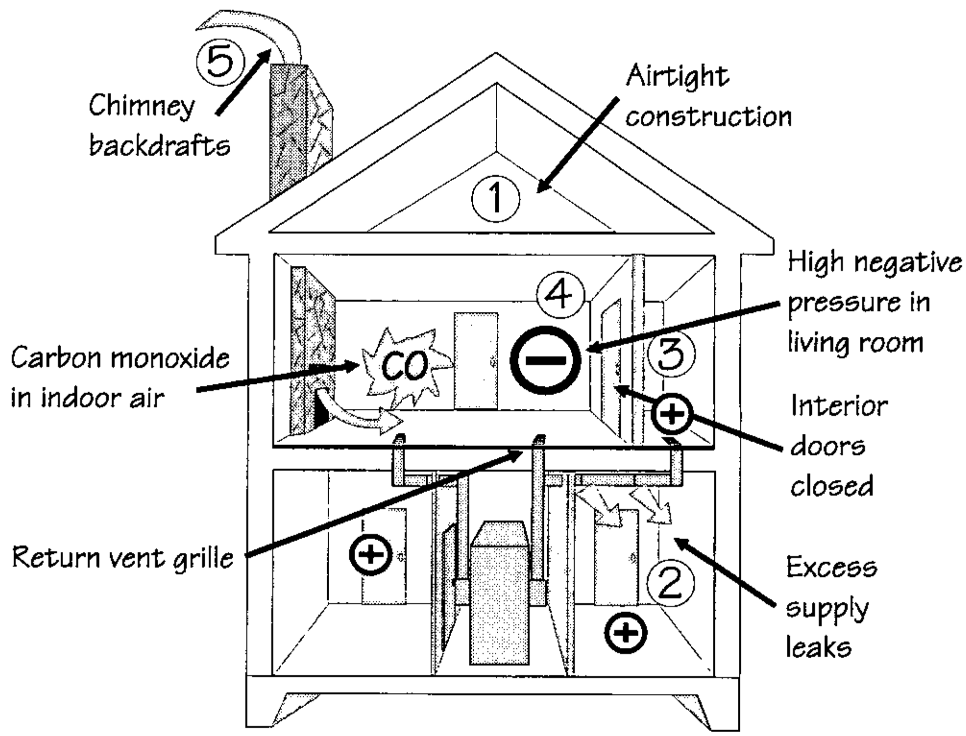
CARBON MONOXIDE DISASTER

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.

Figure 3-22
Carbon Monoxide Example



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 building 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 Florida homes each year. Comparable conditions can also occur with gas-fired hot water heaters. The solution to the problem is not to build leakier homes — they can experience similar pressure imbalances. Instead, eliminate the causes of pressure imbalances, as described in detail in Chapter 7, and install an external source of combustion air for the fireplace.

Chapter 4: Air Leakage - Materials and Techniques

See Sections 406 and 606—Air Infiltration requirements

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

- ❑ Contribute to over 30% of the cooling and heating costs
- ❑ Create comfort and moisture problems
- ❑ Pull pollutants such as radon and mold into buildings
- ❑ Serve as easy access for insects and rodents

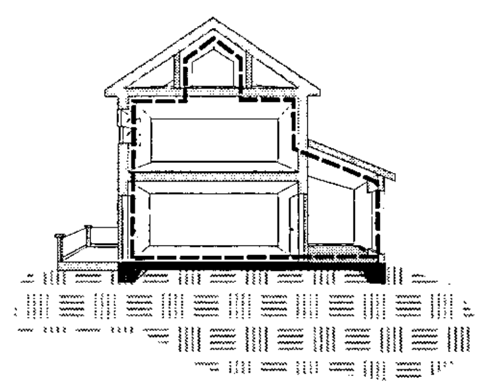
To reduce air leakage effectively requires a *continuous air barrier system*—a combination of materials linked together to create a tight **building envelope** (Figure 4-1). An effective building envelope should form both a continuous air barrier and an insulation barrier (insulation is discussed in detail in Chapter 5). An air barrier 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 building and the unconditioned area. Most standard insulation products are not effective at sealing air leakage. The R-value for these products 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 his or her own crew and subcontractors to seal all penetrations through the envelope. Then, continuous material should be installed around the envelope. It is critical in the air sealing process to use durable materials and install them properly.

Figure 4-1
Creating a Continuous Air Barrier System



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

Infiltration Control

The Florida Energy Code describes the prescriptive requirements for Air Infiltration in Exterior Doors and Windows, Exterior Joints in the Envelope, Exterior Doors and Adjacent Walls, Floors, Ceilings, Recessed Lighting Fixtures, and Building Cavities.

An infiltration barrier shall provide a continuous air barrier from the foundation to the top plate of the ceiling and shall be sealed at the foundation, the top plate, at openings in the wall plane (windows, doors, etc.) and at the seams between sections of infiltration barrier material. When installed on the interior side of the walls, such as with insulated face panels with an infiltration barrier, the infiltration barrier shall be sealed at the foundation or subfloor. This prevents wind from circulating air within the insulation. If properly sealed at the seams and ends, plywood and builder's felt will serve as an infiltration barrier, but not as a moisture retardant. A vapor barrier/retarder will essentially stop moisture transmission or diffusion. Common vapor barriers or retarders are 6-mil polyethylene sheet and aluminum foil-backed paper or boards. **Contrary to northern construction practices, a vapor barrier, including vinyl wall coverings, installed next to the conditioned space is not recommended.** Otherwise, water may condense on the vapor retarder surface within the wall cavity when the inside temperature is below the outside dew point in the summer. This could wet and degrade insulation, deteriorate wall components, and contribute to mold and mildew. **Vapor barriers are not recommended on the conditioned side of walls in Florida buildings**. The ASHRAE 1993 Fundamentals Handbook does not recommend vapor barriers at all in Florida. Check with your local Building Code before including a vapor barrier.

Air Barriers

Housewraps serve as exterior air barriers and 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 affixed and sealed to the wall between the sheathing and exterior finish material (Figure 4-2). 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 airtight drywall approach. Housewraps are 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 (Figure 4-3). Careful sealing of all seams and penetrations is required.

Figure 4-2
Housewrap Installation Details

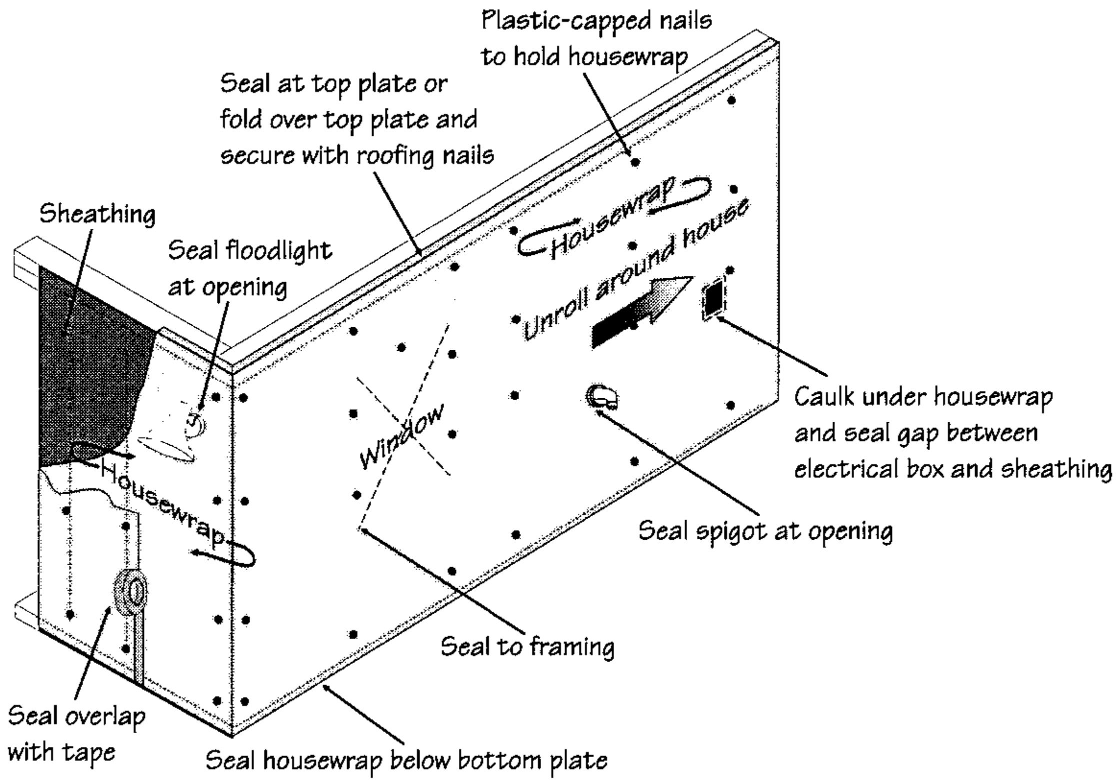
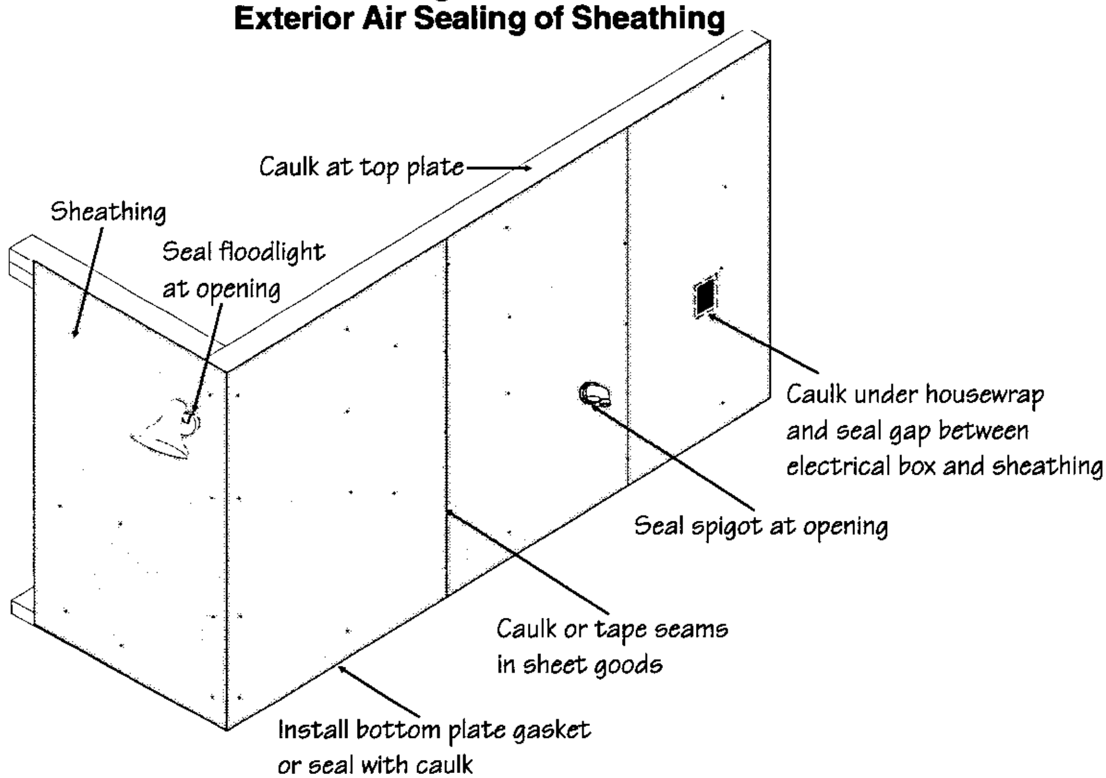


Figure 4-3
Exterior Air Sealing of Sheathing



Materials

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

Use a combination of these different air sealing materials:

Caulk—Use to seal gaps less than ½". Select grade (interior, exterior, high temperature) based on application.

Spray foam—Expands to fill large cracks and small holes. It can be messy; consider new, water-based foams. **Not** recommended near flammable applications (flue vents, etc.). Also not permitted around PVC pipe. May be prohibited around windows by window manufacturer.

Gaskets—Can be applied under the bottom plate before an exterior wall is raised, or used to seal drywall to framing.

Housewrap—Installed between the sheathing and exterior finish material. Must be sealed with tape or caulk to form an airtight seal. Resists liquid water and is *not* a vapor barrier.

Sheet goods (plywood, drywall, rigid foam insulation)—These are solid materials which form the building envelope. Air will only leak at the seams or through unsealed penetrations.

Sheet metal—Used with high temperature caulk for sealing high temperature components, such as flues, to framing.

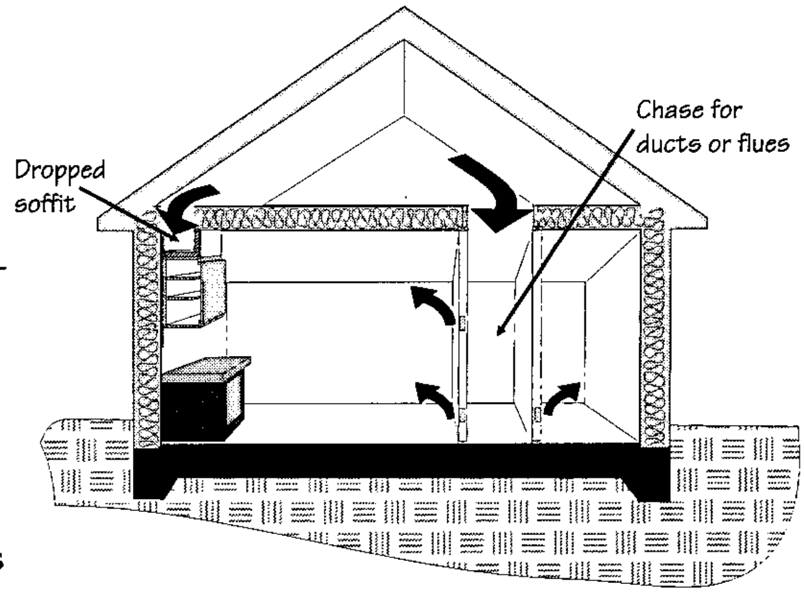
Polyethylene plastic—Inexpensive material for airsealing that also stops vapor diffusion. Must have all edges and penetrations sealed to be effective air barrier. This material is recommended for use under slabs. Incorrect application in wall cavities can lead to mold and mildew problems.

Weatherstripping—Used to seal moveable components, such as doors and windows.

Do not rely on the insulation—The most common insulation, fiberglass, does not stop air leakage. In older houses, dirty fiberglass is a telltale sign of air movement (it simply acts as a filter). Certain types of insulation, such as dense-packed cellulose and urethane foams, can be effective at reducing air flow.

Seal Penetrations and Bypasses

Figure 4-4
Air Leakage Through Bypass



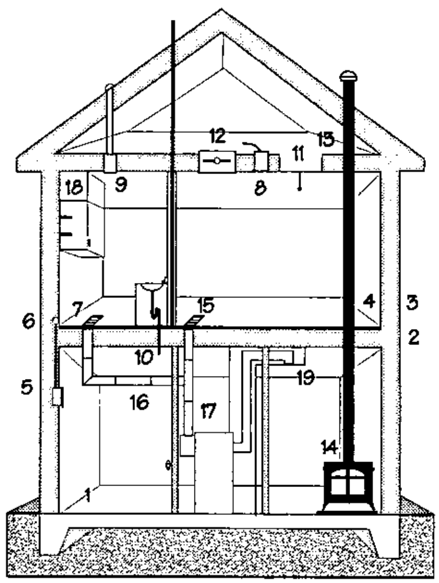
The first step for successfully creating an air barrier system is to seal all of the holes in the building envelope. Too often, builders concentrate on air leakage through windows, doors, and walls, and ignore areas of much greater importance. Many of the key sources of leakage—called *bypasses* (Figure 4-4) are hidden from view behind soffits for cabinets, bath fixtures, dropped ceilings, chases for flues and ductwork, recessed lighting fixtures, or insulation. Attic access openings and whole house fans are also common bypasses. Sealing these bypasses is critical to reducing air leakage in a building and maintaining the performance of insulation materials. Table 4-1 provides examples of commonly used sealants for various types of leaks.

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 foam sheathing material that covers the entire opening. Seal penetrations. If a flue requires a non-combustible clearance, use a noncombustible metal collar, sealed in place, to span the gap.
Final air barrier material	Install airtight drywall approach or other air barrier system.

The guidelines that follow in Figure 4-5 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 4-5
Typical Home Air Leakage Sites



1. *Slab Floors*—If a house is to be constructed on a concrete slab, a vapor barrier of plastic sheeting should be placed under the slab. Without a vapor barrier, moisture will migrate from the ground through the porous slab and into the house. If a house is to be built off-grade, a sheet of 6-mil polyethylene plastic should always be placed directly on the ground under the house to prevent moisture from moving upward from the soil.

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 contact. Ensure fixtures meet appropriate fire codes.

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 sealant or caulk.

11. *Attic Access in Conditioned Spaces*—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 (Figure 4-7).

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.

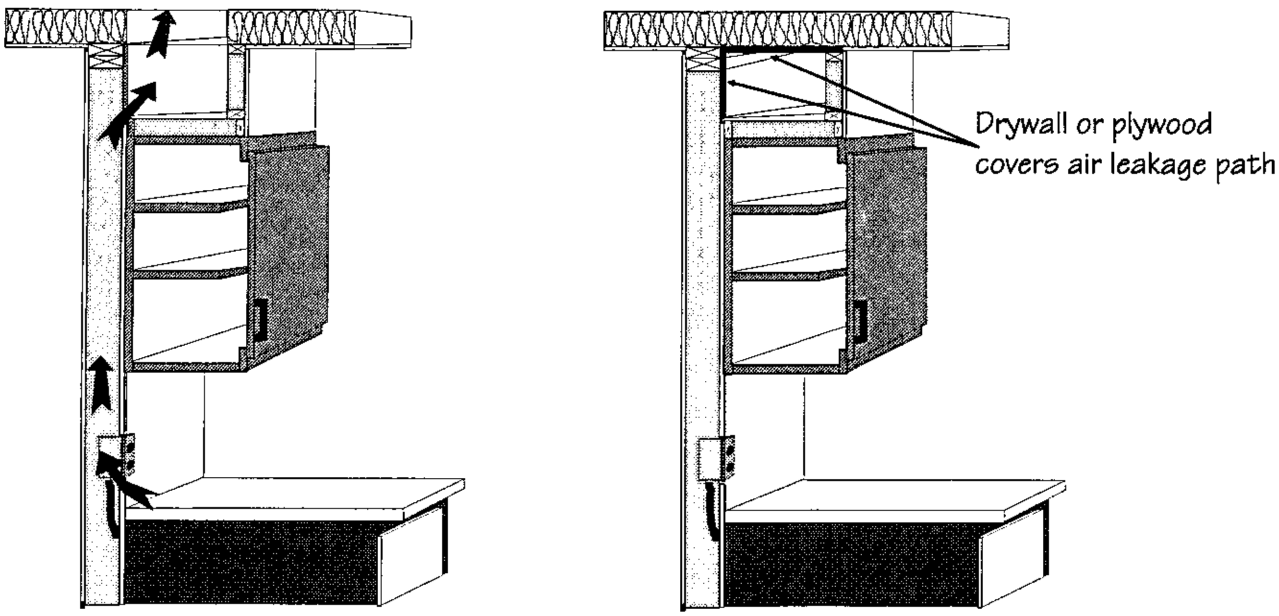
16. *Ductwork*—seal all joints in supply and return duct systems with mastic. Mechanically attach duct systems to prevent dislocation and massive leakage.

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 (See Figure 4-6 for more details).

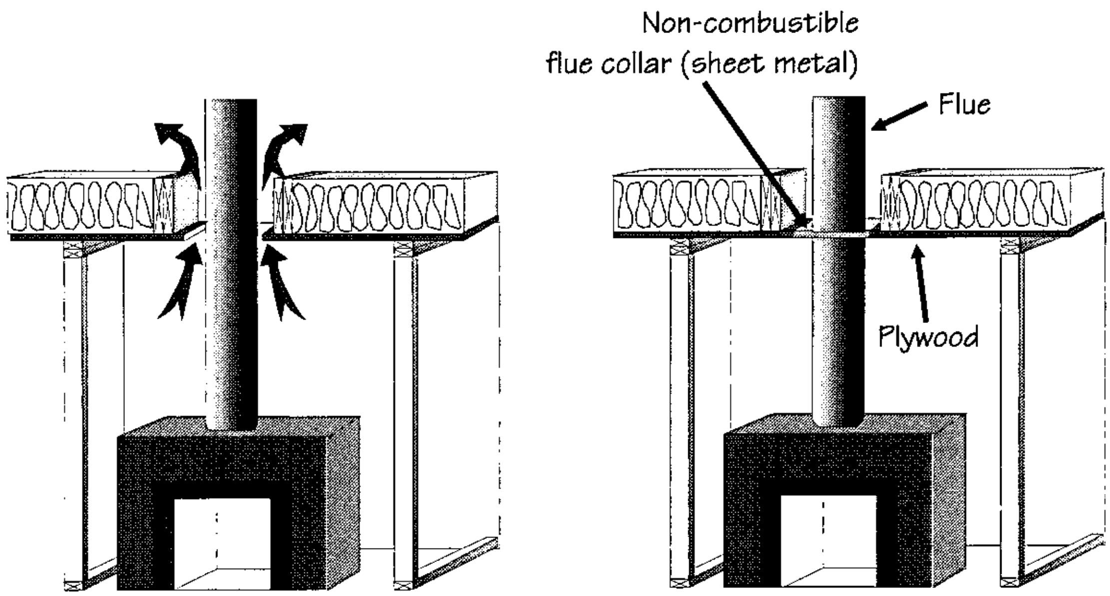
19. *Chases* (for ductwork, flues, etc.)—prevent air leakage through these bypasses with sheet materials and sealants (See Figures 4-7 and 4-8 for more details).

Figure 4-6
Sealing Ceiling Soffit



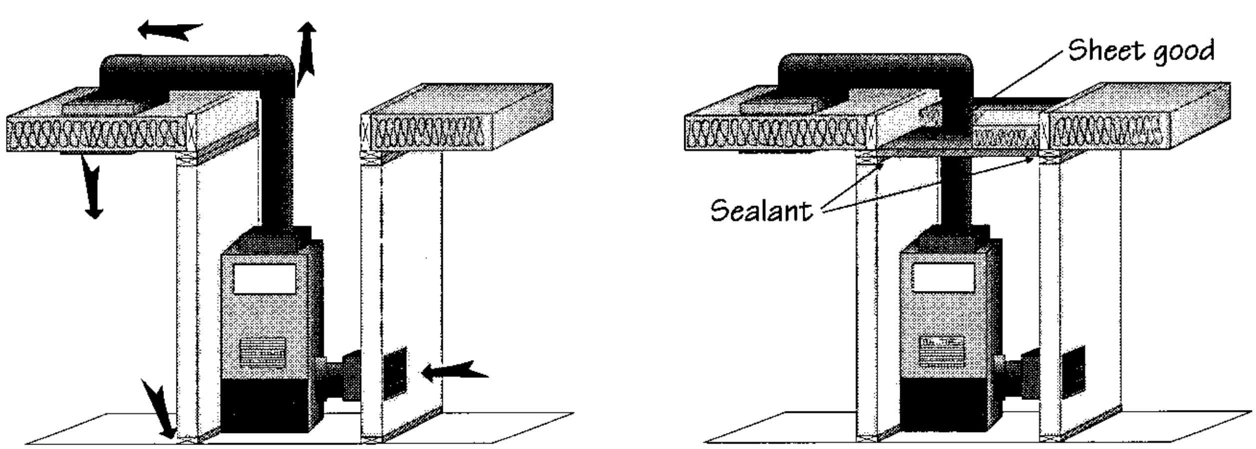
Dropped ceiling soffit - If kitchen or bath/shower enclosures have dropped soffits, provide a continuous seal at the attic floor.

Figure 4-7
Sealing Bypasses for Flues



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.

Figure 4-8
Sealing Bypasses for Ductwork



Return and supply plenums - Seal framed areas for ductwork

AIR LEAKAGE DRIVING FORCES

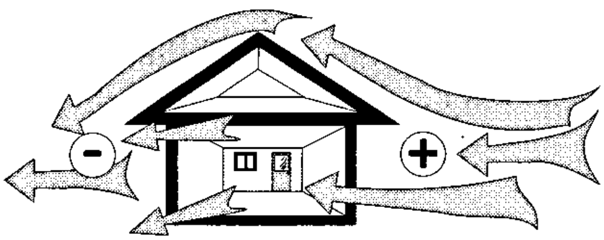
Requirements for air leakage to occur:

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

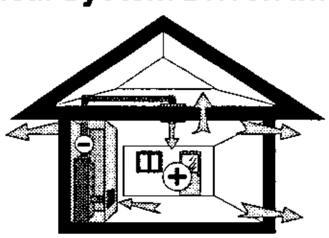
Figure 4-9
Wind Driven Infiltration



On average, wind in the Southeast creates a pressure difference of 10 to 20 Pascals on the windward side.

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.

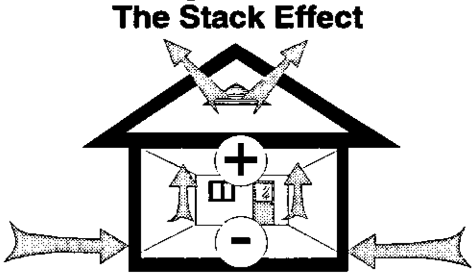
Figure 4-10
Mechanical System Driven Infiltration



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.

Poorly designed and installed forced-air systems can create strong pressure imbalances inside the building, 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 building. Correcting duct leakage problems is critical when constructing an energy efficient building.

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.

The temperature difference between inside and outside causes warm air inside the building to rise while cooler air falls, creating a driving force known as the *stack effect*. The stack effect is weak but always present. Most buildings have large holes into the attic and crawl space. 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.

MEASURING AIRTIGHTNESS WITH A BLOWER DOOR

While there are many well known sources of air leakage, virtually all buildings 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 (Figure 4-12).

One measure of a building'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 (Table 4-2).

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 less than 5 air changes per hour at 50 Pascals pressure (ACH50).

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

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
Older, leaky home	20.0 - 50.0

Figure 4-12
Blower Door

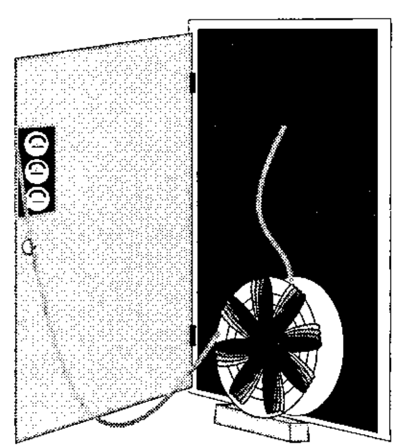
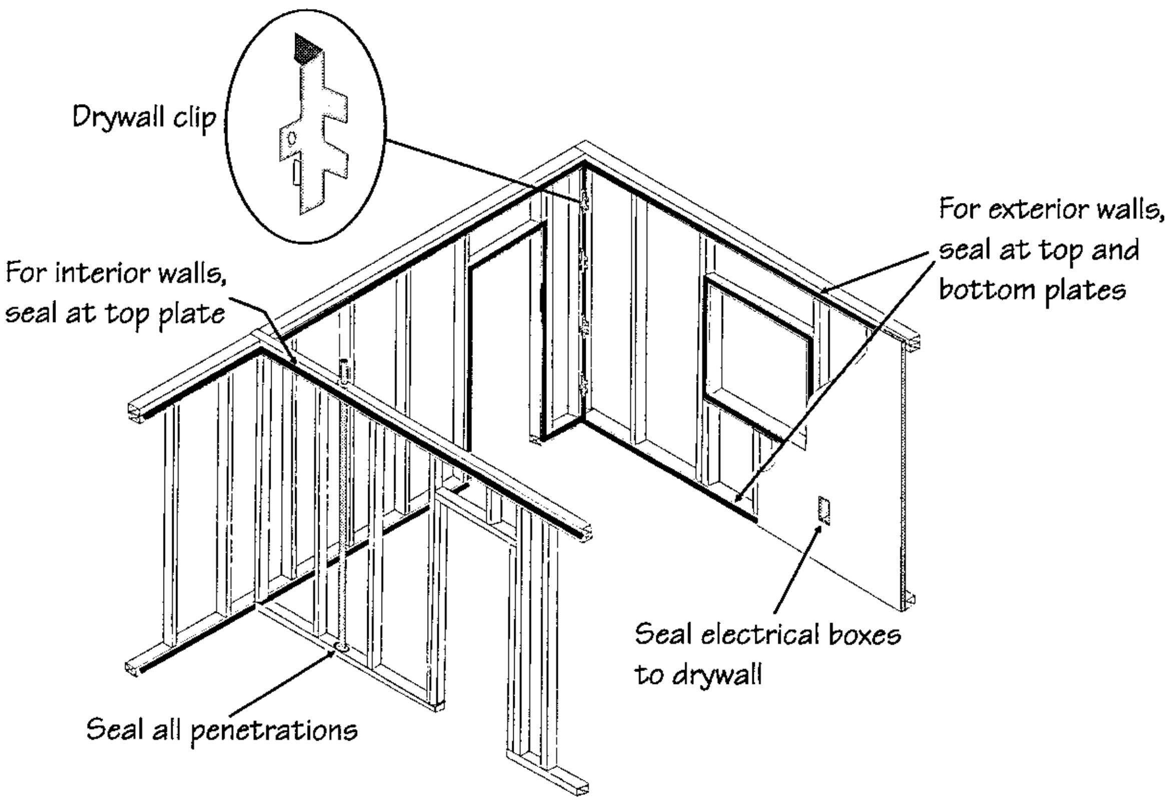


Figure 4-13
Airtight Drywall Approach Air Barrier



Airtight Drywall Approach

The airtight drywall approach is an air sealing system that connects the interior finish of drywall and other building materials together to form a continuous barrier (Figure 4-13). The airtight drywall approach 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 building.

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 building 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.

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

ADVANTAGES

Effective—the airtight drywall approach 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 the airtight drywall approach 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 when the drywall is attached to framing.

Adaptable—builders can adapt airtight drywall approach principles to suit any design and varying construction schedules.

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

DISADVANTAGES

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

Requires thought—while the airtight drywall approach is simple, new construction techniques require careful planning to ensure that the air barrier remains continuous. However, the airtight drywall approach 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.

INSTALLATION TECHNIQUES

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 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.
- ❐ 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.

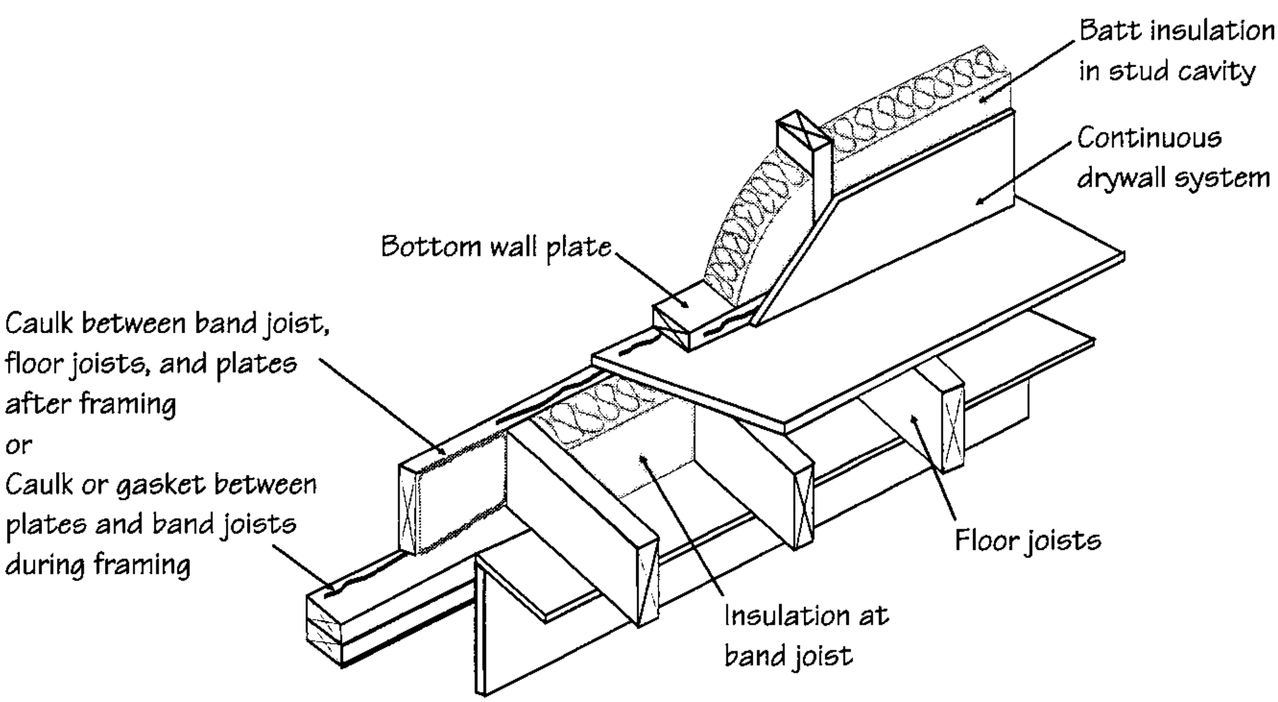
Ceiling

- ❐ Follow standard finishing techniques to seal the junction between the ceiling and walls.
- ❐ When installing ceiling drywall do not damage 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.

WOOD FRAMED FLOORS

- ❐ Seal the rim joist to minimize air currents around floor insulation. Also, seal rim joists for multi-story construction (Figure 4-14).
- ❐ For unvented crawl spaces or basements, seal beneath the sill plate.
- ❐ Seal the seams between pieces of subflooring with quality adhesive.

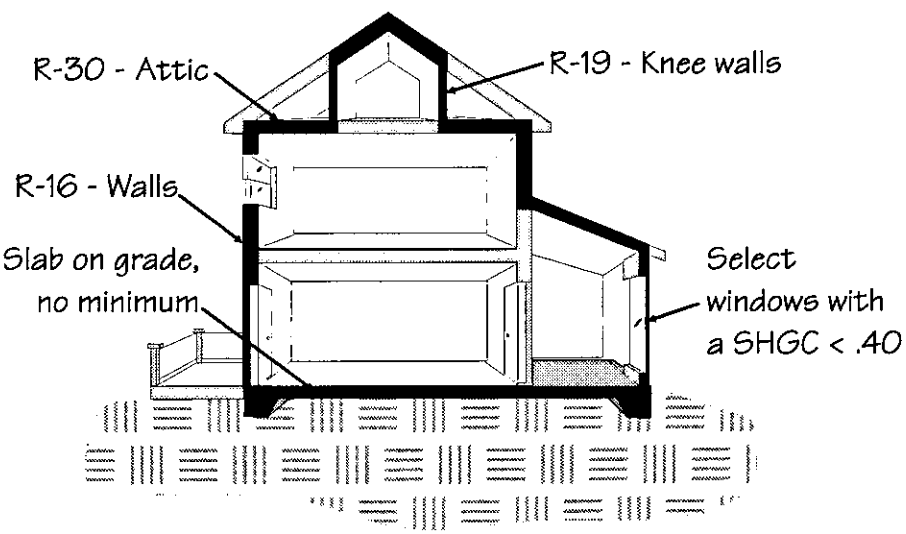
Figure 4-14
Between Floor Air Barrier



Chapter 5: Insulation Materials and Techniques

Sections 401 and 601—Fenestrations
Sections 402 and 602—Walls
Sections 403 and 603—Doors
Sections 404 and 604—Roofs/Ceilings
Sections 405 and 605—Floors

Figure 5-1
Insulating the Building Envelope — Typical New Construction R-Values



The key to an **effective insulation** system is proper installation of quality insulation products. A building should have a continuous layer of insulation around the entire building envelope (Figure 5-1). Studies show that improper installation can cut performance by 20% or more.

Insulation Materials

The wide variety of insulation materials makes it difficult to determine which products and techniques are the most cost effective (Table 5-1, next page).

❒ *Fiberglass and mineral wool* products come in batt (Table 5-2a, next page), 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 walls to attics to ductwork.

❒ *Cellulose insulation*, made from recycled newsprint, comes primarily in loose-fill form (Table 5-2b, next page). 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 stop 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, such as structural insulated panels (SIPs).

Table 5-1
Comparison of Insulating Materials

Material	Typical R-Value (per inch)
Batts, blankets and loose-fill insulation	
Mineral wool, fiberglass, rock wool	
Batts or blankets	2.9–3.8
Loose-fill	2.2–2.9
Cellulose (loose-fill)	3.1–3.7
Foam insulation and sheathing	
Polyisocyanurate and polyurethane	5.6–7.0
Extruded polystyrene	5.0
Expanded polystyrene	4.0
Fiberboard sheathing (blackboard)	2.6
OSB sheathing	1.3
Polyicynene	3.6–4.3
Reflective insulation	4.3–5.2

Determine actual R-values and costs from manufacturers or local suppliers.

- *Extruded polystyrene* (XPS), also a foam product, is a homogenous polystyrene produced primarily by three manufactures 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.

Table 5-2a
Batt Insulation Characteristics

Fiberglass Thickness (inches)	R-value
3 ½ – 4	11
6 – 6 ½	19
7 – 7 ½	22
9 ½ – 10	30
12 – 13	38

Table 5-2b
Blown Fill Insulation Characteristics

Cellulose Thickness (inches)	R-value
3	11
5 ½	19
6	22
8 ½	30
10 ½	38

- *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.

- *Reflective insulation,* often used between furring strips on concrete block walls to reflect the heat.

INSULATION AND THE ENVIRONMENT

There has been considerable study and debate about potential negative environmental and health impacts of insulation products. These concerns range from detrimental health effects for the installer to depletion of the earth's ozone layer.

Fiberglass and mineral wool—concerns about impacts on health from breathing in fibers—no universal proof as yet accepted.

Cellulose—concerns about flammability, but the fire retardant chemical added to cellulose, along with its greater density, may provide greater fire safety than other insulation products. Long term fire retardancy is unknown.

Foam products and chlorofluorocarbons —for years, many foam products contained chlorofluorocarbons (CFCs), which are quite detrimental to the earth's ozone layer. The CFCs were the blowing agent which helped create the lightweight foams. Current blowing agents are:

- Expanded polystyrene - pentane, which has no impact on ozone layer, but may increase potential for smog formation.

- Extruded polystyrene, polyisocyanurate and polyurethane - use primarily hydrochloro-fluorocarbons (HCFCs) which are 90% less harmful to the ozone layer than CFCs. Some companies are moving to non-HCFC blowing agents.

- Open-cell polyurethane - uses carbon dioxide, which is much less detrimental than other blowing agents.

Insulation Strategies

Commonly used fiberglass and cellulose products are the most economical, while foam products should be used more judiciously. Builders may want to use fiberglass, rockwool, or cellulose insulation in attics, walls, and raised 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.

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, especially around doors and windows
- ❒ Minimize air leakage through the material
- ❒ Avoid compressing insulation
- ❒ Avoid lofting (installing too much air) in loose-fill products

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:

- ❒ 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

Foundations

Slab-on-Grade

Most of Florida's buildings are built concrete slab-on-grade, meaning that a slab situated near ground level serves as the floor itself. Florida has no minimum requirement for slab-on-grade insulation. Raised floor systems (wood and concrete) have specific requirements depending on climate zones.

Walls

Walls are the most complex component of the building envelope to provide adequate thermal insulation, air sealing, and moisture control.

CONCRETE WALL INSULATION

Foundation walls and other masonry walls are usually built of concrete block or poured concrete. Insulating concrete block walls is more difficult than framed walls.

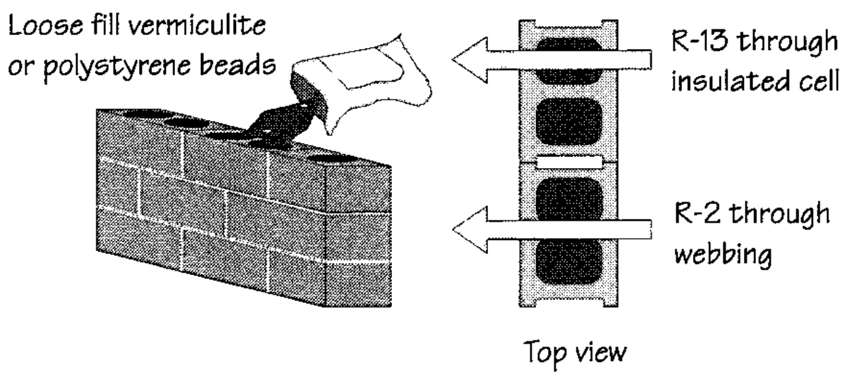
Insulating concrete block cores

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

- *Vermiculite*
  R-2.1 per inch (Figure 5-2)
- *Polystyrene inserts or beads*
  R-4.0 to 5.0 per inch
- *Urethane foam*
  R-7.2 per inch

Figure 5-2
Insulating Concrete Block Cores

(R-4 to R-6 overall)



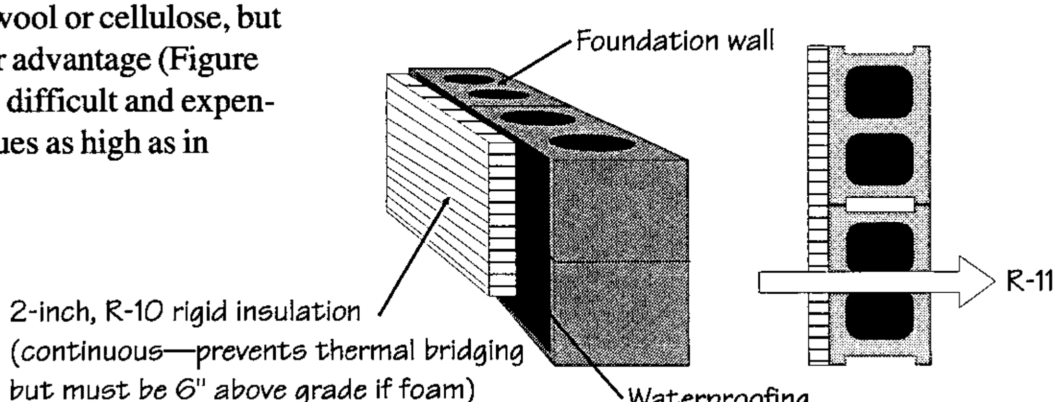
Unfortunately, as shown in Figure 5-2, the substantial thermal bridging in the concrete connections between cores continues to depreciate the overall R-value. This approach is only a partial solution to providing a quality, well-insulating wall. Other techniques, as explained in the next few pages, provide a more cost-effective solution.

Exterior rigid fiberglass or foam insulation

Rigid insulation is more expensive per R-value than mineral wool or cellulose, but its rigidity is a major advantage (Figure 5-3). However, it is difficult and expensive to obtain R-values as high as in framed walls.

Figure 5-3
Exterior Foam Insulation

(R-11 to R-12 overall)

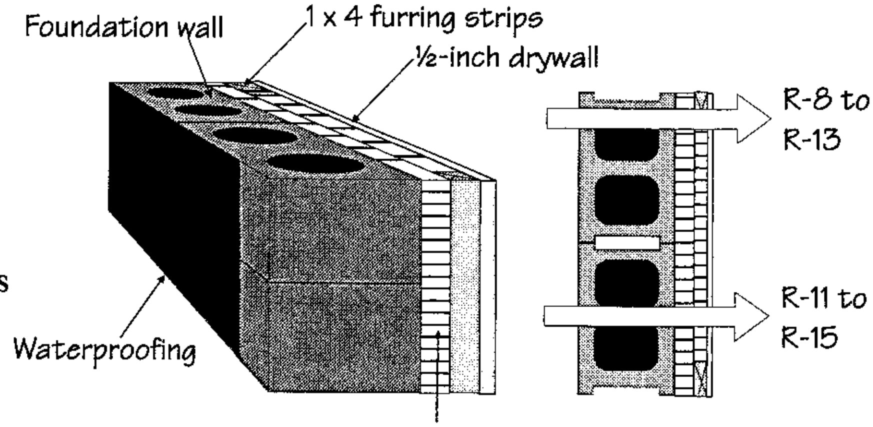


Interior foam wall insulation

Foam insulation can be installed on the interior of concrete block walls (Figure 5-4); 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 of the nailing strips.

Figure 5-4
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 (Figure 5-5). Standard framed wall insulation and air sealing practice can then be applied.

Figure 5-5
Interior Framed Wall

(R-11 to R-13 overall)

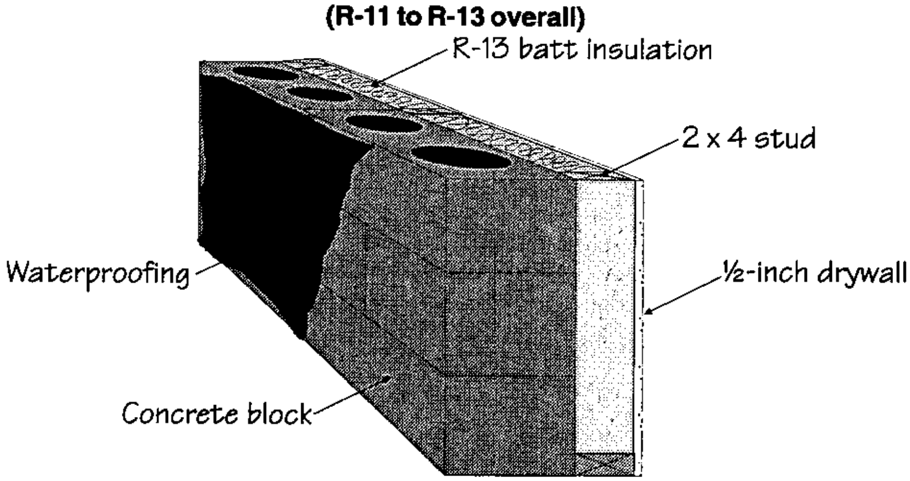
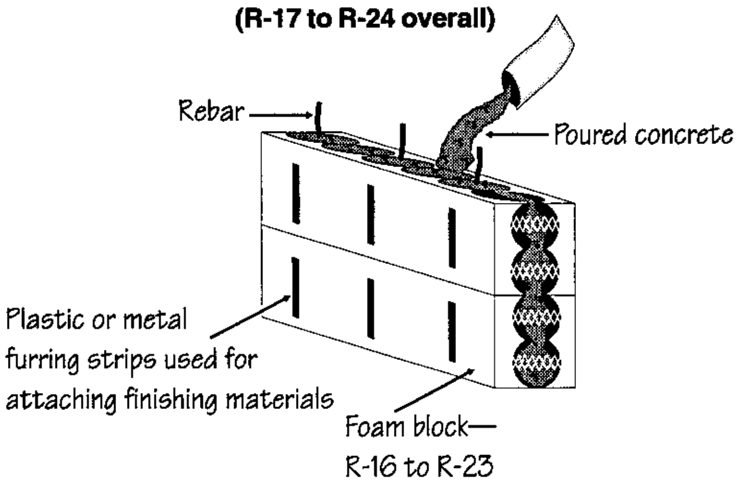


Figure 5-6
Insulated Concrete Form System



Insulated concrete form systems

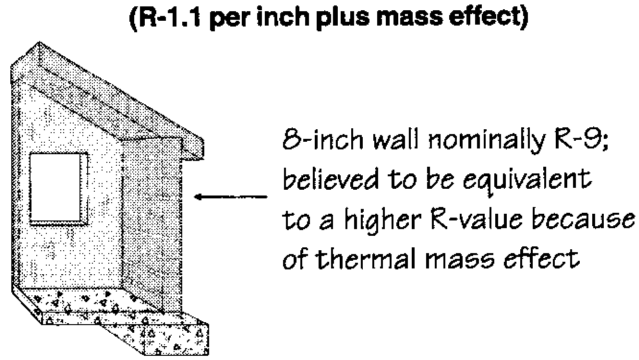
Polystyrene or polyurethane foam can be used as formwork for poured or sprayed structural concrete (Figure 5-6). Many of these systems can be economically attractive in areas with substantial cooling and heating requirements.

They are often referred to as *Insulated Concrete Forms* or *ICF*.

Lightweight concrete products

Lightweight, air entrained concrete is an alternative wall system (Figure 5-7). Autoclaved aerated concrete (AAC), sometimes referred to as precast autoclaved aerated concrete (PAAC), which can be shipped either as blocks or panels, combines elevated R-values (compared to standard concrete) with thermal mass.

Figure 5-7
Lightweight Concrete Products

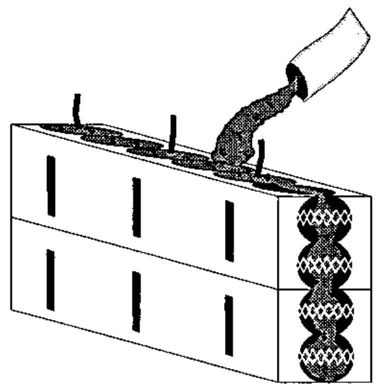


INSULATED CONCRETE FORM SYSTEMS

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:

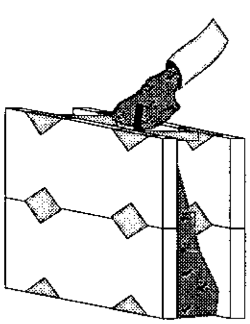
Foam blocks (Figure 5-8) - Several companies manufacture foam blocks that can be installed quickly on the footings of a building. Once stacked, reinforced with rebar, and braced, they can be filled with concrete. Key considerations are:

Figure 5-8
Foam Blocks



- ❐ 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 "blow-outs" when the installer did not fully comply with the manufacturer's specifications. A blow-out occurs when the foam or its support structure breaks and concrete pours out of the form.
- ❐ Termites - be sure to follow local or state codes and consult a reputable termite control expert.

Figure 5-9
Foam Panel



Spray-on systems - Concrete can be applied to foam panels 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 (Figure 5-9) - 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.

2 × 4 Wall Insulation

Throughout the United States, debates continue on optimal wall construction. Table 5-3 summarizes typical problems and solutions in walls framed with 2 × 4 studs. 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:

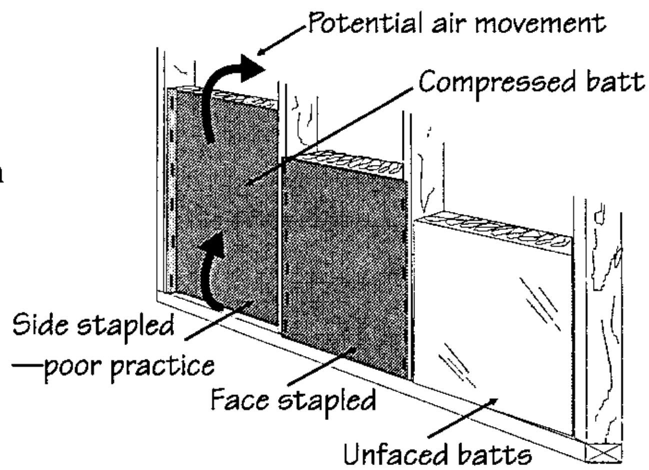
- ❒ Foam sheathing for insulating headers
- ❒ 1 × 4 or metal T-bracing for corner bracing
- ❒ R-13 batts for insulating areas during framing behind shower/tub enclosures and other hidden areas
- ❒ 1/2" drywall or other sheet material where needed for sealing behind shower-tub enclosures and other areas that cannot be reached after construction
- ❒ Caulking or foam sealant for sealing areas that may be more difficult to seal later

Table 5-3
2 × 4 Framed Wall Problems and Solutions

Problem	Solution
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. 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.

Avoid side stapling

Figure 5-10
Insulating Walls With Batts



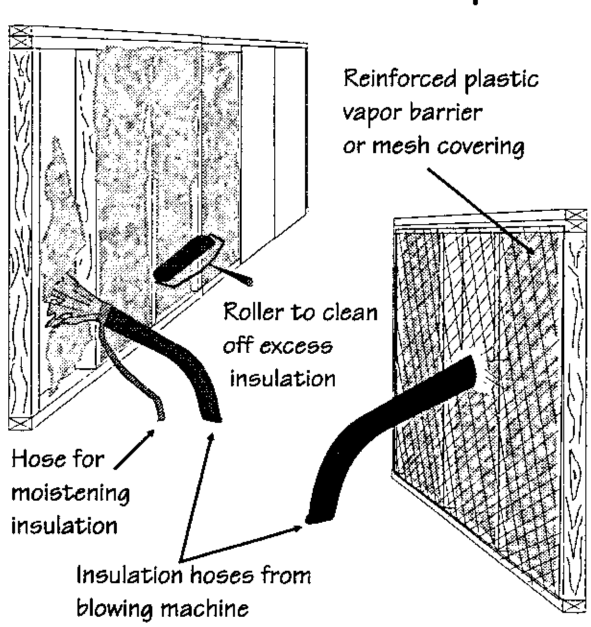
Walls are usually insulated with batts having an attached vapor retarder facing. Many builders question whether it is best to side staple or face staple batt insulation. The common arguments illustrate that face stapling results in less compression, while side stapling interferes less with drywall installation.

The ideal solution should focus on where the kraft paper (vapor barrier) is, rather than how it is installed.

The face stapling question is an appropriate question in northern or "heating dominated" climates. In northern areas, vapor barriers should be installed on the "warm" side of the wall cavity. In southern or "cooling dominated" climates the vapor barrier should be on the outside surface of the wall cavity. Because of this, the use of unfaced batts is recommended in Florida (Figure 5-10).

Unfaced batts 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 5-11
Blown Sidewall Insulation Options

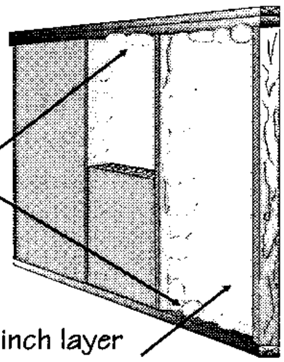


Blown loose-fill insulation

Loose-fill cellulose, fiberglass, 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 (Figure 5-11). 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 an interior finish.

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 seal 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.

Figure 5-12
Blown Foam Insulation



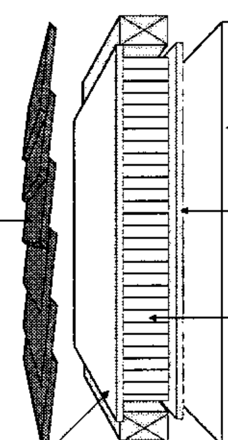
Blown foam insulation

Some insulation contractors are now blowing polyurethane or polyicynene insulation into walls of new buildings (Figure 5-12). 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 structural insulated panels (SIP), also known as stress-skin panels (Figures 5-13 and 5-14). They consist of 4-inch or 6-inch thick foam panels onto which sheets of structural ply wood or oriented strand board (OSB) 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.

Figure 5-13
Structural Insulated Panels (SIP)

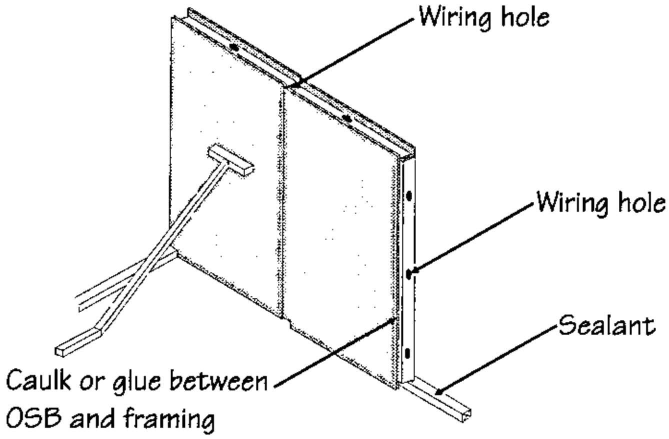


SIPs are 4 feet wide and generally 8 to 12 feet long. There are a wide variety of manufacturers, each with its own method of attaching panels together. Procedures for installing windows, doors, wiring, and plumbing have been worked out by each manufacturer. In addition to their use as wall framing, SIPs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

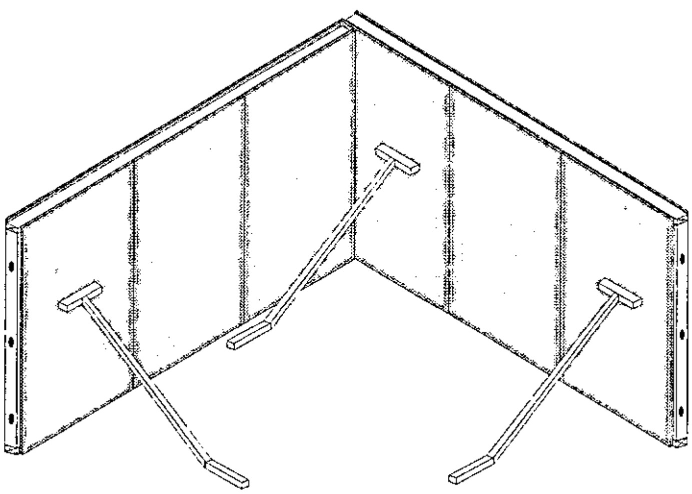
While buildings built with SIPs may be more expensive than those with standard framed and insulated walls, research studies have shown SIP-built buildings have higher average insulating values and are tighter. Thus, they can provide substantial energy savings.

STRUCTURAL INSULATED PANELS CONSTRUCTION

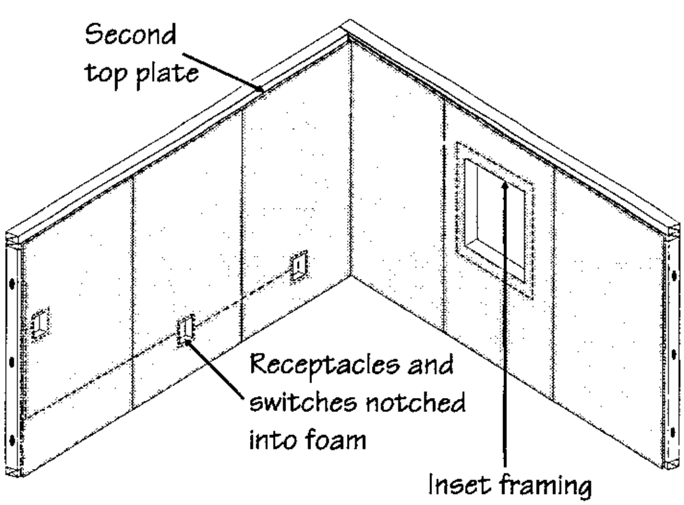
Figure 5-14
Structural Insulated Panels



- ❒ 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.

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. Buildings 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 buildings. Table 5-4 summarizes some of their findings.

Moisture-related problems have been reported in metal frame buildings 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, studs covered by cold outside air can also cause streaking. Attention to proper insulation techniques can alleviate this problem.

Table 5-4
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

WALL SHEATHINGS

Many 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, consider using expanded polystyrene (R-2), extruded polystyrene (R-2.5 to 3), polyisocyanurate or polyurethane (R-3.4 to 3.6) foam insulated sheathing (Table 5-5). (All R-values are per ½ inch.)

The advantages of foam sheathing over wood or blackboard include:

- Energy savings
- Easier to cut and install
- Protects against condensation
- Less expensive than plywood or oriented strand board if used as a combination wall sheathing and insulation

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 bottom plate at the floor but does not extend below grade. Check state or local termite protection code. 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.

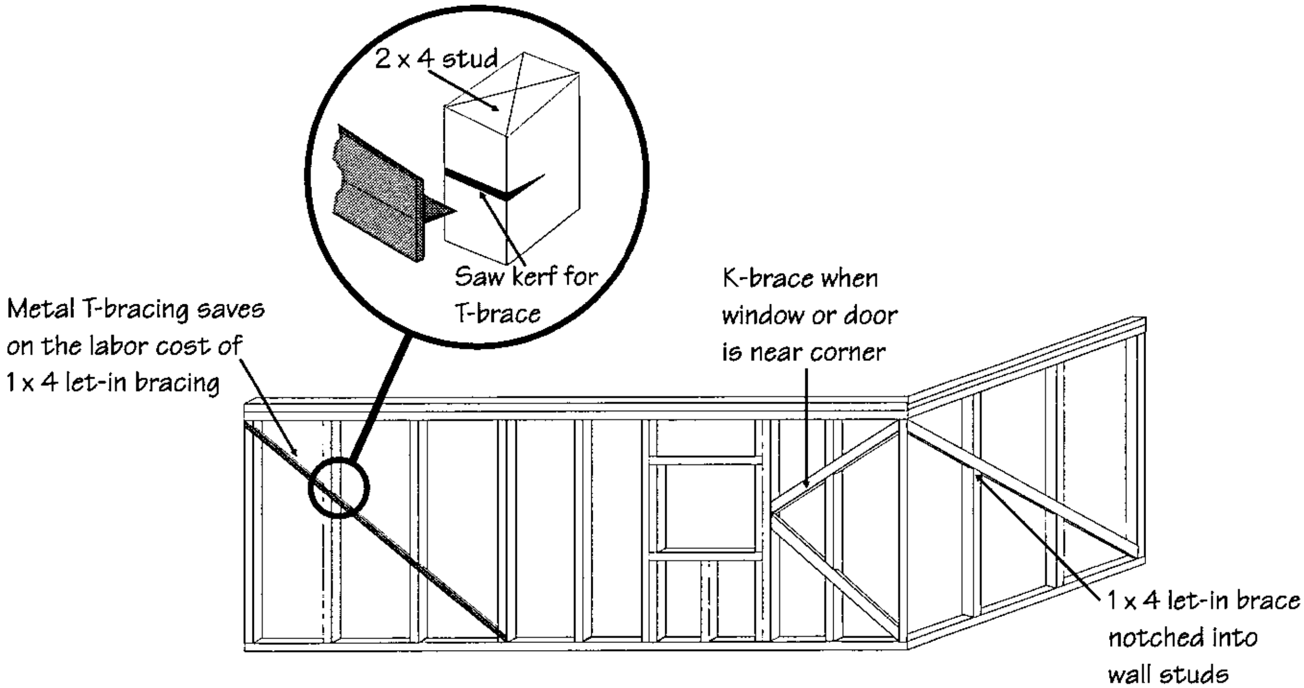
Because of its advantages over plywood, foam sheathing should be used continuously in combination with let-in bracing, which provides structural support (Figure 5-15). Be sure, as always, to check and comply with local building code regulations.

Table 5-5
Sheathing Costs*

	Cost ($)	R-Value
½" oriented strand board (OSB)	350	0.60
½" extruded polystyrene	383	2.5
½" blackboard	255	1.3
½" polyisocyanurate	383	3.5–3.7
½" beadboard (EPS)	255	2.0

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

Figure 5-15
Let-In Bracing



2 × 6 Wall Construction

There has been interest in Florida in the use of 2 × 6s for construction. In most code jurisdictions, 2 × 6s can be spaced on 24-inch centers, rather than the 16-inch centers required for 2 × 4s. 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 2 × 6s.
- Less framing reduces labor costs.
- There is more space for insulating around piping, wiring, and ductwork.

Disadvantages of 2 × 6 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 2 × 4 walls and leave relatively little area for actual insulation.

Table 5-6
Analysis of 2 × 6 Walls*

Description of Wall	Average R-values		Extra Costs or Savings $		
	Wall Only	Average with Windows**	Costs ($)	30-year Savings ($)	Net Savings ($)
No windows					
2 × 4	15.37	same			
2 × 6	19.94	same	18	60	42
2 windows (double-paned)					
2 × 4	14.94	9.65			
2 × 6	19.78	11.31	31	59	26
5 windows (double-paned)					
2 × 4	14.20	6.20			
2 × 6	19.15	6.82	103	57	(-46)

* 400 sq ft. with R-13, 2 × 4 construction versus R-19, 2 × 6 construction
** All windows double-glazed, 15 square feet

The economics of 2 × 6 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 5-6 shows a comparison of 2 × 4 versus 2 × 6 framing. Walls built with 2 × 6s 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 questionable.

Ceilings and Roofs

Attics over flat ceilings are usually the easiest part of a building'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 summer, properly-designed ventilation reduces roof and ceiling temperatures, thus potentially saving on cooling costs and lengthening the life of the roof. In winter, roof vents expel moisture which could otherwise accumulate and deteriorate insulation or other building materials.

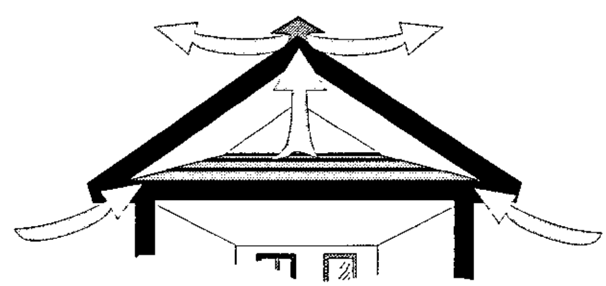
At present, several research studies are investigating whether attic ventilation is beneficial. For years, researchers have believed the cooling benefits of ventilating a well-insulated attic are negligible. However, some experts are now questioning whether ventilation is even effective at moisture removal.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

Testing is being performed by a variety of organizations to verify leak-free operation of continuous ridge vents in high wind situations. Care should be taken to ensure that the vents chosen are appropriate for hurricane-prone areas of Florida.

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 (Figure 5-16). There is a wide variety of products available including ridge, gable, soffit, and mushroom vents.

Figure 5-16
Ridge and Soffit Vents



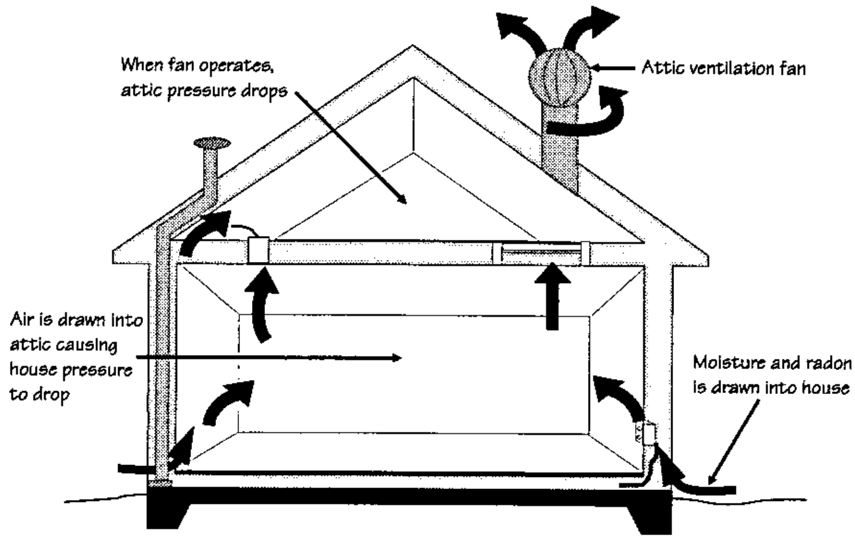
The combination of continuous ridge vents along the peak of the roof and continuous soffit vents at the eave provides the most effective ventilation. Ridge vents come in a variety of colors to match any roof. Some brands are made of plastic covered by cap shingles to hide the vent from view.

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 (Figure 5-17):

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

Figure 5-17
Pressure Problems Due to Powered Attic Ventilators



Attic Floor Insulation Techniques

Either loose-fill or batt insulation can be installed on an attic floor. As shown in Table 5-7, blowing loose-fill attic insulation is usually less expensive than installing batts or rolls. Most attics have either blown fiberglass, rock wool or cellulose. Ceilings with a rise greater than 5 and a run of 12 (5 over 12) should not be insulated with blown-in insulation. See sections 404 and 604 of the Florida Energy Efficiency Code for specific restrictions for blown-in insulation.

Table 5-7
Typical Attic Insulation Costs*

Flat Ceiling	
R-19 Batt Insulation	$471
R-30 Batt Insulation	$745
R-19 Blown Insulation	$271
R-30 Blown Insulation	$428
R-38 Blown Insulation	$542

* For a 1,056 square-foot attic (materials only).

Steps for installing loose-fill attic insulation:

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

2. Follow manufacturer's 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 later in the chapter.

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. Foam boxes are available for providing a degree of insulation over a pull-down attic stairway.

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 5-8 (next page) shows a sample chart for cellulose insulation. Cellulose is heavier than fiberglass for the same R value. Closer spacing of roof joists and thicker drywall is required for larger R values. Check this detail with the insulation contractor.

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 (obtainable from insulation contractors) to ensure uniform depth of insulation.

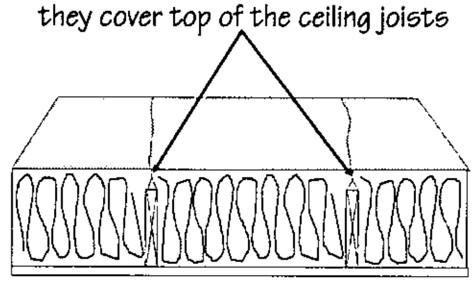
Table 5-8
Blown Cellulose in Attics

R-value at 75°F	Minimum thickness (in)	Minimum weight (lb/ft²)	2 x 6 joists spaced 24" on center		2 x 6 joists spaced 16" on center	
			Coverage per 25-lb bag (ft²)	Bags per 1,000 ft²	Coverage per 25-lb bag (ft²)	Bags per 1,000 ft²
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

Steps for installing batt insulation

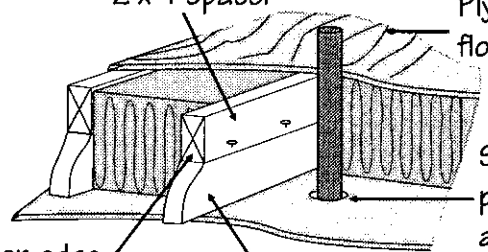
1. Seal attic air leaks, as prescribed by fire and energy codes.
2. Block around heat-producing devices, as described in Step 2 for Loose-fill Insulation.
3. Insulate the attic hatch or attic stair as described in Step 4 for Loose-fill Insulation.
4. Determine the attic insulation area; based on the 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. (See Figure 5-18)

Figure 5-18
Full Width Batts



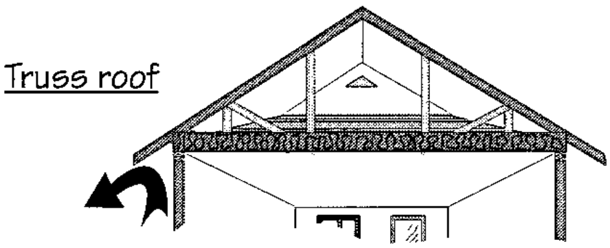
5. When installing the batts, make certain they completely fill the joist cavities. Shake batts to ensure proper loft. If the joist spacing is uneven, patch gaps in the insulation with scrap pieces. Try not to compress the insulation with wiring, plumbing or ductwork. In general, obtain complete coverage 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 2 × 10s), raise the finished floor using 2 × 4s or other spacing lumber. Install the batts before nailing the storage floor in place. (See Figure 5-19)

Figure 5-19
Insulating Under Attic Floors

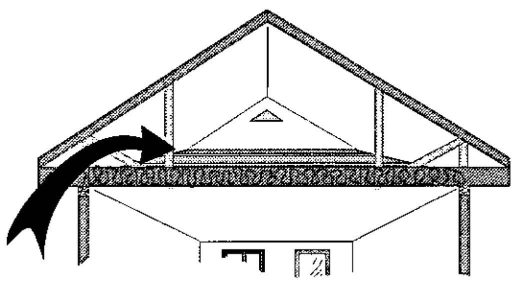


INCREASING THE ROOF HEIGHT AT THE EAVE

Figure 5-20
Insulation Options for Eaves



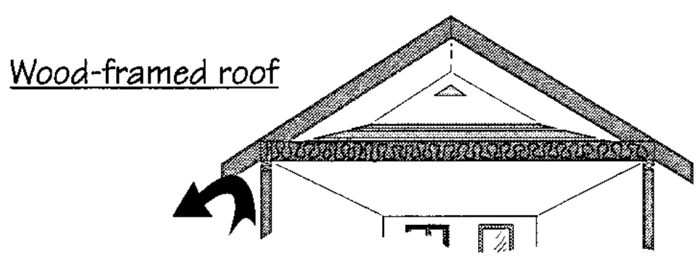
Problem: Roof deck compresses insulation and blocks air flow from soffit vent



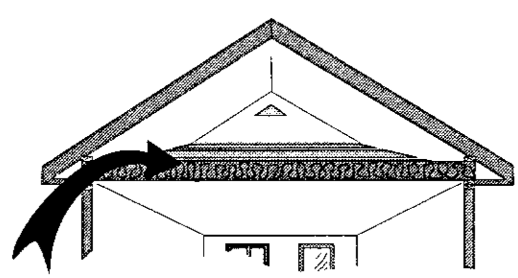
Solution: Raised heel trusses—insulation not compressed; air flow path is open

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. Figures 5-20 and 5-21 show 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.

Figure 5-21
Insulation Options for Eaves



Problem: Roof compresses insulation at eave and blocks air flow from soffit vent



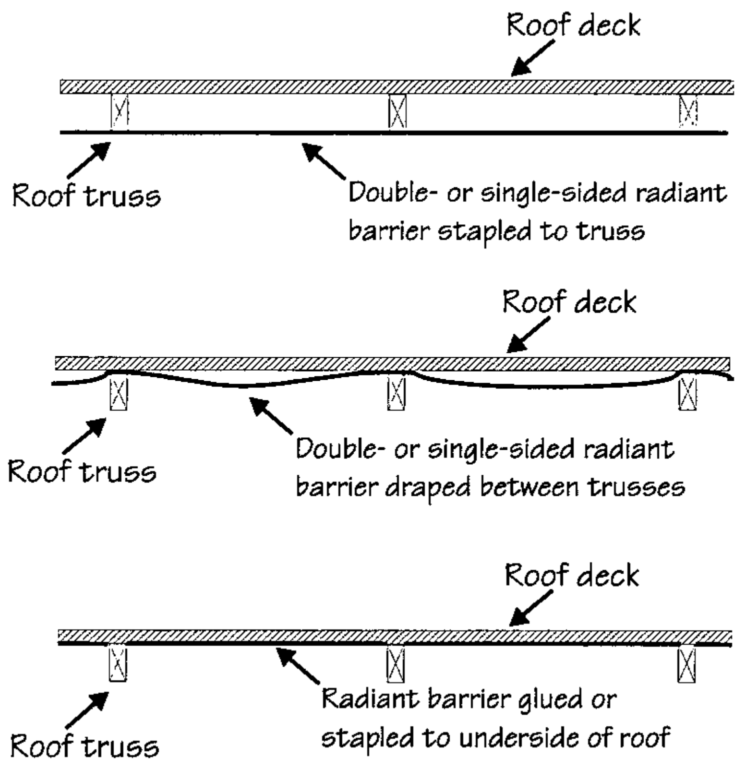
Solution: Raised top plate—insulation not compressed; air flow path is open

In stick-built roofs, where rafters and ceiling joists are cut and installed on the construction site, an additional top plate that lies 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 insulation and ventilation.

Radiant Heat Barriers

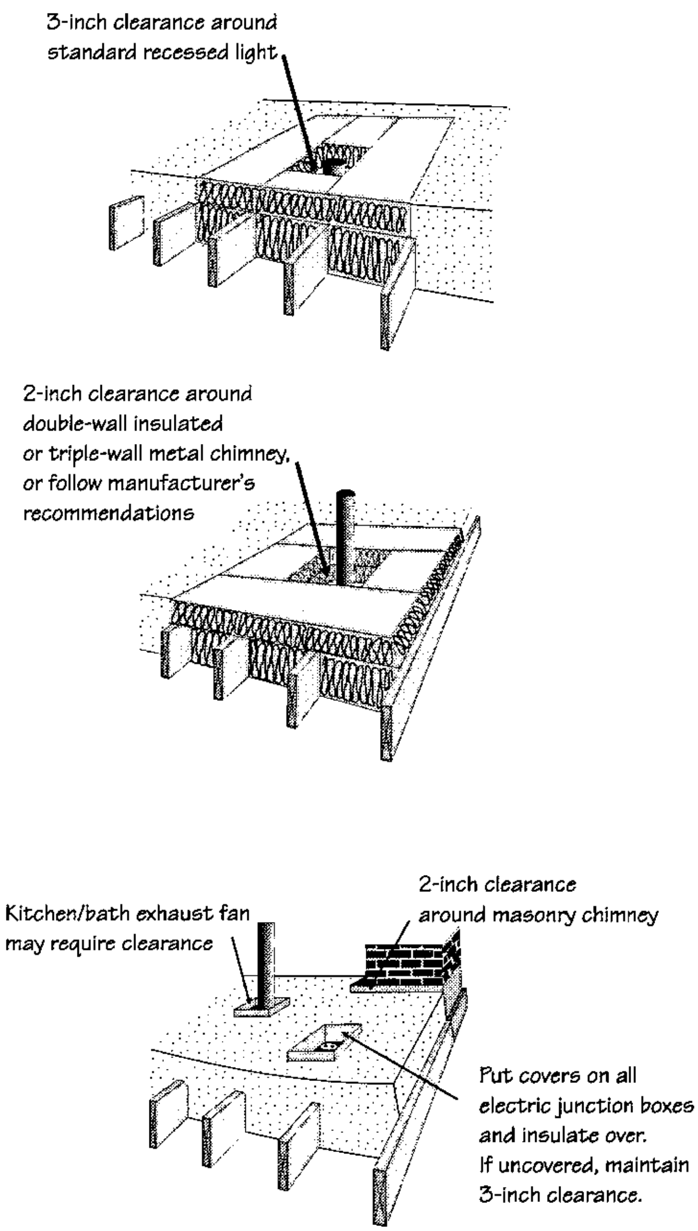
Radiant heat barriers (RHB) are reflective materials that can reduce summer heat gain by the insulation and building materials in attics and walls. RHBs work two ways: first, they *reflect* thermal radiation well and second, they *emit* (give off) very little heat. RHBs should always face a vented airspace 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. Acceptable attic radiant barrier configurations can be found in Figure 5-22.

Figure 5-22
Radiant Barriers



ATTIC BLOCKING REQUIREMENTS

Figure 5-23
Attic Blocking Requirements



Object	Recommended Action*
Recessed light	3-inch clearance on all sides, unless rated as Insulated Contact (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

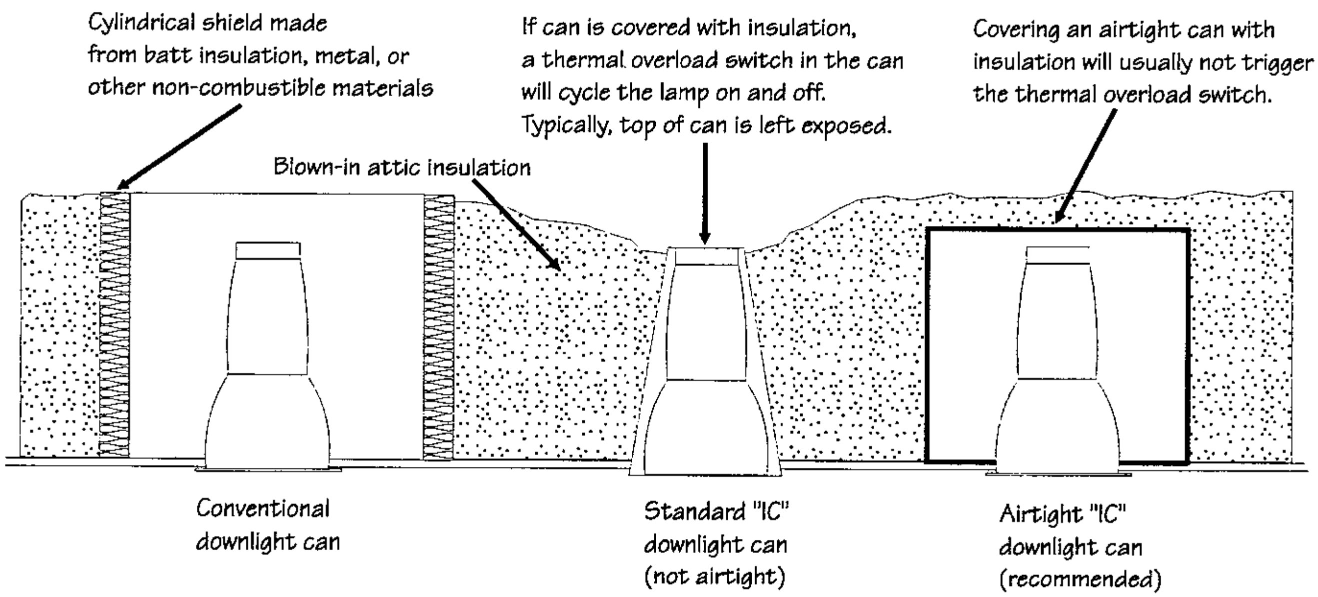
*These are general guidelines. Follow specific manufacturer's recommendations.

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.

Insulation contact (IC) rated fixtures have a heat sensor switch which allows the fixture to be covered—except for the top—with insulation. (See Figure 5-24 for proper insulation methods for these fixtures.) However, these units also leak air. Specific air tightness requirements can be found in the Florida Energy Code (606.1.ABC.1.2.4). If you have to use recessed lights, install airtight IC-rated lamps. There are alternatives to recessed lights, including surface-mounted ceiling fixtures and track lighting.

Figure 5-24
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 2 × 6 or 2 × 8 rafter (R-19 or R-25 respectively).

The Florida Energy Code allows R-10 cathedral ceiling insulation for some house designs. For most areas of the state, R-30 insulation is recommended. Builders may find considerable 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.

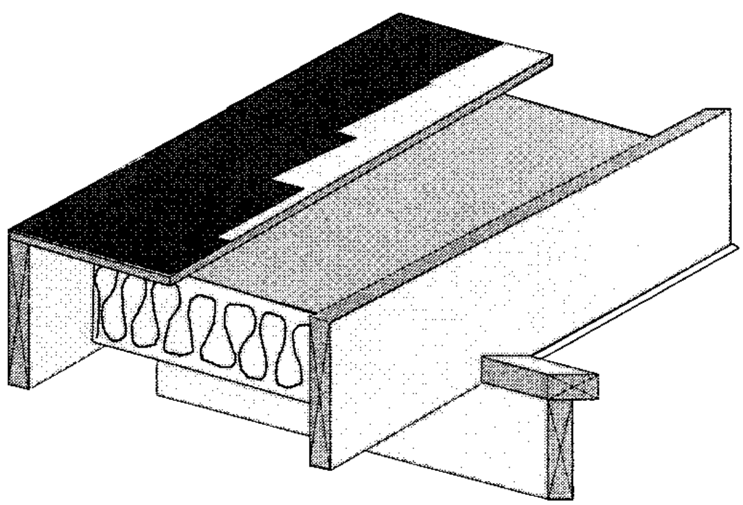
BUILDING R-30 CATHEDRAL CEILINGS

Cathedral ceilings built with 2 × 12 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.

If 2 × 12s are not required structurally, most builders find it cheaper to construct cathedral ceilings with 2 × 10 rafters and high-density R-30 batts, which are 8 1/4 inches thick (Table 5-9).

Some contractors wish to avoid the higher cost of 2 × 10 lumber and use 2 × 8 rafters. These roofs are usually insulated with R-19 batts. However, by using lower grade 2 × 10 lumber the additional costs may be avoided.

Table 5-9
Cathedral Ceiling Insulation Options



Rafter	Batt	Typical Cost*
2 × 10	R-25	$1.50/ sq ft
2 × 10	R-30 High Density	$1.65/sq ft
2 × 12	R-30 Regular Density	$1.95/sq ft

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

In framing with 2 × 6 and 2 × 8 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.

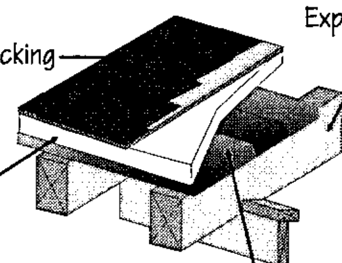
Difficulties with exposed rafters

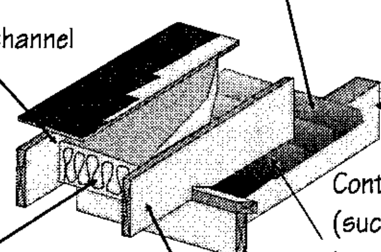
A cathedral ceiling with exposed rafters or roof decking is difficult and expensive to insulate well. Often, foam insulation panels are used over the attic deck as shown in Figure 5-25. However, to achieve R-30, 4 to 7 inches of foam insulation, which typically cost $1 to $3 per square foot, are needed. 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.

Figure 5-25

Cathedral Ceiling - Exterior Roof Insulation





Chapter 6: Windows and Doors

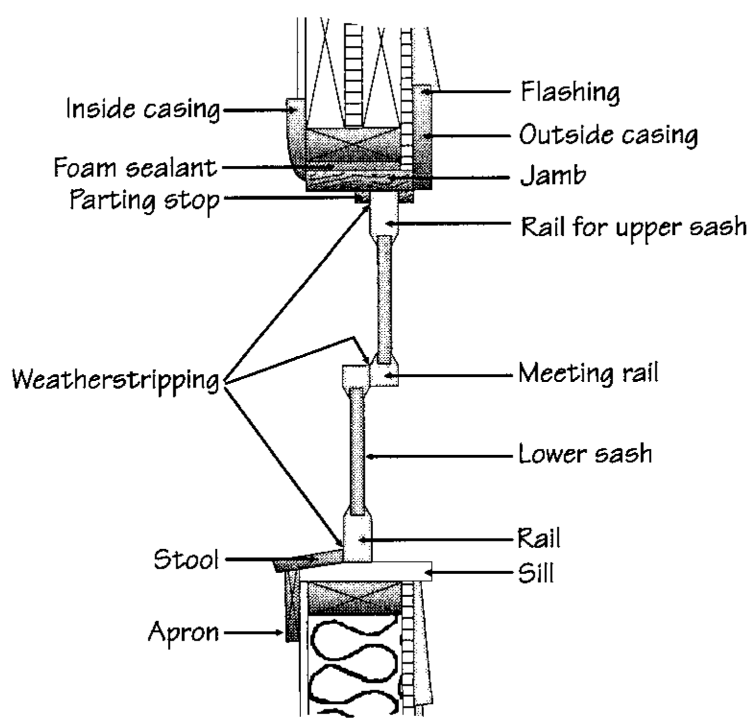
See Sections 401 and 601—Fenestration
See Section 603—Doors

Windows connect the interior of a house to the outdoors, provide ventilation and daylighting, and are key aesthetic elements. Windows and doors are often the architectural focal point of residential designs, yet they provide the lowest insulating value in the building envelope. Poorly chosen windows can increase the costs of keeping a house cool, cause glare, fading of fabrics, and reduce residents' comfort. Well designed buildings carefully consider location, size and performance.

Although recent developments in energy efficient products have markedly improved the efficiency of windows, poorly engineered windows still represent a major energy liability in new construction. The type, size, and location of windows greatly affect cooling and heating costs. Select good quality windows, but shop wisely for the best combination of price and performance. Many housebuilding budgets have been exceeded by spending thousands of additional dollars on premium windows suitable for northern and central climates with marginal, if any, energy savings for southern climates. In general, if the windows are well-built, reduce solar heat gain and have good weather-stripping, they will serve you well.

In passive design buildings, windows can provide a significant amount of heat, ventilation and light for a house. Details are covered in Chapter 11, *Siting and Passive Design Features,* and Chapter 7, *Heating, Ventilation, Air-conditioning (HVAC).*

Figure 6-1
Cross-section of single-hung window



Windows

To understand new window technologies, it is helpful to understand how they gain and lose heat (Figures 6-2 and 6-3):

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

U.S. Department of Energy Goals of Efficient Windows*

- ❒ Low Solar Heat Gain Coefficients—transmission rates of invisible radiation (ultraviolet and infrared light energy)—0.40 or lower, which most often requires double-glazed units
- ❒ Low overall U-factors—preferably 0.7 or lower, which can also require double-glazed units
- ❒ Low air leakage rates
    - less than 0.25 cfm (cubic feet per minute) per linear foot of sash opening for double-hung windows
    - less than 0.10 cfm per linear foot for casement, awning, and fixed windows
- ❒ Moderate to high transmission rates of visible light - preferably above 0.70

In the past several years, the window industry has unveiled an exciting array of high efficiency products that meet these goals. The most useful developments for Florida include:

- ❒ Low-emittance coatings, which hinder radiant heat flow (Figures 6-2 and 6-3).
- ❒ Tighter weather-stripping systems to lower air leakage rates.
- ❒ Thermal breaks to reduce heat losses through highly conductive glazing systems and metal frames (Figure 6-4, next page).

* *All numbers are for whole window performance.*

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

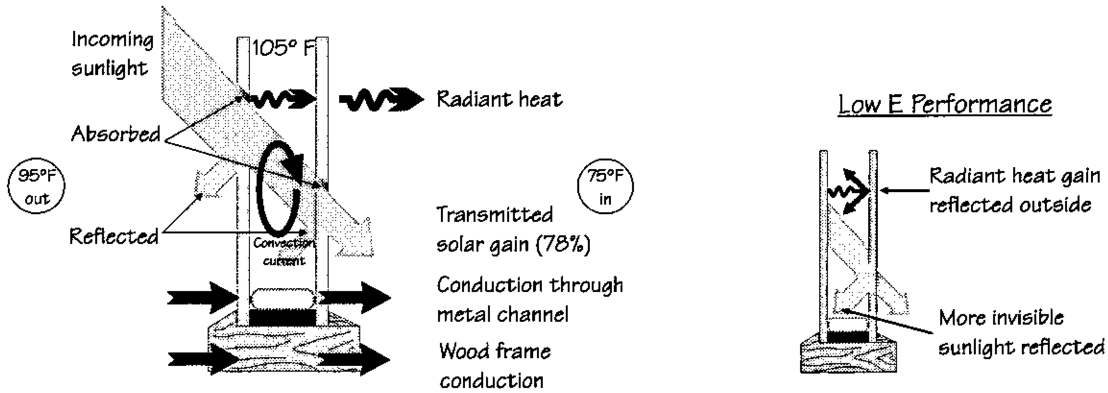
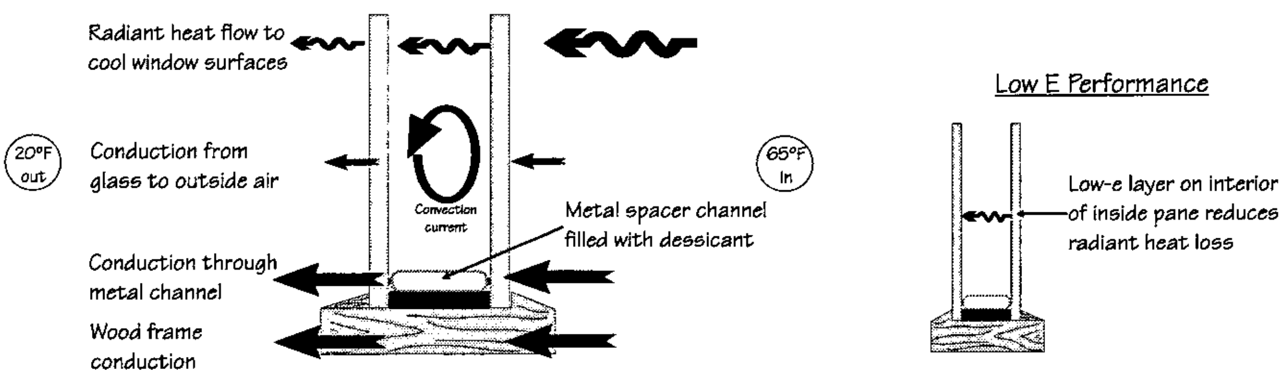


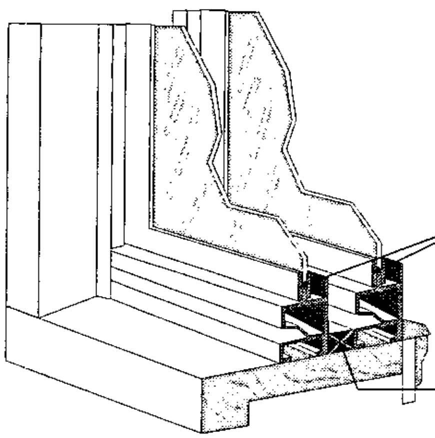
Figure 6-3 Winter Heat Loss in a Double-glazed Window



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 *good conductor* of heat. A thermal break separates inside and outside pieces of the window frame with an insulating material, thus improving U-factors or R-values. Always specify windows with thermal breaks, listed as "T.I.M" (thermally improved metal) when purchasing metal windows.

Figure 6-4
Metal Window Frame With Thermal Break



When shopping for windows note:

- the U-factor (or R-value) for the entire window, not just that for the glass
- how the U-factor was determined
- whether any standardized test procedure was used to derive it
- gas fill will improve thermal performance but is not really needed in Florida

It makes no sense to pay top dollar for a window that looks great on paper, but performs poorly in the real world. Depend on certification like National Fenestration Rating Council (NFRC), AAMA (American Architechtural Association), or WDMA (Window and Door Manufacturers Association), to get the quality and performance you purchased.

Low Emittance Technologies

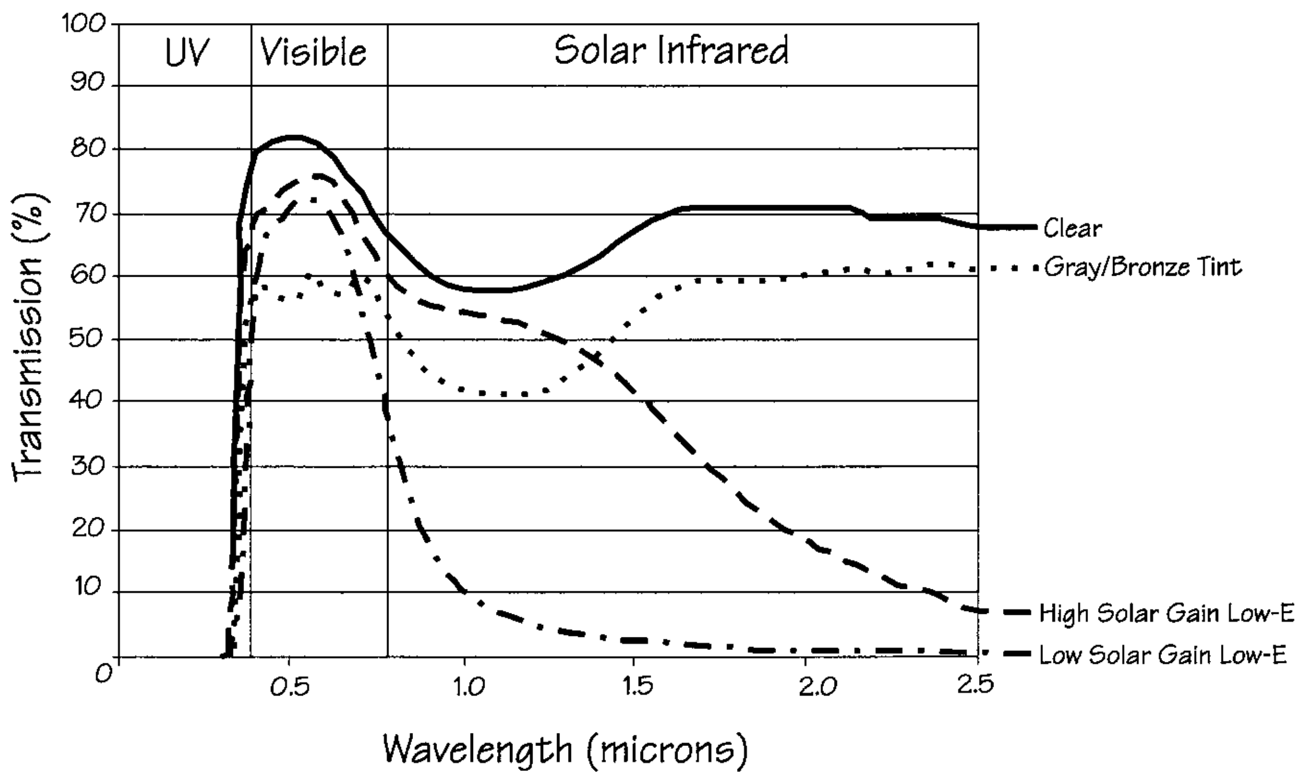
Figure 6-5 shows the solar control properties of several glass types available in Florida. On the graph, light is characterized as UV, visible and infrared. UV and infrared are invisible to the naked eye. Note that the space beneath each line is the amount of light and heat each window type admits to the building envelope.

As shown in Figure 6-5, there are different types of low-E (for emissivity) coatings. The low solar gain coating is most applicable for Florida because it blocks the most heat while admitting more than 60% of the visible light. The high solar gain coating lets in more heat, which is desirable in northern climates to maximize passive solar heating. However, this kind of window is counterproductive for Florida, since keeping heat *out* of a building is the dominant concern for most of the year. High solar gain windows can actually *increase* a Florida building's energy load, because they not only admit solar heat, but prevent it from escaping as well. High solar gain windows are sold in Florida, so make sure you ask for a solar heat gain coefficient of 0.40 or less.

WHY DO LOW-E WINDOWS WORK?

The sun's complete solar spectrum produces heat, but only a small portion is seen as light. Invisible radiation has either shorter (UV) or longer (infrared) wavelengths than visible light (See Figure 6-5). Some surfaces, such as the 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 at elevated temperatures. Low emittance (or low-E) coatings are primarily designed to hinder radiant heat flow. Some block more than others do. The lower the solar heat gain coefficient, the more wavelengths are blocked. That's why low-E windows are also better for interior furnishings—they block the UV light that fades upholstery.

Figure 6-5
Spectral Selectivity



Comparing Windows

The National Fenestration Rating Council (NFRC) offers a voluntary testing program for window and door products. The NFRC has an approved procedure to determine several key characteristics:

- ❒ Solar Heat Gain Coefficient (SHGC)
- ❒ U-Factor
- ❒ Visible Light Transmission (the fraction of visible light that passes through the window)—optional
- ❒ Air Leakage Rates—optional

The NFRC reports an average whole window U-factor. If windows used in your building are certified by the NFRC, they will include a label showing test results (see Figure 6-6).

Figure 6-6
Components of the NFRC Label

The Manufacturer Name displays the name of the window, door, or skylight manufacturer.

The Product Description provides information about the characteristics of the product.

The U-Factor measures the amount of heat that escapes through the product. It refers to the whole window U-factor. The lower the rating, the better the window is at preventing heat loss. The label provides a rating for both residential and nonresidential versions of the same product for all energy performance characteristics. NFRC certified products require U-factor ratings. In Florida, select windows with a U-factor at least as low as 0.7.

The Solar Heat Gain Coefficient (SHGC) measures the ability of the window to absorb or reflect solar radiation. The lower the SHGC, the better the product is at blocking unwanted solar heat gain. This rating is optional and it is up to the manufacturer to decide whether to include it on the label. In Florida, select windows with a SHGC less than 0.40.

The Visible Light Transmittance rating measures the percentage of visible light that passes through the window. The higher the number, the more light allowed in. This rating is also optional. Select windows with a minimal VT rating as high as you can find.

Difficulties in Reporting Window Values

Insulating Values

Window insulating values are typically reported in U-factors—the inverse of R-values. Double-glazed products can have R-values as high as 3.3, or U-factors of about 0.30 (1/R = 1/3.3 = 0.30). Single-glazed windows generally have R-values of 1.0 and thus have U-factors of 1.0. The R-value is no longer commonly used by certifying agencies to evaluate window performance, but many window manufacturers include it in their window ratings. It can be confused with the R-classification of structural design pressure values, so ask for the U-factor to avoid confusion.

Component vs. Whole Window Performance

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

For an example on insulating value, there are two companies that 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 U-factor of 0.13 for the glass. However, losses through the edges and frames changes the overall window U-factor to 0.25. (Remember, *lower* numbers indicate *better* ratings.) Another window is filled with air rather than argon yielding an U-factor of 0.15 for the glass. Due to its unique edge system, which has thermal breaks made of nylon spacers with insulation in between, the ***overall*** window U-factor is 0.16—better than the window with the higher glass U-factor.

Shading Coefficients

In warm climates such as Florida, a low Solar Heat Gain Coefficient or SHGC is the most important criteria in window selection. SHGC measures the amount of solar radiation that enters a building through the window and causes heat gain. A poor performance window that has a SHGC of 0.80 allows 80% of the solar heat to pass through it. Windows with low SHGCs are good at preventing heat gain caused by solar radiation. Select windows with a SHGC of less than 0.40 in warm climates.

Construction professionals are more likely to be familiar with the *shading coefficient* or SC, which measures how the solar gain of a glazing system compared to that transmitted through clear, single-pane 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.

SC was formerly widely used to measure solar control properties, but is now being phased out in favor of the more accurate SHGC. However, you can still find SC rating listed in window and window treatment performance literature (Table 6-1). To make an approximate conversion from SC to SHGC, multiply the SC value by 0.87. Divide by 0.87 to covert from SHGC to SC.

Table 6-1
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.

Window Options

Up to 40% of unwanted heat gain is due to windows, according to the Energy Efficient and Renewable Energy Network at the U.S. Department of Energy. Construction professionals in Florida have a wide choice of options in addition to high efficiency windows to reduce heat gain:

- ❒ Window tints and films
- ❒ Overhangs
- ❒ External shades and shutters
- ❒ Interior shades and shutters
- ❒ Landscaping and trees (see Chapter 11 for detailed information)

The effectiveness of different window shading options depends on the composition of the incoming sunlight. Sunlight reaches the building 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 building'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. Excessive overhangs make the home building structurally vulnerable to hurricane winds. A better approach would be to use exterior shutters, such as Bahama shutters, for shading the window, allowing the view and protecting the window from damage.

HIGH PERFORMANCE WINDOWS

Figure 6-7
ENERGYSTAR® Logo

The US Department of Energy recently added windows to its line of ENERGY STAR® identified products. Three geographic zones reflect different performance criteria needed for each climate. E NERGY STAR® windows suitable for Florida should be identified for southern or cooling climates.

Many large national glass and window manufacturers actively participate in the program. However, few local manufacturers are even aware of the program's existence. Therefore, insist on products that meet the same requirements for the Southern region: U-factor of 0.75 or lower and SHGC of 0.40 or lower.

Visible transmittance is not included in the criteria. However, it should be considered, given current technologies. Again, high efficiency does not mean reduced visibility. Glazings with low SHGC rates and high visible transmittance (0.70 and above) do exist. Windows with these glazings may be more expensive and difficult to obtain, but the investment may be worth it for unobstructed, east/west waterfront exposures.

Lastly, a few manufacturers have created hurricane-resistant windows. While not purely an energy efficiency topic, considerable energy and resources can be saved if a building's integrity remains intact during a windstorm. Windows are a key failure point. Hurricane-resistant windows may be required for code. It is possible to achieve low solar heat gain with windstorm-resistant windows. Ask your supplier about options.

REFLECTIVE FILMS AND TINTS

Reflective or low emittance films, which adhere to glass and are found often in commercial buildings, can block up to 85% of incoming sunlight. If visible transmittance is similarly reduced, this can lead to higher interior electric lighting use, and the same or higher electricity bills. In fact, many of the same films are inserted between glazings during assembly of low-emittance windows by manufacturers. The film blocks sunlight all year, so it may be inappropriate on south windows in passive solar buildings. However, it may be practical for unshaded east and west windows. Also, it can often degrade when applied post-installation, requiring replacement. 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. Many double-paned window manufacturers void their warranties if unapproved window films are applied to their products. In cooler parts of Florida where solar heat gain is desired in the winter, choose films with moderate SHGC ratings. The installed cost of reflective films varies. Price should not be the sole criterion when selecting a film installer—quality is a vital consideration affecting the appearance of the house and the beauty of the view to the outside.

Most window manufacturers also offer tints—a color, such as green, amber, rose, or blue, added to the glazing mixture. They can have shading coefficients under 0.30. In some cases, the window can have a reflective finish to block additional sunlight. These tints are often inexpensive, but, don't forget that the tint is permanent, so incoming sunlight will be blocked in both summer and winter. Some homeowners have a perception that their entire home will have a blue hue, although it is hardly noticeable once installed.

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. Keep in mind long overhangs should be adequately designed for typical hurricane wind loads.

Retractable awnings allow full winter sunlight, yet provide effective summer shading where they do not conflict with hurricane codes. 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.

While other overhangs and awnings provide considerable energy savings, they should be carefully considered with regard to hurricane preparedness. Poorly designed overhangs can be a serious detriment in windstorms. Look for awnings or other external operable shutters that are wind resistant. Check local codes for parameters.

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 can be removed in winter in north Florida where full sunlight is desired for the colder season.

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. Again, refer to local hurricane code before investing in these devices. There are edge-encapsulated exterior roller shades that may not be as susceptible to these problems.

Interior Shades and Shutters

Shutters and shades located inside the building 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 (Table 6-2). 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 building cooler than more expensive louvered blinds, which do not provide a solid surface and allow trapped heat to migrate between the blinds into the building.

Table 6-2
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.

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.

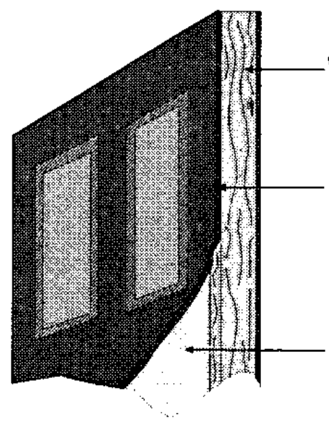
Step 3: Use non-expanding foam sealant to seal between the jamb and the rough opening, or stuff the gap with backer rod or insulation and cover the insulation with caulk (remember—most insulation doesn't stop air leaks, it just serves as a filter).

Step 4: If using an air barrier, seal the barrier to the window jamb with long-life caulk or other appropriate, durable sealant.

Step 5: After interior and exterior trim is installed, seal the gap between the trim and the interior or exterior finish with long-life caulk.

Doors

Figure 6-8
Insulated Metal Door



Exterior wood doors have low insulating values, typically R-2.2. Storm doors increase the U-factor or 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 (Figure 6-8). 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 buildings to ensure accessibility for the physically impaired adds little to the cost of a building. 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.

Chapter 7: Heating, Ventilation, Air Conditioning (HVAC) 107

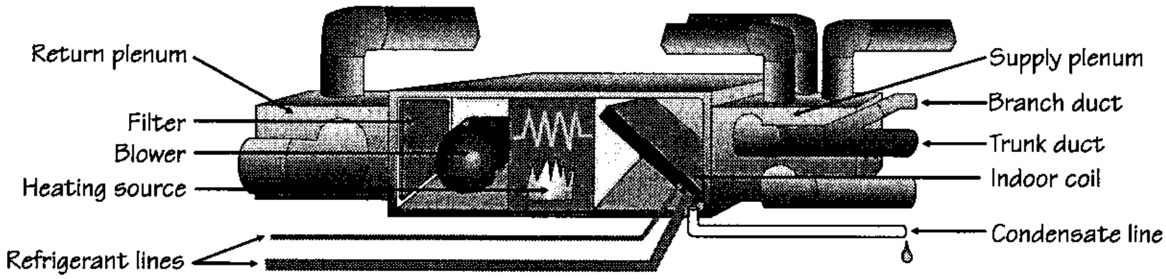
See Sections 407 and 607—Space Cooling Systems

One of the most important decisions regarding a new building is the type of heating and cooling system to install. Equally critical is the heating and cooling contractor selected, as the operating efficiency of a system depends as much on proper installation as on the performance rating. Keys to obtaining the design efficiency of a system in the field include:

- ❒ Sizing the system for the specific heating and cooling load of the building being built
- ❒ Selection and proper installation of controls
- ❒ Correct design of the ductwork or piping
- ❒ Insulating and sealing all ductwork

Improper installation of components, in particular of ductwork, has negative impacts on comfort and energy bills, and can dramatically degrade the quality of air in a building. Poorly designed and installed ducts can create dangerous conditions that may reduce comfort, degrade indoor air quality, or even threaten the lives of the occupants.

Figure 7-1
Components of Forced Air Systems



Types of HVAC Systems

Most new buildings have *forced-air heating and cooling systems*—either using a central furnace and air conditioner or a heat pump. As shown in Figure 7-1, in forced air systems, a series of *ducts* distributes the conditioned heated or cooled air throughout the building. The conditioned air is forced through the ducts by a *blower*, located in a unit called an *air handler*.

Most buildings in Florida have a choice of two approaches for central, forced air systems: fuel-fired furnaces with electric air conditioning units or electric heat pumps. The best system for each building depends on the cost and efficiency of the equipment, annual energy use, and the local price and availability of energy sources. In most buildings, either type of system, if designed and installed properly, will deliver comfort economically.

When considering a HVAC system for a residence, remember that energy efficient and passive solar buildings have less demand for heating and cooling, so substantial savings may be obtained by installing smaller units that are properly sized to meet the load.

Sizing

Since January 1, 1993, it has been required by law to perform HVAC load calculations for new homes constructed in Florida. The Florida Energy Code states that: "Cooling and heating design loads, for the purpose of sizing HVAC systems, shall be determined for each zone within a dwelling in accordance with ACCA Manual J, ACCA Manual N, or the ASHRAE Cooling and Heating Load Calculation Manual, Second Edition."

Many contractors select air conditioning systems based on a rule such as 600 square feet of cooled area per ton of air conditioning (a ton provides 12,000 Btu per hour of cooling). Instead, use a sizing procedure such as:

- ❐ Calculations in *Manual J* published by the Air Conditioning Contractors Association
- ❐ Similar procedures developed by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
- ❐ Software procedures developed by electric or gas utilities, the U.S. Department of Energy, or HVAC equipment manufacturers

The heating and cooling load calculations should be based on the exact area and type of construction for each component of the building envelope, as well as the heat given off by the lights, people, and equipment inside the building. If a zoned heating and cooling system is used, the loads in each zone should be calculated.

An oversized air conditioning system will operate for a short time and then cycle off. Since it takes a certain length of time for the air conditioning coil to become cool enough for proper dehumidification, short cycling will limit the amount of time that the system is effectively removing moisture from the dwelling.

For example, a building equipped with an oversized air conditioner on the hottest days of the year will see the compressor operate 20 minutes each hour. The first 3 minutes of this period are required to develop low coil temperatures for adequate dehumidification. During an eight-hour period proper dehumidification is occurring for only 136 minutes.

A building equipped with a properly sized air conditioner on the hottest days of the year could see the compressor operate up to 50 minutes or more, each hour. During an eight-hour period, proper dehumidification is occurring for 376 minutes. This is nearly three times as much dehumidification as the over-sized case.

A properly sized air conditioning system should operate nearly continuously on the hottest days of the year.

A properly sized air conditioning system will:

- ❐ Minimize construction costs
- ❐ Provide maximum dehumidification
- ❐ Minimize energy costs

It is important to size heating and air conditioning systems properly. Not only does oversized equipment cost more, but it can waste energy and may decrease comfort.

Table 7-1
Equipment Sizing and Cost Comparison

Type of House	More Efficient	Less Efficient
Insulation R-Values and Areas:		
R-30 Attic	2,000 sq ft	1,000 sq ft
R-25 Cathedral Ceiling	0 sq ft	1,000 sq ft
Wall Area/ R-value	1,750 sq ft / R-21	1,600 sq ft / R-16
Window Area/ R-value	250 / R-3	400 / R-2
Floors	2,000 / R-21	2,000 / R-13
Air Leakage (ACH)*	0.35	0.60
Duct Leakage (CFM25)**	50	250
HVAC System Sizing:		
Heating (Btu/hour)	22,000	34,000
Cooling (Btu/hour)	20,000	27,000
Estimated tons of cooling***	2	2.5
Square feet/ton	1,000	800
Typical Equipment Cost:		
Lower Efficiency	$3,600	$4,200
Higher Efficiency	$4,000	$4,700

* ACH means the number of natural air changes per hour the home has due to air leakage.
** CFM25 is the duct leakage rate at a pressure of 25 Pascals—a standard number used during a duct leakage test.
*** There are 12,000 Btu/hour in a ton of cooling.

Table 7-1 compares the size of heating and cooling systems for two homes with identical floor areas. The more efficient home reduces the heating load 35% and the cooling load 26%. Thus, the additional cost of the energy features in the more efficient home is offset by the $600 to $700 savings from reducing the size of the HVAC equipment.

Oversimplified rules would have provided an oversized heating and cooling system for the more efficient building. The oversized unit would have cost more to install. In addition, the operating costs would be higher, it would suffer greater wear, and it may not provide adequate dehumidification.

Proper sizing includes designing the cooling system to provide adequate dehumidification. In Florida's humid climate it is critical to calculate the *latent load*—the amount of dehumidification needed for the building. If the latent load is ignored, the building may become uncomfortable due to excess humidity.

The Sensible Heating Ratio (SHR) designates the portion of the cooling load for reducing indoor temperatures (*sensible cooling*). For example, in a HVAC unit with a .75 SHR, 75% of the energy expended by the unit goes to cool down the temperature of indoor air. The remaining 25% goes for latent heat removal—taking moisture out of the air in the building. If the designer of a HVAC system accurately estimates the cooling load, they will also calculate the desired SHR and thus, the latent load.

Many buildings in Florida have design SHR's of approximately 0.7—70% of the cooling will be sensible and 30% latent. Systems that deliver less than 30% latent cooling may fail to provide adequate dehumidification in summer.

MANUAL J EXAMPLE*

Manual J, Load Calculation for Residential Winter and Summer Air Conditioning, is published by the Air Conditioning Contractors of America (ACCA). The procedures in the manual calculate the building heating and cooling loads as follows:

1. Determine all dimensions of the exterior building envelope for each type of surface (wall, floor, window, door, ceiling, etc.).
2. Note R-values of all components.
3. Find the Construction Number of each component based on tables in the book.
4. Look up climatic data in the manual for the locality in which the building is being constructed.
5. Based on the Construction Number and the climatic data, find the Heat Transfer Multiplier (HTM) for the different components during the heating (Htg.) and cooling (Clg.) seasons.
6. Fill in the tables for the heating and cooling load.
7. Calculate the infiltration loads, internal gains, and latent loads in separate charts.
8. Find the grand total loads.
9. Use ***Manual S, Residential Equipment Selection***, also published by ACCA, to help select the equipment for the home.

1	Name of Room	Entire House
2	Running Ft. Exposed Wall	94.5
3	Room Dimensions Ft.	32 x 62.5
4	Ceiling Ht. Ft.	8

	TYPE OF EXPOSURE		Const No.	HTM Htg.	HTM Clg.	Area/ Length	Btuh Htg.	Btuh Clg.
5	Gross Exposed Walls & Partitions	a b c d	12F				1,512	
6	Windows & Glass Doors Htg.	a b c d	3b	30.5		300	9,150	
7	Windows & Glass Doors Clg.	North E & W South			16 46 25	75 150 75		1,200 6,900 1,875
8	Other Doors		10D	23	10.9	42	966	458
9	Net Exposed Walls & Partitions	a b c d	12F	3.5	1.7	1,170	4,095	1,989
10	Ceilings	a b	16G	1.6	1.2	2,000	3,200	2,400
11	Floors	a b	19D	1.3	0	2,000	2,600	0
12	Infiltration HTM						11,757	5,878
13	Sub Total Btuh Loss = 6+8+9+10+11+12						31,768	20,700
14	Duct Btuh Loss			0.1			3,177	0
15	**Total Btuh Loss = 13 + 14**						**34,945**	
16	People @ 300 & Appliances = 1200							2,400
17	Sensible Btuh Gain = 7+8+9+10+11+12+16							23,100
18	Duct Btuh Gain				0.05			1,155
19	**Total Sensible Gain**							**24,255**
	Latent Gain Calculations							
	Latent Infiltration						2,471	
	Latent Ventilation							0
	Latent Internal Gains							1,920
	Total Latent Gain							**4,391**

* An experienced person can perform a *Manual J* calculation in 30 to 60 minutes for an average home. The measurements for the calculations are available from the construction drawings. *Manual S* calculations require an additional 15 to 30 minutes.

TEMPERATURE CONTROLS

The most basic type of control system is a heating and cooling thermostat. *Programmable thermostats,* also called setback thermostats, can be big energy savers for buildings by automatically adjusting the temperature setting when people are sleeping or not in the building (Table 7-2). Be certain that the programmable thermostat selected is designed for the particular heating and cooling equipment it will be controlling. This is especially important for heat pumps, as an improper programmable thermostat can actually increase energy bills. Also, look for those with the ENERGY STAR® label.

A thermostat should be located centrally within the building or zone. It should not receive direct sunlight or be near a heat-producing appliance. A good location is often 4 to 5 feet above the floor in an interior hallway near a return grille.

The interior wall on which it is installed, like all walls, should be well sealed at the top and bottom to prevent circulation of cool air in winter or hot air in summer. Some building occupants have experienced headaches for years because air from the attic leaked into the wall cavity behind the thermostat and caused the cooling or heating system to run much longer than needed.

Table 7-2
Typical Savings from Programmable Thermostats

Winter Heating Setting	Energy Savings ($/yr)
72°F Day / 72°F Night	0
72°F Day / 65°F Night	28
68°F Day / 68°F Night	48
68°F Day / 60°F Night	74
68°F Day / 55°F Night	77

COOLING EQUIPMENT SELECTION

Tables 7-3 and 7-4 show equipment charts for two sample air conditioning units. Each system provides a wide range of outputs, depending on the blower speed and the temperature conditions. The SHR in the chart is the Sensible Heating Ratio—the fraction of the total output that cools down the air temperature. The remainder of the output dehumidifies the air—provides latent cooling. Note that both systems provide about 36,000 Btu/ hour of cooling.

System A: with 80° return air, SEER = 12.15

At low fan speed, provides 35,800 Btu/hour, 0.71 SHR, and thus 29% latent cooling (dehumidification).

At high fan speed, provides 38,800 Btu/hour, but a 0.81 SHR, and only 19% latent cooling—not enough dehumidification in many Florida buildings.

System B: with 80° return air, SEER = 11.55

At low fan speed, provides 32,000 Btu/ hour, 0.67 SHR and 33% dehumidification.

At high fan speed, provides 35,600 Btu/hour, 0.76 SHR and 24% dehumidification.

Thus, System A, while nominally more efficient than B, provides less dehumidification and potentially less comfort.

Table 7-3
Sample Cooling System A Data
SEER = 12.15

Total Air Volume (cfm)	Total Cooling Capacity (Btuh)	Sensible Heating Ratio (SHR) Dry Bulb Temperature		
		75°F	80°F	85°F
950	35,800	0.58	0.71	0.84
1,200	37,500	0.61	0.76	0.91
1,450	38,800	0.64	0.81	0.96

Table 7-4
Sample Cooling System B Data
SEER=11.55

Total Air Volume (cfm)	Total Cooling Capacity (Btuh)	Sensible Heating Ratio (SHR) Dry Bulb Temperature		
		75°F	80°F	85°F
950	32,000	0.56	0.67	0.78
1,200	34,100	0.58	0.71	0.84
1,450	35,600	0.61	0.76	0.90

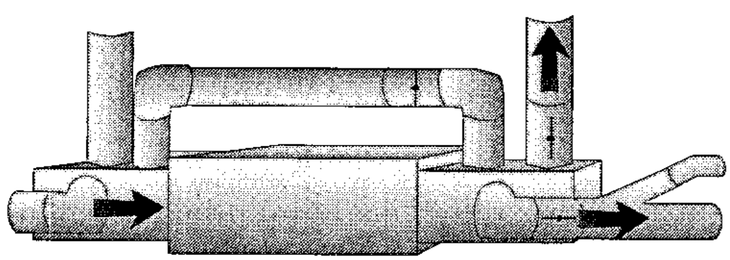
Zoned HVAC Systems

Larger buildings often use two or more separate heating and air conditioning units for different floors or areas. Multiple systems can maintain greater comfort throughout the building while saving energy by allowing different *zones* of the building to be at different temperatures. The greatest savings come when a unit serving an unoccupied zone can be turned off.

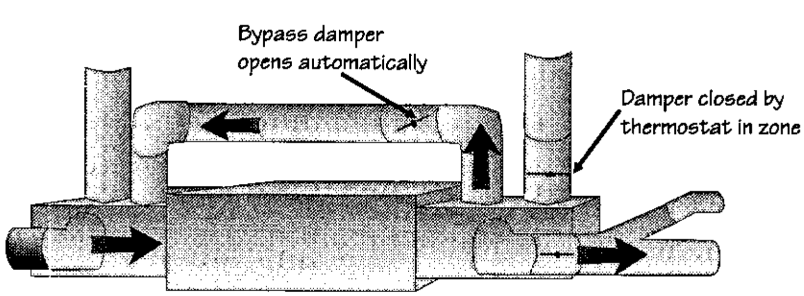
Rather than install two separate systems, contractors can provide automatic zoning systems that operate with one system. The ductwork in these systems typically has a series of thermostatically controlled dampers that regulate the flow of air to each zone. Although somewhat new in residential construction, thermostats, dampers, and controls for zoning large central systems have been used for years in commercial buildings. An example is shown in Figure 7-2.

If your heating and air conditioning subcontractor feels that installing two or three separate HVAC units is necessary, have him or her also estimate the cost of a single system with damper control over the ductwork. Such a system must be carefully designed to ensure that the blower is not damaged if dampers are closed to several supply ducts. In this situation, the blower still tries to deliver the same air flow as before, but now through only a few ducts. Back pressure created against the blades of the blower may cause damage to the motor. There are three primary design options:

Figure 7-2
Automatic Zoned System



Air flow to both zones



Air flow to one zone

1. Create two zones and oversize the ductwork so that when the damper to one zone is closed, the blower will not suffer damage.

2. Install a manufactured system that uses a dampered bypass duct connecting the supply plenum to the return ductwork. These controls always allow the same approximate volume of air to circulate.

3. Use a variable speed HVAC system. Because variable speed systems are usually more efficient than single-speed systems, they will further increase savings.

Air Conditioning Equipment

Air conditioners and heat pumps work similarly to provide cooling and dehumidification. In the summer, they extract heat from inside the building and transfer it outside. In winter, a heat pump reverses this process and extracts heat from outside and transfers it inside.

Both systems typically use a vapor compression cycle, which is described on the following page. This cycle circulates a *refrigerant*, a material that increases in temperature significantly when compressed and cools rapidly when expanded. The exterior portion of a typical air conditioner is called the *condensing unit* and houses the *compressor*, the noisy part that uses most of the energy, and the *condensing coil.*

An air-cooled condensing unit should be kept free from plants and debris that might block the flow of air through the coil or damage the thin fins of the coil. Ideally the condensing unit should be located in the shade. However, do not block air flow to this unit with dense vegetation, fencing or overhead decking.

The inside mechanical equipment, called the *air-handling unit*, houses the *evaporator coil*, the *indoor blower*, and the *expansion*, or *throttling valve*. The controls and ductwork for circulating cooled air to the building complete the system.

The SEER Rating

The cooling efficiency of a heat pump or an air conditioner is rated by the *Seasonal Energy Efficiency Ratio (SEER)*, a ratio of the average amount of cooling provided during the cooling season to the amount of electricity used. Current national legislation mandates a minimum SEER 10.0 for most residential air conditioners. Efficiencies of some units can exceed SEER 15.0. Packaged units, which combine the outdoor and indoor components into one package located outside, have a minimum SEER of 9.5.

Builders should be aware that the SEER rating is a national average based on equipment performance in Virginia. Some equipment may not produce the listed SEER in actual operation in Florida's buildings. One of the main problems has been the inability of some higher efficiency equipment to dehumidify buildings adequately (see p. 109).

If units are not providing sufficient dehumidification, the typical owner response is to lower the thermostat setting. Since every degree the thermostat is lowered increases cooling bills 3 to 7%, systems that have nominally high efficiencies, but inadequate dehumidification may suffer from higher than expected cooling bills.

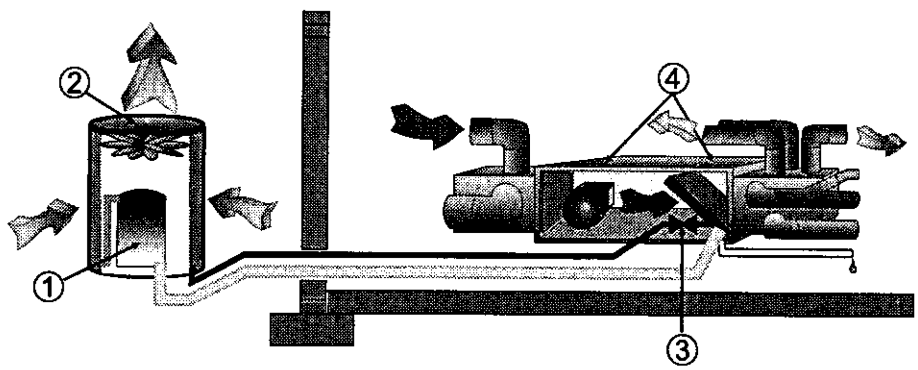
As illustrated in Tables 7-3 and 7-4, poorly functioning "high" efficiency systems may actually cost more to operate than a well designed, moderate efficiency unit. Make certain that the contractor has used *Manual J* techniques so that the air conditioning system meets both sensible and latent (humidity) loads at the manufacturer's claimed efficiency.

AIR CONDITIONERS AND HEAT PUMPS

Air Conditioners use the vapor compression cycle, a 4-step process:

1. The compressor (in the outside unit) pressurizes a gaseous refrigerant. The refrigerant heats up during this process.
2. Fans in the outdoor unit blow air across the heated, pressurized gas in the condensing coil; the refrigerant gas cools and condenses into a liquid.
3. The pressurized liquid is piped inside to the air-handling unit. It enters a throttling or expansion valve, where it expands and cools.
4. The cold liquid circulates through evaporator coils. Inside air is blown across the coils and cooled while the refrigerant warms and evaporates. The cooled air is blown through the ductwork. The refrigerant, now a gas, returns to the outdoor unit where the process starts over.

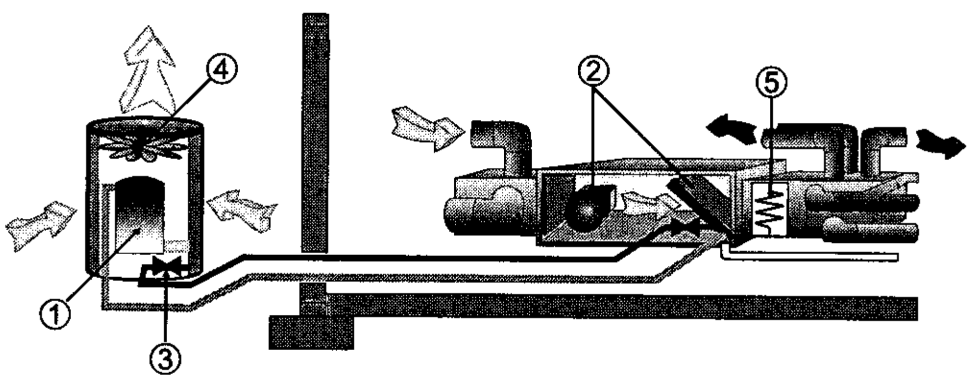
Figure 7-3
Air Conditioner



Heat pumps use a reversed version of the same cycle for heating. A reversing valve allows the heat pump to work automatically in either heating or cooling mode. The steps for heating are:

1. The compressor (in the outside unit) pressurizes the refrigerant, which is piped inside.
2. The hot gas enters the inside condensing coil. Room air passes over the coil and is heated. The refrigerant cools and condenses.
3. The refrigerant, now a pressurized liquid, flows outside to a throttling valve where it expands to become a cool, low pressure liquid.
4. The outdoor evaporator coil, which serves as the condenser in the cooling process, uses outside air to boil the cold, liquid refrigerant into a gas. This step completes the cycle.
5. If the outdoor air is so cold that the heat pump cannot adequately heat the building, electric resistance strip heaters usually provide supplemental heating.
6. Periodically in winter, the heat pump must switch to a "defrost cycle," which melts any ice that has formed on the outdoor coil.

Figure 7-4
Heat Pump



Packaged systems and room units use smaller versions of these components in a single box.

Variable Speed Units

The minimum standard for air conditioners of SEER 10.0 provides for a reasonably efficient unit. However, higher efficiency air conditioners may be quite economical. Table 7-5 examines the economics of different options for a sample home.

In order to increase the overall operating efficiency of an air conditioner or heat pump, multispeed and variable speed compressors have been developed. These compressor units can operate at low or medium speeds when the outdoor temperatures are not extreme. They can achieve a SEER of 15 to 16.

The cost of variable speed units is generally about 30% higher than standard units. Advantages they offer over standard, single-speed blowers:

- They usually save energy.
- They are quieter, and because they operate fairly continuously, there is far less start-up noise (often the most noticeable sound in a standard unit.)
- They dehumidify better. Some units offer a special dehumidification cycle, which is triggered by a humidistat that senses when the humidity levels in the building are too high.

An example of air conditioner economics is shown in Table 7-5. This table is based on 2400 annual operating hours for the air conditioning system and utility rates of $0.09/kWh.

Table 7-5
Air Conditioner Economics

Type of Treatment	Incremental Energy Savings ($/yr)	Incremental Installed Costs ($)	30 yr. mortgage 7% interest rate ($/year)	30 yr. mortgage 8% interest rate ($/year)
SEER 11 (3 tons) — Compared to SEER 10	71	500	90	94
SEER 13 (3 tons) — Compared to SEER 10	180	900	72	79
SEER 11 (4 tons) — Compared to SEER 10	94	600	48	53

Proper Installation

Unlike a refrigerator or an air conditioner in an automobile, the air conditioner in a house is assembled on-site. Major components, such as the air handler and the condenser are joined together for the first time at the construction site. The efficiency and reliability of the entire system is directly related to the care and quality of the work that goes into the installation of the complete system.

Proper installation techniques include detailed work in the following areas:

- ❒ All gauges and measuring equipment must be properly maintained and calibrated. A quick glance at a calibration sticker should not reveal a date many years in the past. Proper refrigerant charging depends on accurate measurements.
- ❒ Manufacturer's procedures should be followed regarding the proper joining of refrigerant piping.
- ❒ Evacuation is often required before refrigerant charging. The manufacturer's procedures for this process should be followed precisely. Any air that invades the system at the job site will reduce system efficiency and also contain moisture that will accelerate internal corrosion.
- ❒ Charging the system with refrigerant should also be completed by following the manufacturer's recommendations.

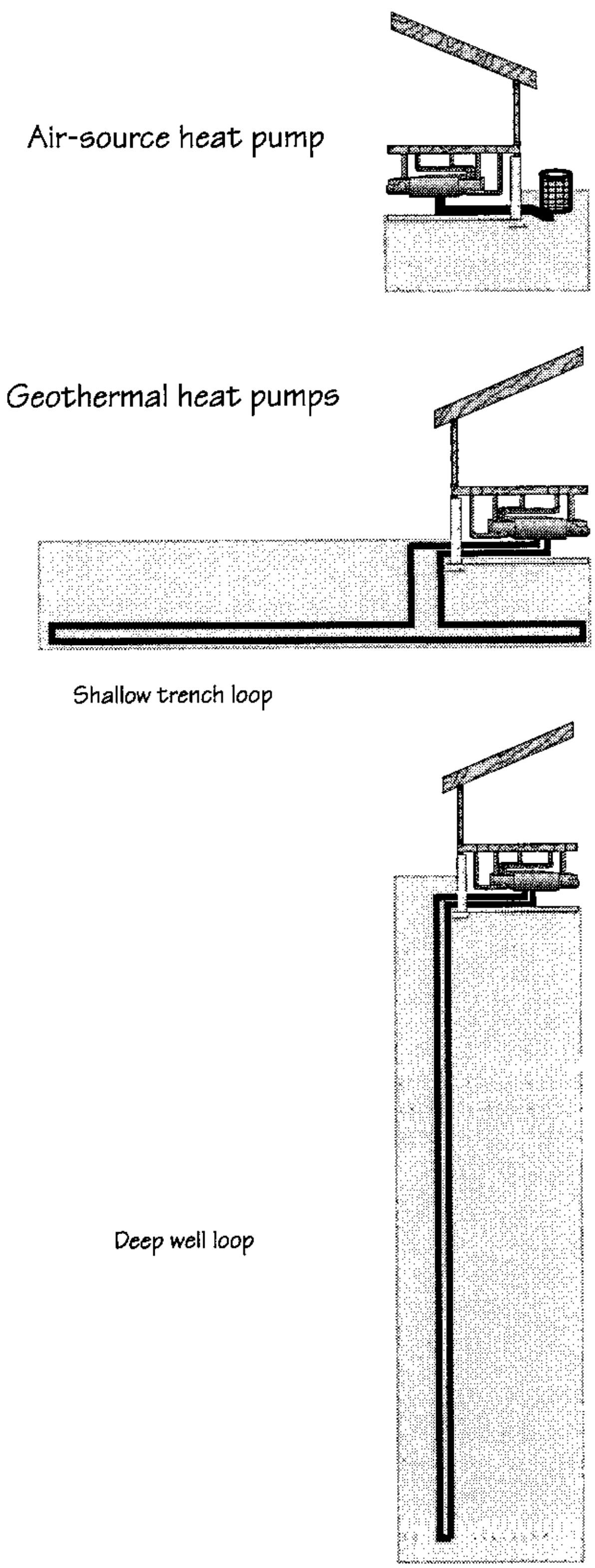
Improper refrigerant charging seriously degrades system performance. The textbook *Refrigeration & Air Conditioning*, published by the Air Conditioning & Refrigeration Institute, provides the following information:

- ❒ A refrigerant under-charge of 5% causes a 2.4% decrease in system efficiency.
- ❒ A refrigerant under-charge of 10% causes an 8.3% decrease in system efficiency.
- ❒ A refrigerant under-charge of 15% causes a 19.6% decrease in system efficiency.

Refrigerant under-charging of these percentages often represents refrigerant amounts of just a few ounces. This should illustrate the necessity of proper charging and measuring techniques.

Another often-neglected area of installation concerns is the placement of the outside unit. Homeowners often want to hide the condenser from view behind a screen, small fence or bushes. Care must be taken to prevent any blockage of air flow from the unit. Manufacturer's recommendations for proper clearance distances should be followed. Limiting the air flow to the condenser will cause the unit to operate less efficiently.

Figure 7–5
Types of Heat Pumps



Heating Systems

Two types of heating systems are most common in new buildings—*furnaces*, which burn natural gas, propane, or fuel oil, and *electric heat pumps*. Furnaces are generally installed with central air conditioners. Heat pumps provide both heating and cooling. Some heating systems are integrated with water heating systems.

Heat Pump Equipment

Air-source heat pumps

The most common type of heat pump is the *air-source heat pump* (Figure 7-5), which extracts heat from warm inside air in the summer, just like an air conditioner. In winter, it reverses the cycle and obtains heat from cool outside air. Most heat pumps operate at least twice as efficiently as conventional electric resistance heating systems. They have typical lifetimes of 15 years, compared to 20 years for most furnaces.

At outside temperatures of 25 to 35°F, a temperature known as the *balance point*, heat pumps can no longer meet the entire heating load of the building, so many use electric resistance coils called *strip heaters* to provide supplemental backup heat. Strip heaters, located in the air handling unit, are much more expensive to operate than the heat pump itself. They should not be oversized, as they can drive up the peak load requirements of the local electric utility. A staged, heat pump thermostat can be used in concert with multi-stage strip heaters to minimize strip heat operation. To overcome this problem, some buildings use a *dual-fuel* or *piggyback* system that heats the building with natural gas or propane when temperatures drop below the balance point.

Air-source heat pumps should have outdoor thermostats, which prevent operation of the strip heaters at temperatures above 35°F or 40°F. The energy code requires controls to prevent strip heater operation during weather when the heat pump alone can provide adequate heating.

GEOTHERMAL HEAT PUMPS

Unlike an air-source heat pump which has an outside heat exchanger, a geothermal heat pump relies on fluid-filled pipes buried beneath the earth as a source of heating in winter and cooling in summer (Figure 7-5). In each season, the temperature of the earth is closer to the desired temperature of the building, so less energy is needed to maintain comfort. Eliminating the outside equipment means higher efficiency, less maintenance, greater equipment life, no noise, and no inconvenience of having to mow around the outdoor unit.

Geothermal heat pumps have SEER ratings above 15 and can save up to 40% on the heating and cooling costs for a standard air-source heat pump. Some products have greater dehumidification ability than air-source heat pumps. Many units can also provide hot water at much greater efficiency than standard electric water heaters. Because of the warmer temperatures of the earth, geothermal heat pumps deliver heated air in winter into the building at a temperature between 95 to 110°F.

The following are types of closed loop designs for piping:

- In deep well systems, a piping loop extends several hundred feet under ground.
- Shallow loops are placed in long trenches, typically about 6-feet deep and several hundred feet long. Coiling the piping into a "slinky" reduces the length requirements.
- For buildings located on private lakes, loops can be installed at the bottom of the lake which usually decreases the installation costs and may improve performance.

Some geothermal heat pump systems that rely on water may require consumptive water use permits and/or discharge permits. Check your local requirements before proceeding.

Proper installation of the geothermal loops is essential for high performance and the longevity of the system, so choose only qualified professionals who have several years' experience installing geothermal heat pumps similar to that designed for your home.

Geothermal heat pumps provide longer service than air-source units. The inside equipment should last as long as any other traditional heating or cooling system. The buried piping usually has a 25-year warranty. Most experts believe the piping will last longer because it is made of a durable plastic with heat-sealed connections, and the circulating fluid has an anticorrosive additive.

Geothermal heat pumps cost $800 to $1,400 more per ton to install than conventional air-source heat pumps. The actual cost varies according to the difficulty of installing the ground loops as well as the size and features of the equipment. Because of their high installation cost, geothermal heat pumps may not be economical for buildings with low heating and cooling needs. However, their lower operating costs, reduced maintenance requirements, and greater comfort may make them attractive to many homeowners.

Measures of efficiency for heat pumps

The heating efficiency of a heat pump is measured by its *Heating Season Performance Factor* (HSPF), which is the ratio of heat provided in Btu per hour to watts of electricity used. This factor considers the losses when the equipment starts up and stops, as well as the energy lost during the defrost cycle.

Typical values for the HSPF are 6.8 for standard efficiency, 7.2 for medium efficiency, and 8.0 for high efficiency. Variable speed heat pumps have HSPF ratings as high as 9.0, and geothermal heat pumps have HSPFs over 10.0. The HSPF averages the performance of heating equipment for a typical winter in the United States, so the actual efficiency will vary in different climates.

Furnace Equipment

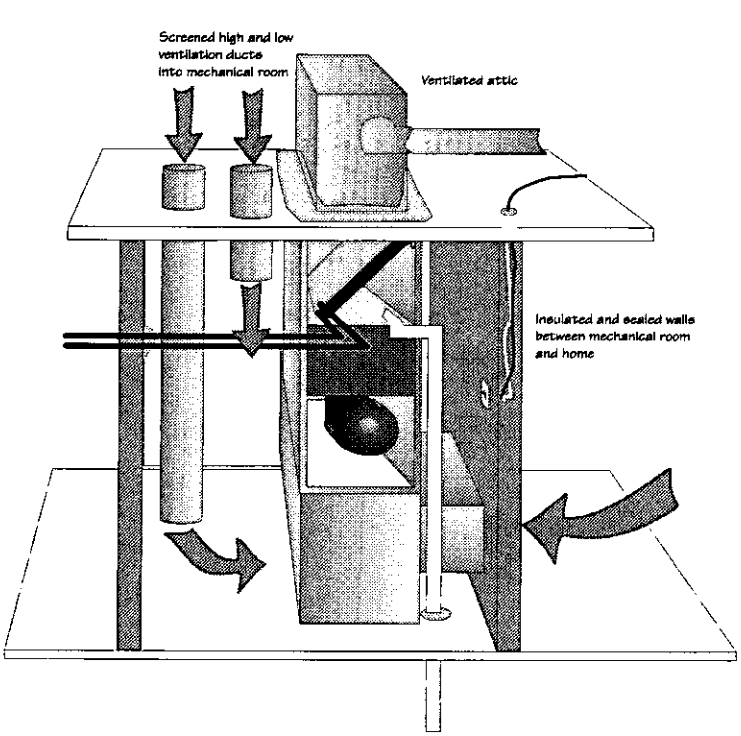
Furnaces burn fuels such as natural gas, propane, and fuel oil to produce heat and provide warm, comfortable indoor air during cold weather in winter. They come in a variety of efficiencies. The comparative economics between heat pumps and furnaces depend on the type of fuel burned, its price, the building's design, and the outdoor climate. In general, moderately efficient natural gas furnaces with central air conditioning and electric, air-source heat pumps have similar installation and operating costs.

Furnace operation

Furnaces require oxygen for combustion and extra air to vent exhaust gases. Most furnaces are *non-direct vent* units—they use the surrounding air for combustion. Others, known as *direct vent* or *uncoupled* furnaces, bring combustion air into the burner area via sealed inlets that extend to outside air. All buildings equipped with a fuel burning furnace of any type or style should be equipped with a carbon monoxide detector.

Direct vent furnaces can be installed within the conditioned area of a building since they do not rely on inside air for safe operation. Non-direct vent furnaces must receive adequate outside air for combustion and exhaust venting. The primary concern with non-direct vent units is that a malfunctioning heater may allow flue gases, which could contain poisonous carbon monoxide, into the area around the furnace. If there are leaks in the return system, or air leaks between the furnace area and living space, carbon monoxide could enter habitable areas and cause potentially severe health problems.

Figure 7-6
Sealed Mechanical Room Design



Most new furnaces have forced draft exhaust systems, meaning a blower propels exhaust gases out the flue to the outdoors. *Atmospheric* furnaces, which have no forced draft fan, are not as common due to federal efficiency requirements. However, some furnace manufacturers have been able to achieve the efficiency requirements in atmospheric units.

Atmospheric furnaces should be isolated from the conditioned space. Those units located in well ventilated crawl spaces and attics usually have plenty of combustion air and encounter no problem venting exhaust gases to the outside.

However, units located in closets or mechanical rooms inside the building, or in relatively tight crawl spaces and basements, may have problems. Furnace mechanical rooms must be well sealed from the other rooms of the building (Figure 7-6). The walls, both interior and exterior, should be insulated. Two outside-air ducts sized for the specific furnace should be installed from outside into the room, one opening near the floor and another near the ceiling, or as otherwise specified in your local gas code.

Measures of Efficiency for Furnaces

The efficiency of a gas furnace is measured by the Annual Fuel Utilization Efficiency (AFUE), a rating which takes into consideration losses from pilot lights, start-up, and stopping. The minimum AFUE for most furnaces is now 78 percent, with efficiencies ranging up to 97 percent for furnaces with condensing heat exchangers.

Unlike SEER and HSPF ratings, the AFUE does not consider the unit's electricity use for fans and blowers. These can vary by over $50 annually.

An AFUE rating of 78 percent means that for every $1.00 worth of fuel used by the unit, approximately $.78 worth of usable heat is produced. The remaining $.22 worth of energy is lost as waste heat and exhaust up the flue. Efficiency is highest if the furnace operates for longer periods of time. Oversized units run intermittently, reducing efficiencies up to 15 percent.

Furnaces with AFUEs of 78% to 87% include components such as electronic ignitions, efficient heat exchangers, better intake air controls, and induced draft blowers to exhaust combustion products.

Models with efficiencies over 90%, commonly called *condensing furnaces*, include special secondary heat exchangers that actually cool flue gases until they partially condense, so that heat losses up the flue are virtually eliminated. A drain line must be connected to the flue to catch condensate. One advantage of the cooler exhaust gas is that the flue can be made of plastic pipe rather than metal and can be vented horizontally through a side wall.

There are a variety of condensing furnaces available. Some rely primarily on the secondary heat exchanger to increase efficiency, while others, such as the *pulse furnace,* have revamped the entire combustion process.

A pulse furnace achieves efficiencies over 90% using a spark plug to explode gases, sending a shock wave out an exhaust tailpipe. The wave creates suction to draw in more gas through one-way flapper valves, and the process repeats. Once such a furnace warms up, the spark plug is not needed because the heat of combustion will ignite the next batch of gas. The biggest potential problem is noise, so make sure the furnace is supplied with a good muffler, and do not install the exhaust pipe where any potential noise will be annoying.

Because of the wide variety of condensing furnaces on the market, compare prices, warranties, and service. Also, compare the economics carefully with those of moderate efficiency units. With the lower heating requirements in Florida, the higher costs of these units might produce an unacceptably long payback period.

Unvented Fuel-Fired Heaters

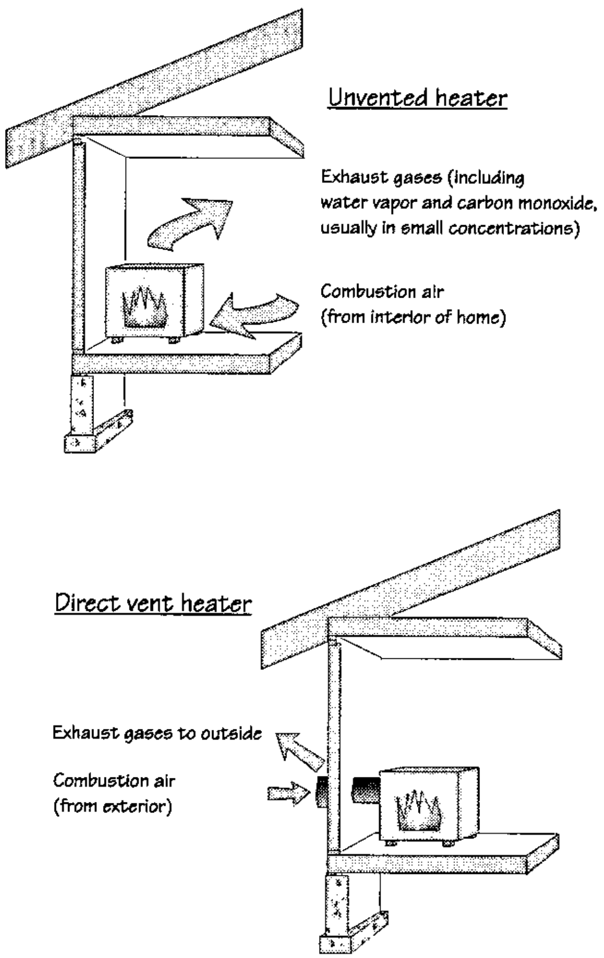
Unvented heaters that burn natural gas, propane, kerosene, or other fuels are not recommended. While these devices usually operate without problems, the consequences of a malfunction are life-threatening—they can exhaust carbon monoxide directly into the air. They also can cause serious moisture problems inside the building (Figure 7-7).

Most devices come equipped with alarms designed to detect air quality problems. However, many experts question putting a family at any risk of carbon monoxide poisoning—they see no rationale for bringing these units into a building. There are a wide variety of efficient, vented space heaters available.

Examples of unvented units to avoid include:

- ❒ Flueless gas fireplaces—use sealed combustion, direct vent units instead.
- ❒ Room space heaters—choose forced draft, direct-vent models instead.

Figure 7-7
Unvented and Direct Vent Heaters



Ventilation and Indoor Air Quality

All buildings need ventilation to remove stale interior air and excessive moisture. There has been considerable concern recently about how much ventilation is required to maintain the quality of air in buildings. While there is substantial disagreement on the severity of indoor air quality problems, most experts agree that the solution is not to build an inefficient, "leaky" building.

Research studies show that standard buildings are as likely to have indoor air quality problems as energy efficient ones. Some building researchers believe that no building is so leaky that the occupants can be relieved of concern about indoor air quality. They recommend mechanical ventilation systems for all buildings.

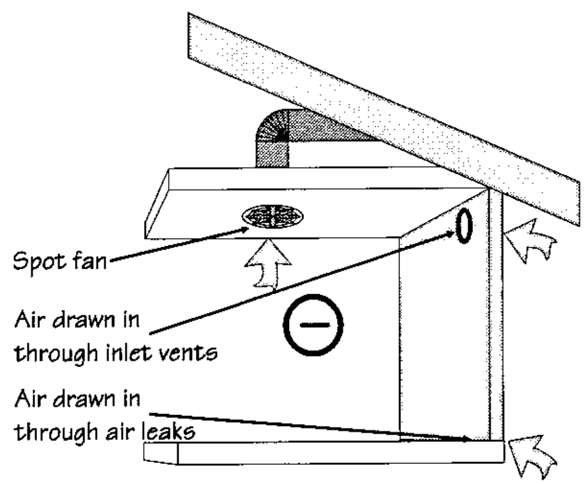
The amount of ventilation required depends on the number of occupants and their lifestyle, as well as the design of the building. The ASHRAE standard, "Ventilation for Acceptable Indoor Air Quality" (ASHRAE 62-1989) recommends that houses have 0.35 air changes per hour (ACH).

Older, drafty houses can have infiltration rates of 1.0 to 2.5 ACH. Standard buildings built today are tighter and usually have rates of from 0.5 to 1.0 ACH. New, energy efficient buildings may have 0.35 ACH or less.

The problem is that infiltration is neither continuous nor constant; it is unpredictable, and rates for all buildings vary. For example, infiltration is greater during cold, windy periods and can be quite low during hot weather. Thus, pollutants may accumulate during periods of calm weather even in drafty houses. These buildings will also have many days when excessive infiltration provides too much ventilation, causing discomfort, high energy bills, and possible deterioration of the building envelope.

Concerns about indoor air quality are leading more and more building owners to install controlled ventilation systems for providing a reliable source of fresh air. The simplest approach is to provide spot ventilation of bathrooms and kitchens to control moisture. Nearly all exhaust fans in standard construction are ineffective—a prime contributor to interior moisture problems in Florida buildings (Figure 7-8). Bath and kitchen exhaust fans should vent to the outside—not just into an attic or crawl space. General guidelines call for providing a minimum of 50 cubic feet per minute (cfm) of air flow for baths and 100 cfm for kitchens. Manufacturers should supply a cfm rating for any exhaust fan.

Figure 7-8
Ventilation with Spot Fans

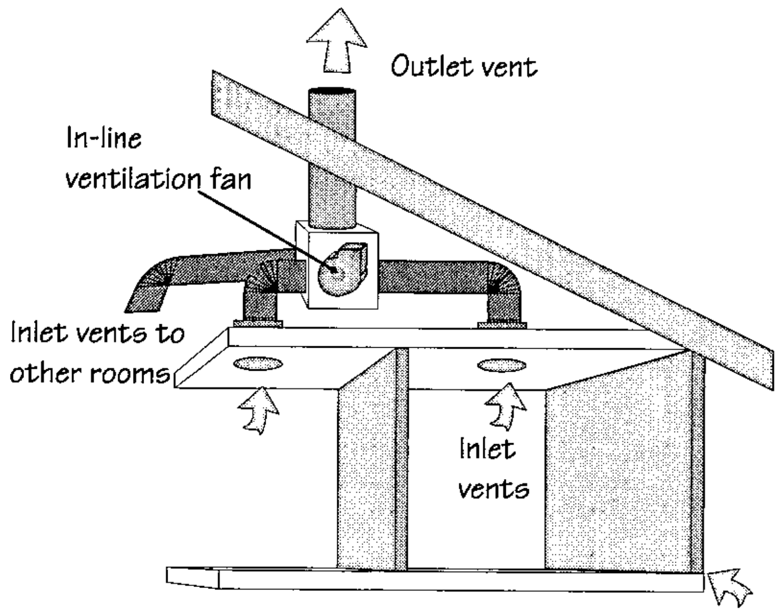


The cfm rating typically assumes the fan is working against an air pressure resistance of 0.1 inch of water—the resistance provided by about 15 feet of straight, smooth metal duct. In practice, most fans are vented with flexible duct that provides much more resistance. Some fans are also rated at pressures of 0.25 to 0.30 inches of water—the resistance found in most installations. Most ventilation experts suggest choosing a fan based on this rating.

While larger fans cost more, they are usually better constructed and therefore last longer and run quieter. The level of noise for a fan is rated by *sones*. Choose a fan with a sone rating of 2.0 or less. Top quality models are often below 0.5 sones.

Many ceiling- or wall-mounted exhaust fans can be adapted as "in-line" blowers located outside of the living area, such as in an attic. Manufacturers also offer in-line fans to vent a single bath or kitchen, or multiple rooms (Figure 7-9). Distancing the in-line fan from the living area lessens noise problems.

Figure 7-9
In-Line Ventilation Fans



While improving spot ventilation will certainly help control moisture problems, it may not provide adequate ventilation for the entire building. A *whole house ventilation system* can exhaust air from the kitchen, all baths, and perhaps the living area or bedrooms.

Whole house ventilation systems usually have large single fans located in the attic. Ductwork extends to rooms requiring ventilation. These units typically have two-speed motors. The low speed setting gives continuous ventilation—usually 10 cfm per person or 0.35 ACH. The high speed setting can quickly vent moisture or odors.

Supplying Outside Air

From air leaks

The air vented from the building by exhaust fans must be replaced by outside air—either through air leakage or a controlled inlet. Relying on air leaks requires no extra equipment; however, the occupant has little control over the air entry points. Plus, many of the air leaks come from undesirable locations, such as crawl spaces or attics. If the building is too airtight, the ventilation fans will not be able to pull in enough outside air to balance the air being exhausted. It will generate a negative pressure in the building, which may cause increased wear on fan motors. Plus, the exhaust fans may threaten air quality by pulling exhaust gases from flues and chimneys back into the building.

From inlet vents

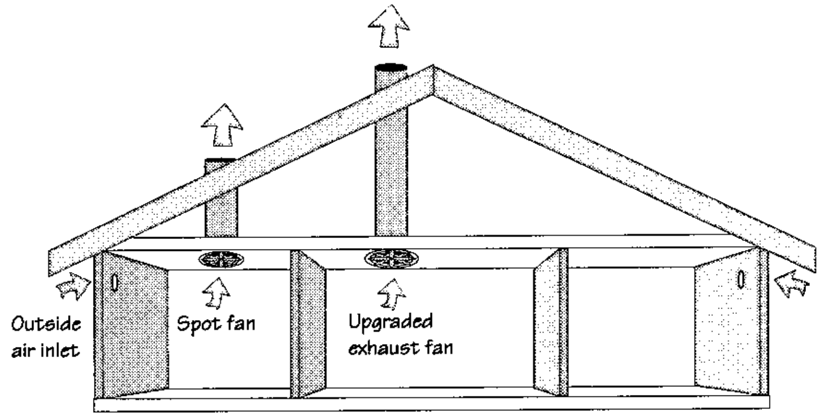
Providing fresh outside air through inlet vents is another option. These vents can often be purchased from energy specialty outlets by mail order. They are usually located in exterior walls. The amount of air they allow into the building can be controlled manually or by humidity sensors.

Locate inlet vents where they will not create uncomfortable drafts. They are often installed in bedroom closets with louvered doors or high on exterior walls.

SAMPLE VENTILATION PLANS

Figure 7-10: Upgraded Spot Ventilation

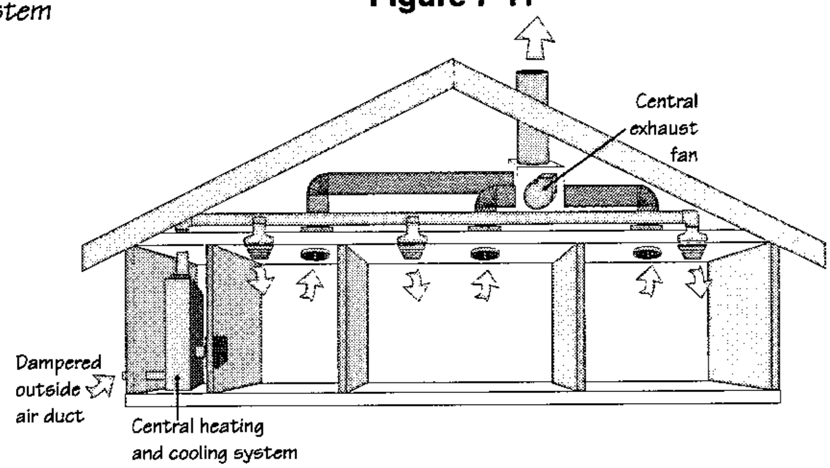
Figure 7-10



This relatively simple and inexpensive whole house ventilation system integrates spot ventilation using bathroom and kitchen exhaust fans with an upgraded exhaust fan (usually 100 to 150 cfm) in a centrally located bathroom. When the fan operates, outside air is drawn through inlets in closets with louvered doors. The fan is controlled by a timer set to provide ventilation at regular intervals. Interior doors are undercut to allow air flow to the central exhaust fan. The fan must be a long-life, high-quality unit that operates quietly. In addition to the automatic ventilation provided by this system, occupants can turn on all exhaust fans manually as needed.

Figure 7-11: Whole House Ventilation System

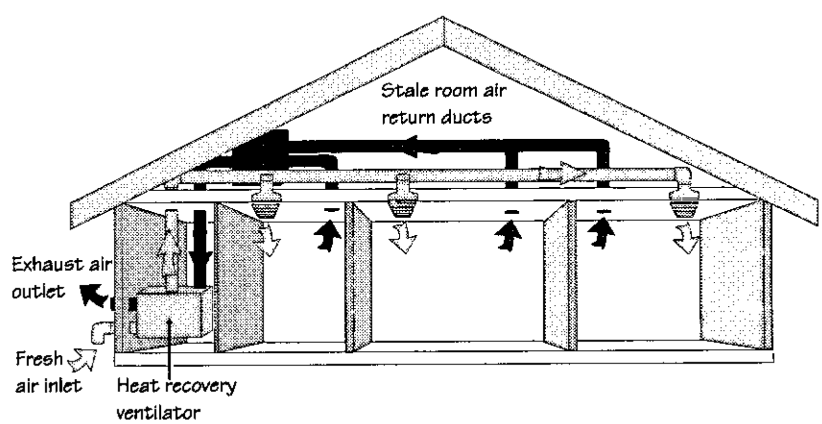
Figure 7-11



This whole house ventilation system uses a centralized two-speed exhaust fan to draw air from the kitchen, bath, laundry, and living area. The blower is controlled by a timer. The system should provide approximately 0.35 ach on low speed and 1.0 ach on high speed. Outside air is supplied by a separate dampered duct connected to the return air system. When the exhaust fan operates, the outside air damper opens and allows air to be drawn into the house through the forced-air ductwork.

Figure 7-12: Heat Recovery Ventilation (HRV) System

Figure 7-12



An enthalpy air-to-air heat exchanger draws fresh outside air through a duct into the heat exchange equipment and recaptures heating or cooling energy from stale room air as it is being exhausted. The system also dries incoming humid air in summer — a particular benefit in the Southeast. Fresh air flows into the house via a separate duct system, which should be sealed as tightly as the HVAC ductwork. Room air can either be ducted to the exchanger from several rooms or a single source. Some HRV units can be wall-mounted in the living area, while others are designed for utility rooms or basements.

VIA DUCTED MAKE-UP AIR

Outside air can also be drawn into and distributed through the building via the ducts for a forced-air heating and cooling system. This type of system usually has an automatically controlled outside air damper in the return duct system.

The blower for the ventilation system is either the air handler for the heating and cooling system or a smaller unit that is strictly designed to provide ventilation air. A disadvantage of using the HVAC blower is that incoming ventilation air may have sufficient velocity to affect comfort conditions during cool weather.

The ductwork for the heating and cooling system may be connected to a small outside air duct that has a damper which opens when the ventilation fan operates. The resulting reduced air flow should not adversely affect comfort. Special controls are available to ensure that the air handler runs a certain percentage of every hour, thus drawing fresh air in on a regular basis.

Dehumidification Ventilation Systems

Florida buildings are often more humid than desired. A combined ventilation-dehumidifier system can bring in fresh, but humid outdoor air, remove moisture, and supply it to the building. These systems can also filter incoming air. Because these systems require an additional mechanical device—a dehumidifier installed on the air supply duct—they should be designed for the specific needs of the building.

Heat Recovery Ventilators

Air-to-air heat exchangers, or heat recovery ventilators (HRV), typically have separate duct systems that draw in outside air for ventilation and distribute fresh air throughout the house. Winter heat from stale room air is "exchanged" to the cooler incoming air. Some models, called *enthalpy* heat exchangers, can also recapture cooling energy in summer by exchanging moisture between exhaust and supply air. The term *enthalpy* is referring to the energy content due to the sensible temperature difference plus the latent heat due to the moisture content as well.

While energy experts have questioned the value of the heat saved in Florida buildings for the $400 to $1,500 cost for an HRV, recent studies on enthalpy units indicate their dehumidification benefit in summer offers an advantage over ventilation-only systems. The value of any heat recovery ventilation system should not be determined solely on the cost of recovered energy—the controlled ventilation and improved quality of the indoor environment must be considered as well.

Chapter 8: Duct Design and Sealing

See Sections 410 and 610—Air Distribution Systems

The Problem of Duct Leakage

Studies conducted throughout the country have found that poorly sealed ductwork is often the most prevalent and yet easily solved problem in new construction. Duct leakage contributes 10 to 30% of heating and cooling loads in many homes. In addition, duct leakage can lessen comfort and endanger health and safety.

Locating ducts in conditioned space eliminates many problems with leakage. They are often installed in *chases*—framed air passageways situated behind the ceiling or wall finish. However, these chases are often connected more directly to unconditioned space than interior space. Therefore, it is important to seal these areas completely from unconditioned spaces.

A common practice sometimes locates the air-handling unit in the garage. Supply and return air ducts are connected to the unit through the main supply duct and a return air plenum. While this practice saves interior space by locating the equipment in the garage, it can cause other problems. The garage is a storage area for gasoline, paints, solvents, and insecticides. Starting a car also fills the garage with by-products of combustion. Any leaks in the return side of the air handling unit can draw these fumes into the air conditioning system. This can create indoor air quality problems that could be serious.

The heating and cooling contractor should use proper materials when sealing ductwork—in particular, duct sealing mastic. Duct insulation does not provide an airtight seal. To ensure ducts are tight, have your HVAC contractor conduct a duct leakage test.

Efficient operation requires that duct systems are installed as tightly as possible. In particular, mastic and mesh tape must be used to seal leaks.

Duct Leaks and Air Leakage

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, then the pressure of the building can be affected. Pressure imbalances can increase air leakage into or out of rooms in the building.

Pressure imbalances can create dangerous air quality in homes including:

- ❒ Potential backdrafting of combustion appliances such as fireplaces, wood stoves and gas burners. An improperly balanced system can create negative pressures within a structure. This imbalance or negative pressure can pull hot, humid attic air into a home. In homes with gas or propane fired appliances and furnaces this imbalance can prevent combustion gases from exiting the flue. This can cause a build up of carbon monoxide within the home, which can cause illness and even death.
- ❒ Increasing air leakage from the crawl space or slab to the home, which may draw in dust, radon gas, molds, and humidity.
- ❒ Pulling pollutants into the air handling system via return leaks.

Typical causes and concerns of pressure imbalances, addressed more fully in Chapter 3, include:

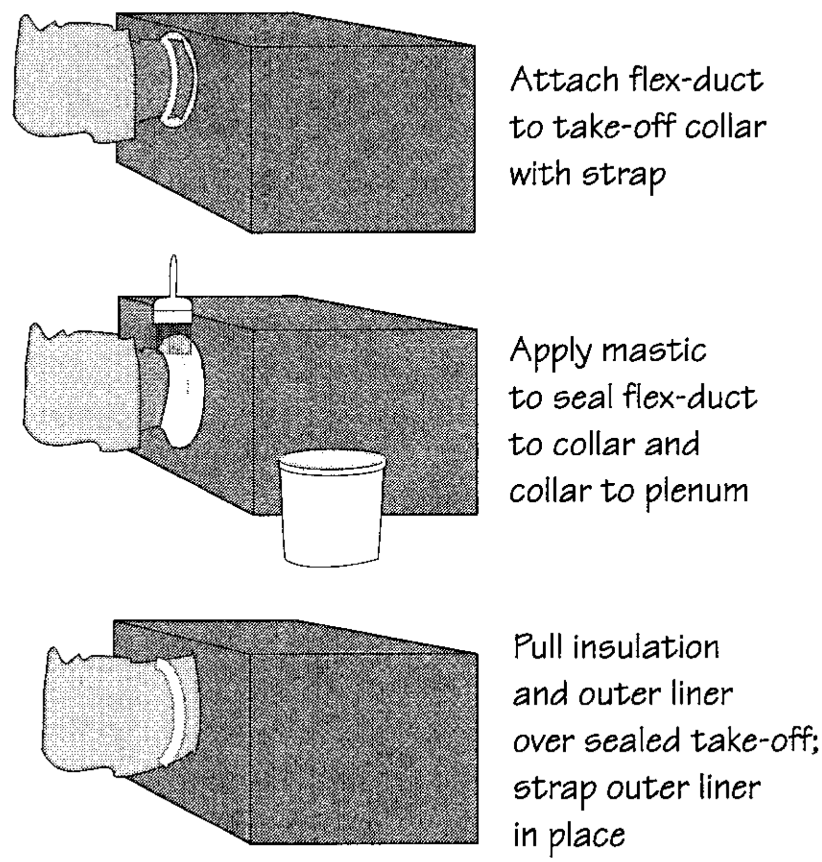
- ❒ HVAC systems with excessive supply leaks can cause homes to become depressurized, which may cause backdrafting of combustion appliances in the home.
- ❒ HVAC systems with excessive return leaks can cause homes to become pressurized and create negative pressures around the air handling unit. The negative pressures may cause combustion appliances near the air handling unit to backdraft.
- ❒ Homes with central returns can have pressure imbalances when the interior doors to individual rooms are closed. The rooms having supply registers and no returns become pressurized, while the areas with central returns become depressurized. Often the returns are open to living rooms with fireplaces or combustion appliances. When these spaces become sufficiently depressurized, the flues will backdraft.
- ❒ Tighter homes with effective exhaust fans, such as kitchen vent hoods, clothes dryers, and attic ventilation fans, may experience negative pressures whenever these ventilation devices are operating.

Sealing Air Distribution Systems

Duct leakage should be eliminated. In standard construction, many duct seams are not sealed or are poorly sealed with ineffective materials such as cloth "duct tape," unrated aluminum tape, or similar products with lower quality adhesives not designed to provide an airtight seal over the life of the home. The following products are examples of proper materials to be used to seal duct systems:

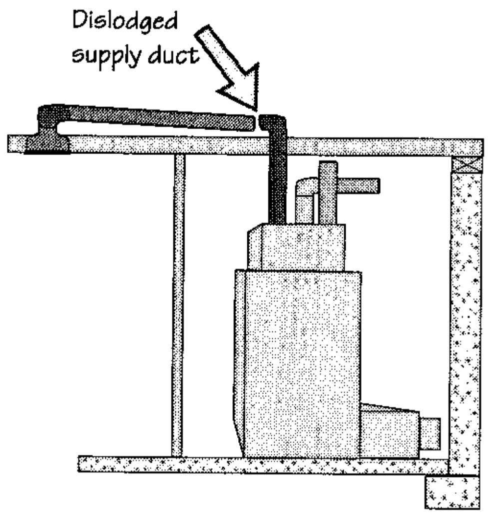
- ❐ Duct sealing mastic with fiberglass mesh tape—highly preferred—may add $20 to $55 to the cost of a $5,000 system, but will provide a lifetime, airtight seal (Figure 8-1).
- ❐ Aluminum tape with a UL-181 A or B rating may be used for assembling fibrous duct board—but must be installed properly to be effective. The duct surface must be clean of oil and dirt, and the tape must fully adhere to the duct with no wrinkles. A squeegee must be used to remove air bubbles from beneath the taped surface. There are some tapes that meet the UL standard that are not aluminum.
- ❐ High quality caulking or foam sealant.
- ❐ Some duct manufacturers are listing closure products that they allow to be used with their products.

Figure 8-1
Sealing Flex-duct Collar with Mastic

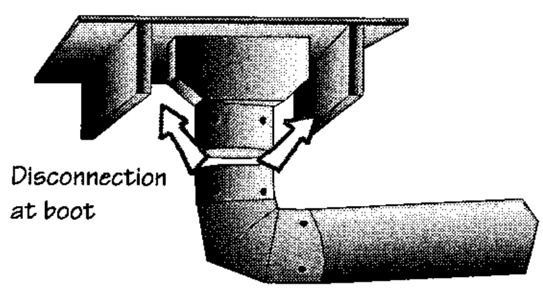


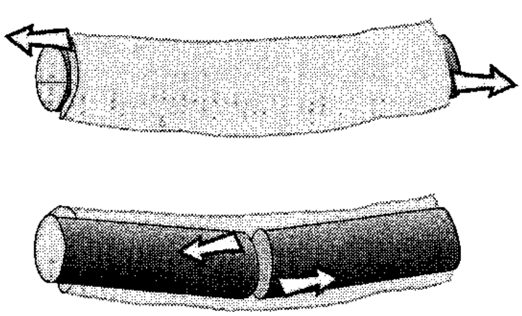
Proper sealing and insulation of the ductwork in unconditioned areas requires careful attention to detail and extra time on the part of the heating and air conditioning contractor. The cost of this extra time is well worth the substantial savings on energy costs, improved comfort, and better air quality that an airtight duct system offers.

Figure 8-2
Disconnected Ducts Are High Priorities



Ducts can become disconnected during initial installation, maintenance, or even normal operation.
They should be checked periodically for problems.





Sometimes, disconnected ducts can be hidden behind the insulation.
Look for patterns of dust or dirt on the insulation that indicate air leaks, or kinks or curves where there is no elbow.

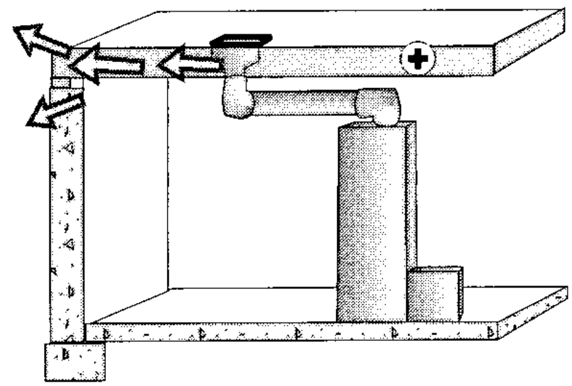
The easiest answer to the question of where to seal air distribution systems is "everywhere." A list of the key locations is as follows:

High priority leaks

- ❐ Disconnected components (Figure 8-2), including takeoffs that are not fully inserted, plenums or ducts that have been dislodged, tears in flex-duct, and strained connections between duct, as in Figure 8-3 (visible when the duct bends where there is no elbow).

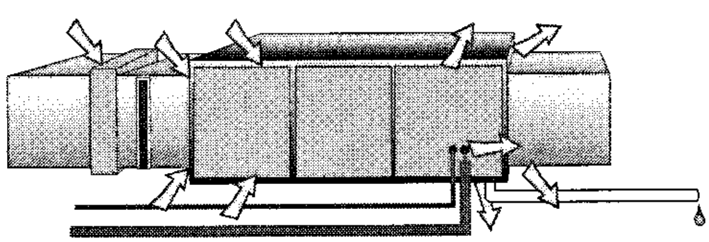
- ❐ The connections between the air handling unit and the supply and return plenums.

Figure 8-3
Duct Leaks in Inside Spaces

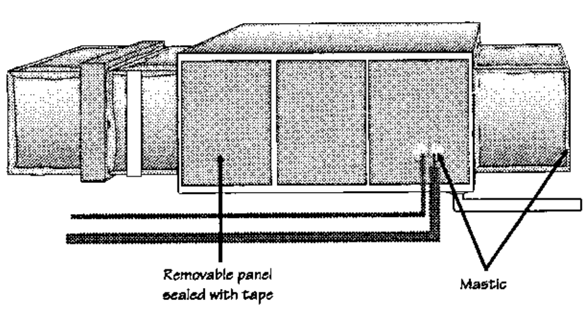


Although this supply duct is theoretically in conditioned space, the supply leaks pressurize the band joist area and air leaks to the outside. The best solution: seal all duct leaks and all building envelope leaks.

Figure 8-4
Seal All Leaks in Air Handling Unit

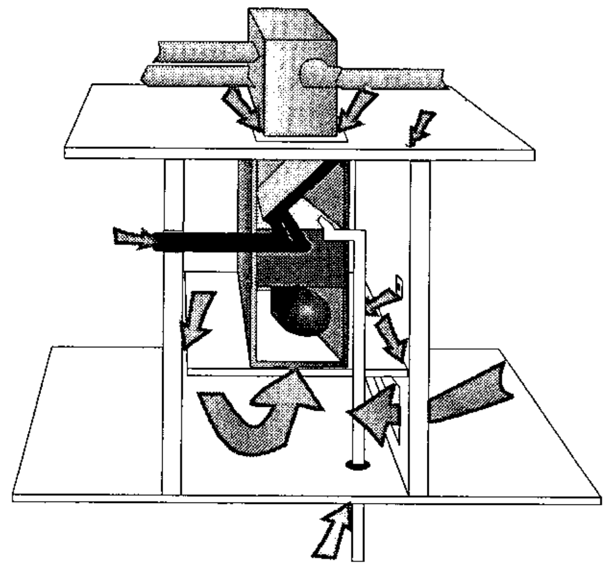


Many air handling cabinets come from the factory with leaks, which should be sealed with duct-sealing mastic. Removable panels should be sealed with tape.

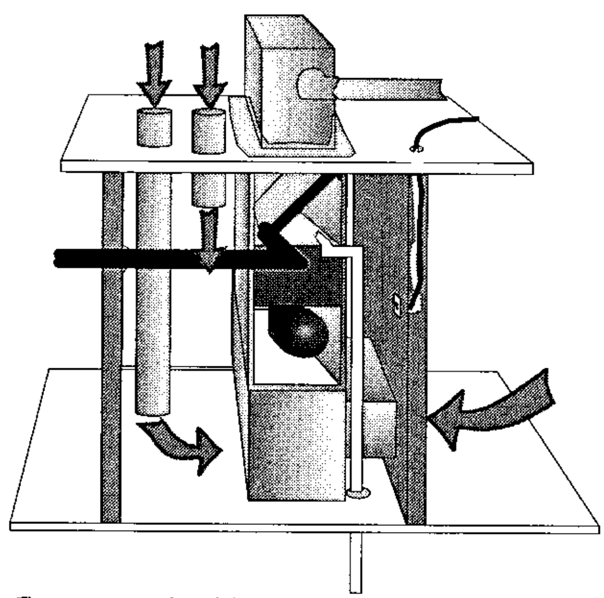


❐ All of the seams in the air handling unit, plenums, and rectangular ductwork—look particularly underneath components and in any other tight areas (Figures 8-4 and 8-5). Also seal the holes for the refrigerant, thermostat, and condensate lines. Use tape rather than mastic to seal the seams in the panels of the air handling unit so they can be removed during servicing. After completion of service and maintenance work, such as filter changing, make sure the seams are retaped.

Figure 8-5
Shelf-Mounted Systems Without Returns



Nonducted returns can severely depressurize mechanical room closets, not only sapping the system's efficiency, but also creating ideal conditions for backdrafting and other air quality problems. Seal all leaks with mastic or caulk.



The return should be connected to the home via a well-sealed duct. All holes from the mechanical room closet to the other spaces should be completely sealed.

- ❒ The return takeoffs, elbows, boots, and other connections (Figure 8-6). If the return is built into an interior wall, all connections and seams must be sealed carefully. Look especially for unsealed areas around site-built materials.
- ❒ The takeoffs from the main supply plenum or trunk line.
- ❒ Any framing in the building used as ductwork, such as a "panned" joist in which sheet metal nailed to floor joists provides a space for conditioned air to flow. It is preferable to avoid using framing as a part of the duct system.

Figure 8-6
Seal All Leaky Takeoffs

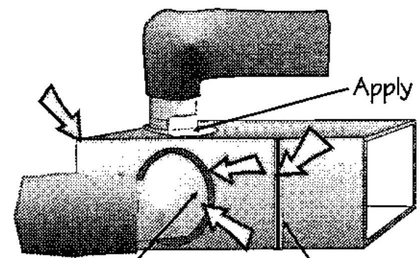
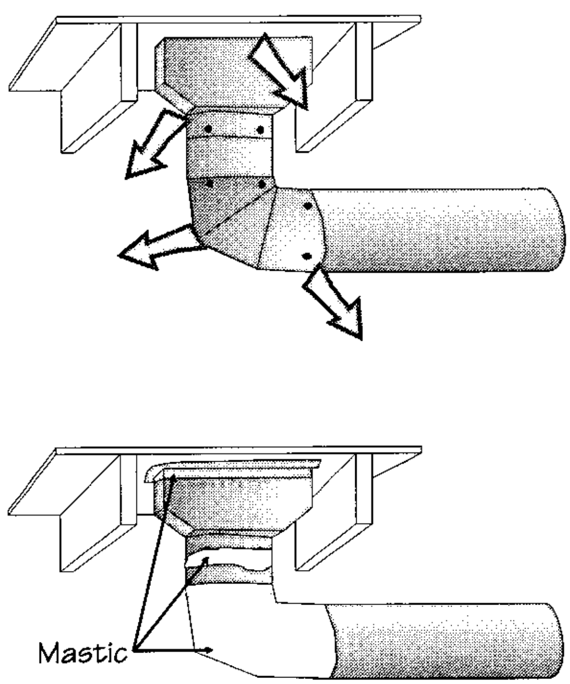


Figure 8-7
Sealing Leaky Boots



Use mastic to completely seal all leaky seams and holes. Use mesh tape with mastic to cover cracks over 1/8-inch wide.

- ❒ The connections near the supply registers—between the branch ductwork and the boot, the boot and the register, the seams of the elbows, and all other potential leaks in this area (Figure 8-7).

Moderate priority leaks

- ❒ The joints between sections of the branch ductwork.

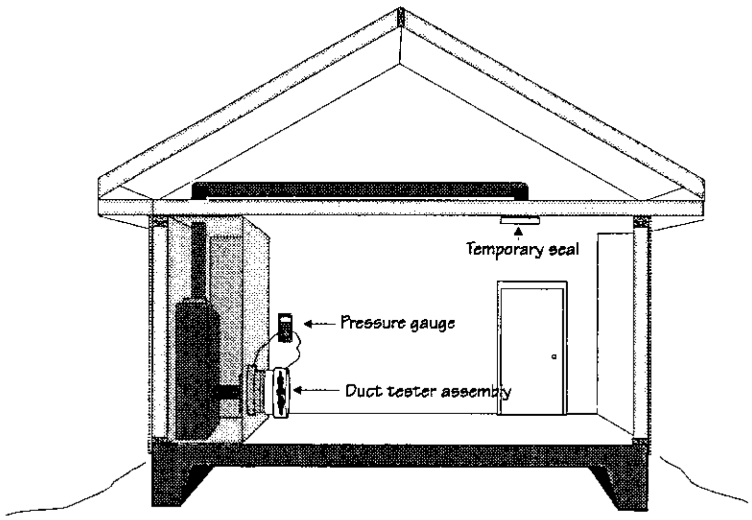
Low priority leaks

- ❒ Longitudinal seams in round metal ductwork.

TESTING FOR DUCT LEAKAGE

The best method to ensure airtight ducts is to pressure test the entire duct system, including all boot connections, duct runs, plenums, and air handler cabinet. Much like a pressure test required for plumbing, ductwork can be tested during construction so that problems can be easily corrected.

Figure 8-8
Duct Test on Return Grille



In most test procedures, a technician temporarily seals the ducts by taping over the supply registers and return grilles. Then, the ducts are pressurized to a given pressure—usually 25 Pascals. This pressure is comparable to the pressure the ducts experience when the air handler operates.

The ducts are usually tested for tightness using a duct testing fan. Measuring the airflow through the fan gives an estimate of the air leakage through unsealed seams in the ductwork.

Some energy efficiency programs require that the cubic feet per minute of duct leakage measured at a 25 Pascal pressure (CFM25) be less than 3% of the floor area of the house. For example, a 2,000-square-foot house should have less than 60 CFM25 of duct leakage.

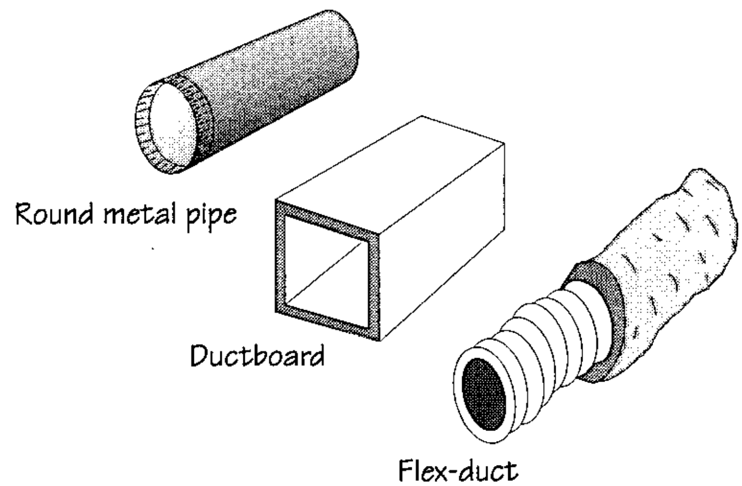
Another test is to use a blower door (described in Chapter 3) and a duct testing fan together to measure duct leakage after construction is complete. This procedure gives the most accurate measurement of duct leakage to the outside of the home. A duct leakage test can usually be done in about one hour for an average sized home.

Duct Design

Duct Materials

The three most common types of duct material used in building construction are *metal, fiberglass duct board*, and *flex-duct* (Figure 8-9). Both metal and fiberglass duct board are rigid and installed in pieces, while flex-duct comes in long sections.

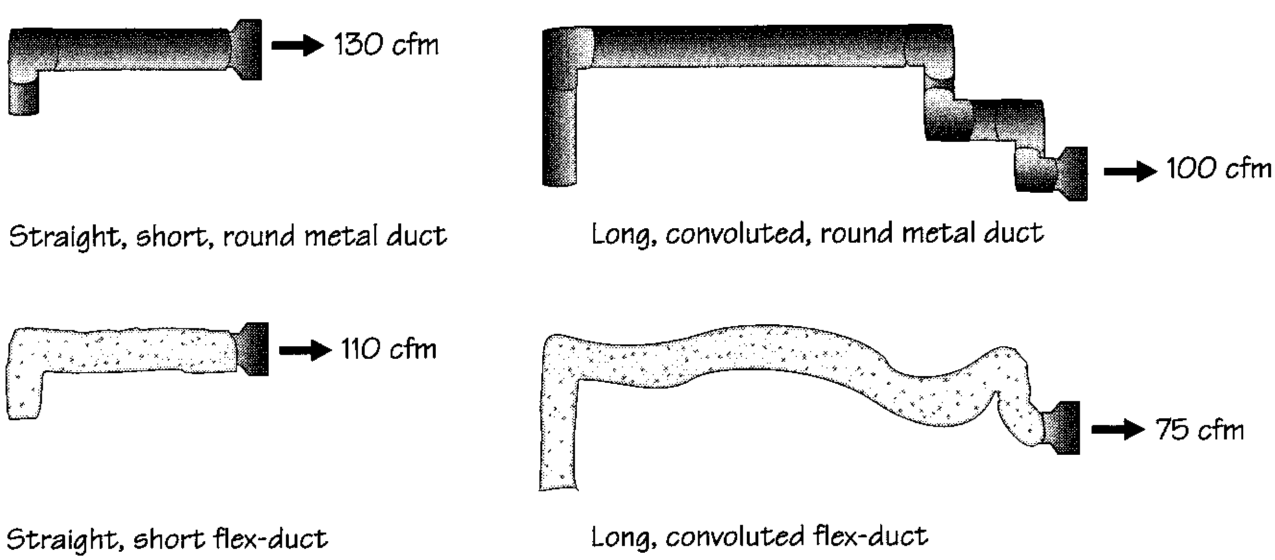
Figure 8-9
Types of Ductwork



Flex-duct is usually installed in a single, continuous piece between the register and plenum box, or plenum box and air handler. While it has fewer seams to seal, it is important that the soft lining material not be torn. The flex-duct must also not be pinched or constricted. Long flex-duct runs can severely restrict air flow, so they must be designed and installed carefully (Figure 8-10). Flex-duct takeoffs, while often airtight in appearance, can have substantial leakage and should be sealed with mastic.

Round and rectangular metal duct must be sealed with mastic and insulated during installation. It is important to seal the seams first, because the insulation does not stop air leaks. Rectangular metal duct used for plenums and larger trunk duct runs is often insulated with duct liner, a high density material that should be at least 1 inch thick.

Figure 8-10
Comparison of Air Flow in Different 6-inch Ducts



Metal ducts often use fiberglass insulation having an attached metal foil vapor retarder. The duct insulation should be at least R-6, and the vapor retarder should be installed to the outside of the insulation—facing away from the duct. The seams in the insulation are usually stapled together around the duct and then taped. Duct insulation in homes at least two years old provides great clues about duct leakage—when the insulation is removed, the lines of dirt in the fiberglass often show where air leakage has occurred.

Sizing and layout

The size and layout of the ductwork affects the efficiency of the heating and cooling system and comfort levels in the home. The proper duct size depends on:

- ❒ The estimated heating and cooling load for each room in the house.
- ❒ The length, type, and shape of the duct.
- ❒ The operating characteristics of the HVAC system (such as the pressure, temperature, and fan speed).

The lower temperature of the heated air delivered by a heat pump affects the placement of the registers. A heat pump usually supplies heated air between 90°F and 110°F. At these temperatures, air leaving registers may feel cool. It is important that they are placed so as to avoid blowing air directly onto people. Fuel-fired furnaces typically deliver heated air at temperatures between 110°F and 140°F, 40°F to 70°F greater than room temperature, so placement of the supply registers is less important to maintain comfort.

In standard duct placement and design, supply registers are almost always located on outside walls under or above windows, and return registers are placed towards the interior, typically in a central hallway.

Some builders of energy efficient homes have found little difference in temperature between interior areas and exterior walls because of the extra energy features. Locating the supply registers on exterior walls is not as necessary to maintain comfort. These builders are able to trim both labor and material costs for ductwork by locating both supply and return ducts near the core of the house.

In standard duct design, virtually all supply ducts are 6-inch flex-duct or round metal pipe. Most standard designs have only one return for each floor.

The above rules work for some homes, but can create operating problems for others, including:

- Too much heating and cooling supplied to small rooms, such as bathrooms and bedrooms with only one exterior wall.
- Inadequate airflow, and thus, insufficient heating and cooling in rooms located at a distance from the airhandler.
- Overpressurization of rooms when interior doors are closed.

The heating and cooling industry has comprehensive methods to size supply and return ductwork properly. These procedures are described fully in *Manual D, Duct Design* published by the Air Conditioning Contractors' Association (example on the following pages).

Unfortunately, few residences have ductwork designed via *Manual D*. Most HVAC contractors use 6-inch ductwork for every supply register in the home. The primary "design" is determining, usually via intuition, how many registers should be installed in each room.

Figure 8-11 shows the size ductwork *Manual D* would specify for a small home. The design is vastly different than the typical, all 6-inch system. The advantage of proper design is that each room receives air flow proportionate to its heating and cooling load, thus increasing overall comfort and efficiency.

The following recommendations, while no substitute for a *Manual D* calculation, should improve system performance:

- If two rooms have similar orientation, window area, and insulation characteristics, but one room is considerably farther from the air handling unit than the other, consider increasing the size of the ductwork going to the farthest room.
- Bonus rooms over garages often need additional or larger supplies.
- Rooms with large window areas may warrant an extra supply duct, regardless of the room size.
- Likewise, large rooms with few windows, only one exterior wall, well insulated floor, and conditioned space above may need only one small duct.
- Provide return air capability for bedrooms when bedroom doors are shut.

CHECKING SYSTEM AIR FLOW

Use this simple form to check the ductwork for proper sizing:

Step 1: Find the system's cooling capacity in tons.

Step 2: Multiply the tonnage by 400 to get the desired total air flow in cubic feet per minute (cfm) =
400 x ________ tons = ___________ cfm total

Step 3: Check the supply air flow

a. Determine the number of supply registers connected to 4", 6", 8", and 10" branch ducts .

b. Fill in column 2 in the chart below. Then multiply the number of ducts by the air flow and put the result in Column 4. Add the flows in Column 4. If the total is within 10% of the actual air flow (from Step 2), the supply ductwork is probably adequate.

1. Branch Duct Size	2. Number of Supply Registers	3. Air Flow per Register (cfm)	4. Duct Air Flow (cfm) Step 2 x Step 3
4"		50	
6"		100	
8"		200	
10"		400	
Total Air Flow			cfm

Step 4: Check the return air velocity

a. Measure the total area of all return grilles = ________ square inches

b. Multiply the total area in 4a by 70% = _______ square inches

c. Divide the answer to b by 144 to get square feet of area = ________ square feet

d. Write the total air flow here = ________ cfm (total cfm in chart above)

e. Divide the air flow in 4d by the area in 4c to get the estimated return air velocity:
airflow _______ / area ________ = ________ ft/minute

If the velocity is over 650 ft/ minute, add a return or increase the size of a return.

Example:

Home with 2.5 ton system, one 4-inch, eight 6-inch, and one 8-inch branch supply ducts.

Step 1: 2.5 tons

Step 2: 400 x 2.5 = 1,000 cfm

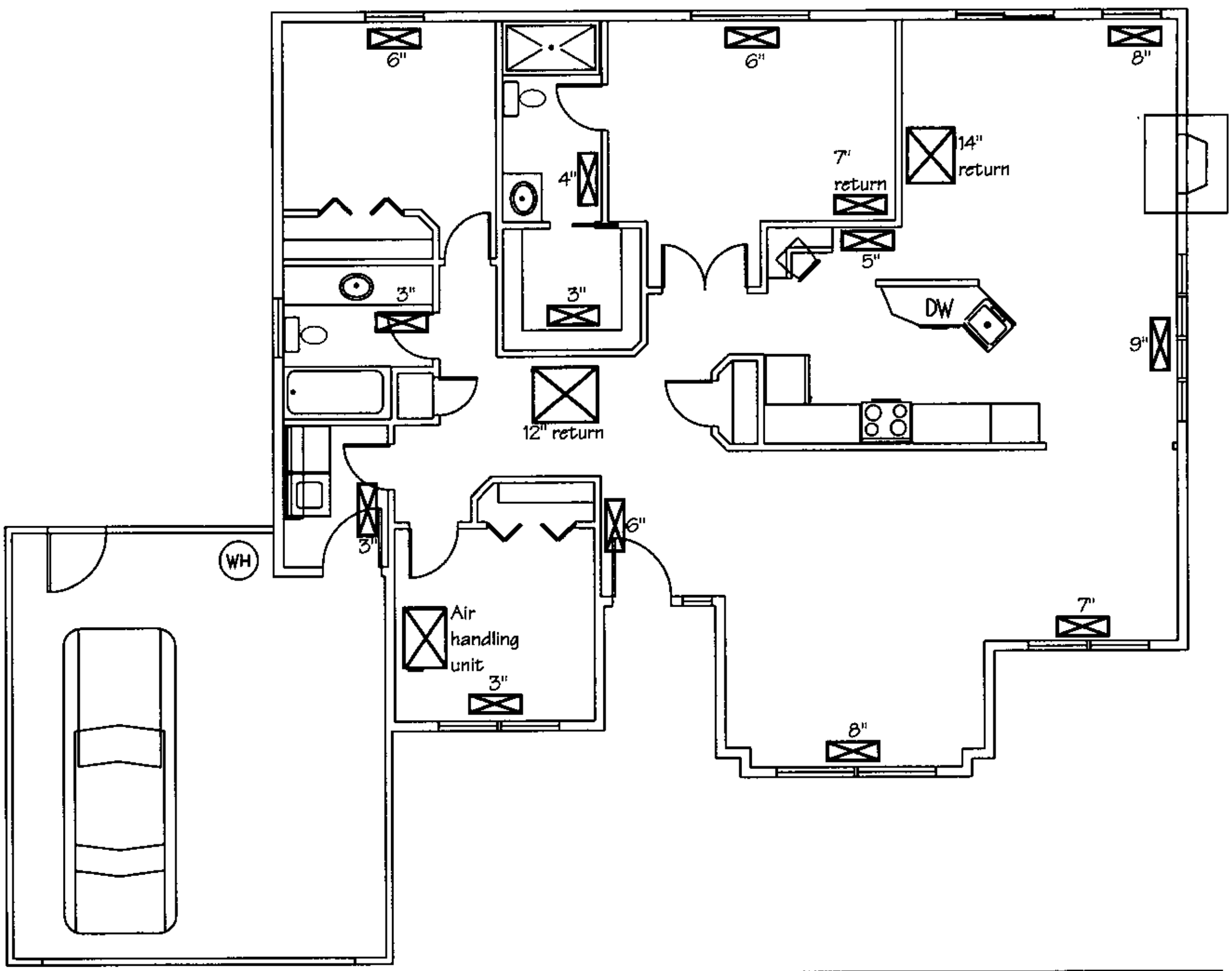
Step 3:

1. Branch Duct Size	2. Number of Supply Registers	3. Air Flow per Register (cfm)	4. Duct Air Flow (cfm) Step 2 x Step 3
4"	1	50	50
6"	8	100	800
8"	1	200	200
10"	0	400	
Total Air Flow			1,050 cfm

Since 1,050 cfm is within 10% of system air flow, there should be enough supply ducts.

Figure 8-11
Duct Design Using Manual D

(In standard duct installation, all supply registers would be 6 inches in diameter, and there would be a single 14-inch to 16-inch return.)



Ductwork Summary			
Supply		**Return**	
Size	**Number**	**Size**	**Number**
3"	4	7"	1
4"	1	12"	1
5"	1	14"	1
6"	3		
7"	1		
8"	2		
9"	1		

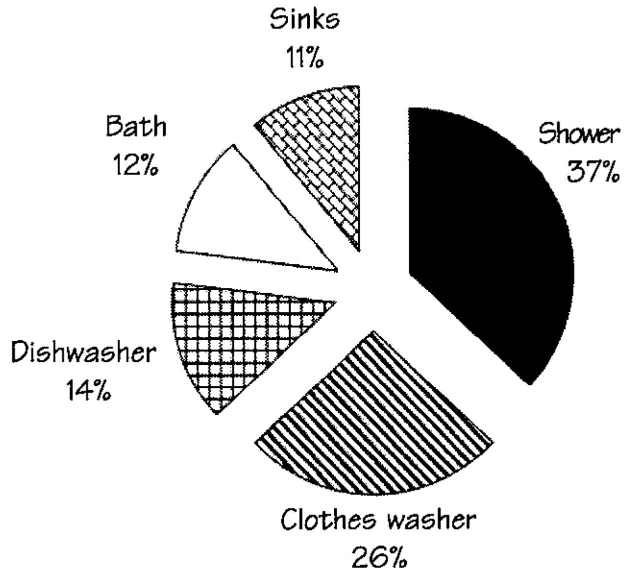
Chapter 9: Domestic Water Heating

See Sections 412 and 612—Water Heating Systems

Water heating is an important end-use that accounts for roughly 16% to 20% of the total energy consumption in the home. Recently enacted efficiency standards on water heaters and hot water-using appliances and equipment (e.g., showerheads, faucets, dishwashers and clothes washers) can and will substantially affect the energy use of water heaters in the future.

The typical U.S. homeowners' hot water consumption, by place of use, is shown in Figure 9-1.

Figure 9-1
Hot Water Use in Typical Homes
(by place of use)



Source: United States Department of Energy

Energy Conservation For Water Heating

No matter what type of energy source is used to heat water, be certain to take advantage of the savings from conservation measures:

❒ Lower the temperature setting on the water heater to 120°F.

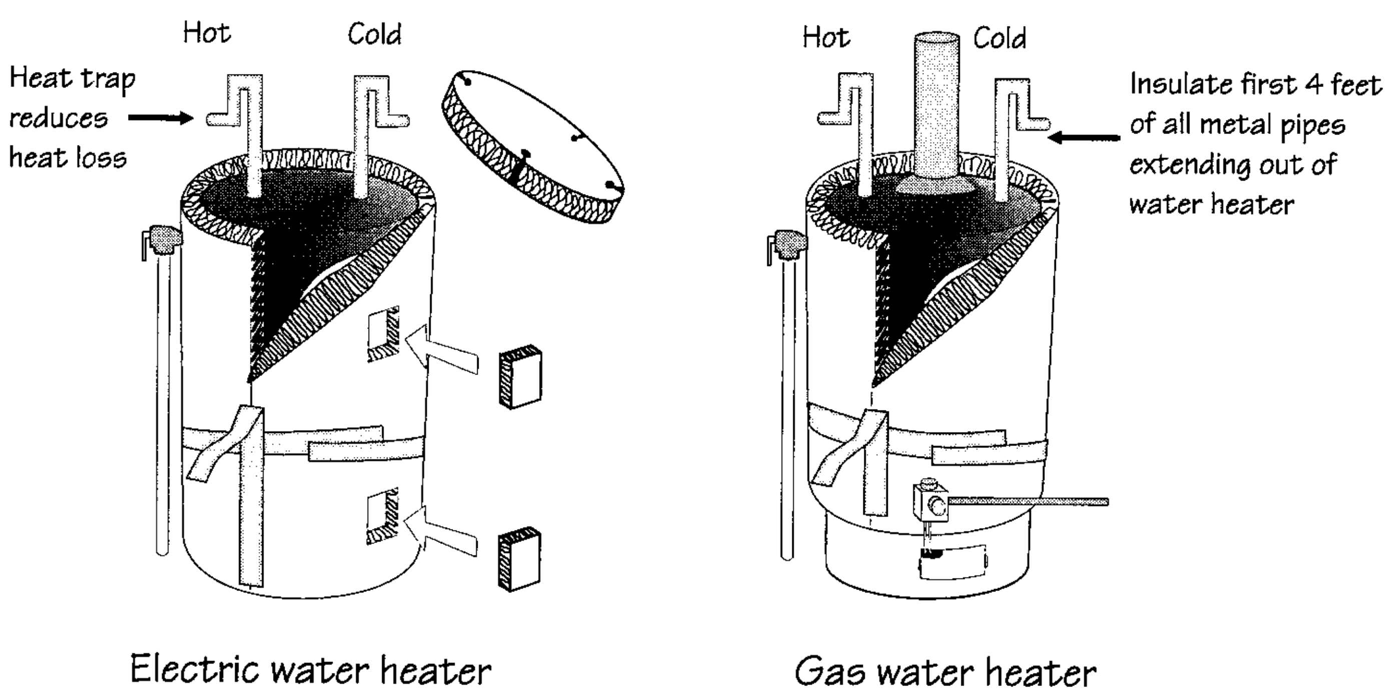
- Saves energy; for each 10°F (5.6°C) reduction in water temperature, water-heating energy consumption can be reduced 3% to 5 %.
- Reduces the risk of injury from scalding.
- Provides plenty of hot water.
- If hotter temperatures are needed for dish washing, select dishwashers with booster heaters.

❐ Wrap the outside of the water heater tank with an insulation jacket (Figure 9-2).

- Simple to install.
- On all types, do not cover the emergency pressure relief or drain valve; pressure buildup due to continuously heated water will force open this valve, allowing hot water to flow out of the tank through the pressure relief pipe to an outlet outside.
- On electric water heaters, do not cover the thermostat or access panels.
- On gas water heaters, do not cover the top, the controls, or the lower third of the tank—the air inlet or the flue vent on the top. Check with the installer for specific instructions, because if insulation is placed over any of these areas, the controls may overheat or the unit may become starved for air—resulting in hazardous explosions. Keep in mind that some models have the temperature/pressure relief valve and the overflow pipe on the side of the tank instead of on the top.

❐ Install heat traps, or one-way valves, which allow water to flow into the tank and prevent unwanted hot-water flow out of the tank. Most new water heater models have factory-installed traps (Figure 9-2). Those not having built-in heat traps should be installed with an external heat trap. The Energy Code states that such devices shall consist of either a commercially available heat trap or a downward and upward bend of at least 3 ½ inches in the hot water distribution line and cold water line located as close as practical to the storage tank.

Figure 9-2
Insulating Jackets for Electric and Gas Water Heaters



- ❒ Insulate the first three or four feet of the cold and hot water pipes connected to the unit.

- ❒ Install low-flow showerheads with well-designed fixtures that deliver water at about 1.5 to 2.5 gallons per minute and still provide plenty of force.

- ❒ Put in shutoff valves on low-flow showerheads and kitchen faucets, which are designed to dribble when closed, so water in the pipe stays at the selected temperature while soaping, shaving or shampooing. These valves are built into many low-flow heads.

- ❒ Include low-flow aerators or laminar flow controls on sink and lavatory faucets.

  - Saves on energy bills as aerators add air to the water stream and make a light flow feel heavier.
  - Laminar flow controls work by producing dozens of streams of water very close to one another. Many believe they make the water feel that it is flowing at a higher rate than in actuality.
  - Kitchen sink may need a higher volume flow faucet (2.5 gallon-per-minute) for washing/rinsing dishes and filling cooking containers.

- ❒ Minimize the piping runs to the bathroom and kitchen.

- ❒ Put in or recommend ENERGY STAR® washing machines; approximately 90% of the energy used is to heat water, with some of the newer energy-efficient models using about one-third the hot water.

- ❒ Install ENERGY STAR® dishwashers; approximately 80% of the energy consumed for dishwashing is used by the hot water heater to heat water to 140°F. New, energy efficient dishwashers are equipped with a temperature boost feature that raises the incoming water temperature by 20°F.

Other Possible Ways to Conserve Water

METLUND® Hot Water D'MAND™ System

This pumping system utilizes the cold water line as a return line for a hot water loop back to the water heater. The system is placed between the cold and hot water line located under the cabinet at the most distant fixture. When the system is activated, an electronic valve opens and the pump moves the cold water in the hot water side rapidly across the valve to the cold water side. The cold water in the line is then replaced by the hot water that is now moving from the water heater through the hot water pipe towards the most distant fixture. Upon the arrival of the hot water, a thermal sensor at the location senses a temperature rise, thus quickly closing the valve and automatically shutting down the pump. This system can be activated in a number of different ways including push button, remote control, light beam, motion sensor, etc. The savings are a result of getting hot water to your farthest fixture faster without the loss of any water down the drain. The energy requirement to run the pump is minimal since it only operates when activated and turns off automatically.

Additional Water Heater

Some builders add a small (2 to 6 gallon) water heater at the end of a long plumbing run. By being connected in a series with the main water heater, the owner has instant hot water and before the small heater runs out of water, the main unit is activated. Energy is spent to save water.

Selecting an Efficient Water Heater

Sizing

Above all, the "capacity" of a water heater should be judged by its first hour rating (FHR), not its tank size. The peak-hour demand capacity or the FHR, required on the EnergyGuide label, is actually more important that the size of the storage tank. The FHR is a measure of how much hot water the heater will deliver during a busy hour. Due to larger burners, some gas water heaters with smaller tanks usually have higher capacities (FHRs) than models with larger tanks. The size tank needed will depend on the number of people living in the home and the patterns of usage. Selecting an oversized water heater, besides raising the purchase cost, will result in increased energy costs due to excessive cycling and standby losses.

Gas water heaters have higher FHRs than electric water heaters of the same storage capacity. Therefore, it may be possible to meet the water-heating needs with a gas unit that has a smaller storage tank than an electric unit with the same FHR. More efficient gas water heaters use various nonconventional arrangements for combustion air intake and exhaust. These features, however, can increase installation costs.

All other things being equal, the smaller the water heater tank, the higher the efficiency. Compared to small tanks, large tanks have a greater surface area, which increases heat loss from the tank and decreases the energy efficiency somewhat, as mentioned above.

Selecting an oversized water heater, besides raising purchase cost, will result in increased energy costs due to excessive cycling and standby losses. The American Council for an Energy-Efficient Economy's (ACEEE) *Consumer Guide to Home Energy Savings* and the Gas Appliances Manufacturers Association's (GAMA) *Consumer's Directory of Certified Efficiency Ratings* provide good, simple guidance on proper sizing of water heaters.

Fuel Type

One of the first steps in choosing a water heater is to determine the appropriate fuel type. Natural gas water heaters are generally less expensive to operate, but not always—check local rates. Also check rebates from local utility companies.

Efficiency Factor

Once you have decided what type of water heater best suits your needs, determine which water heater in that category is the most fuel efficient. The best indicator of a heater's efficiency is its Energy Factor (EF), which is based on recovery efficiency (i.e., how efficiently the heat from the energy source is transferred to the water), standby losses (i.e., the percentage of heat lost per hour from the stored water compared to the heat content of the water), cycling losses, and the average household use of 64 gallons of hot water per day. The higher the EF, the more efficient the water heater. Electric resistance water heaters have EFs ranging from 0.7 to 0.97 (the most efficient electric storage water heaters all have energy factors between 0.94 and 0.97). Note that heat pump water heaters use less than half as much electricity as conventional electric resistance water heaters.

The most efficient gas-fired storage water heaters have energy factors ranging from 0.60 to 0.64 with some high-efficiency models ranging around 0.8; and heat pump water heaters from 1.8 to 2.5. The efficiency of a dual integrated system is given by its combined annual efficiency, which is based on the AFUE of the space heating component and the energy factor of the water heating components.

EnergyGuide label

In the U.S., all water heaters are sold with a bright yellow and black EnergyGuide label to indicate the estimated annual energy consumption and operating cost of the appliance at a given rate. These labels provide an estimated annual energy consumption on a scale showing a range for similar models. By comparing a model's annual operating cost with the operating cost of the most efficient model, you can compare efficiencies. Be sure to check the rates in your area for comparison purposes. See Tables 9-1 and 9-2 for electric and gas water heater examples.

Table 9-1: Electric Water Heater Example[1]

Performance	Base Model for Comparison		Efficient Model		More Efficient Model	
Energy Factor	0.86		0.92		0.95	
Setpoint Temp	120°F	140°F	120°F	140°F	120°F	140°F
Estimated Annual Energy Use in kWh	3175	4507	2973	4209	2878	4078
Estimated Annual Energy Cost	$267	$379	$250	$354	$242	$343
Your Area's Estimated Annual Energy Cost[2]						

[1] Based on:
- 64 gallons of hot water per day (national average for 4-person household)
- 72° F inlet temperature (state average)
- 8.41¢ /kWh electric price (national average)
- using this formula: $\frac{(0.89) \times (\text{gallons/day}) \times (\text{desired water temperature in °F - inlet temperature in °F}) \times (\text{electricity cost in \$/kWh})}{\text{Energy Factor}}$

[2] For comparison purposes, if your price per kWh is different, multiply your price per kWh (include minimum charges, taxes, etc.) by the estimated annual energy use for each model. Note that this example is for Central Florida—the inlet temperature for North Florida is approximately 68°F and for South Florida is approximately 76°F.

Table 9-2: Gas Water Heater Example[1]

Performance	Base Model for Comparison		Efficient Model		More Efficient Model	
Energy Factor	0.53		0.61		0.66	
Setpoint Temp	120°F	140°F	120°F	140°F	120°F	140°F
Estimated Annual Energy Use in therms	174	247	151	214	139	197
Estimated Annual Energy Cost	$105	$149	$91	$129	$84	$119
Your Area's Estimated Annual Energy Cost[2]						

[1] Based on:
- 64 gallons of hot water per day (national average for 4-person household)
- 72° F inlet temperature (state average)
- 60.4¢ /therm gas price (national average)
- using this formula: $\frac{(0.03) \times (\text{gallons/day}) \times (\text{desired water temperature in °F - inlet temperature in °F}) \times (\text{gas price in \$/therm})}{\text{Energy Factor}}$

[2] For comparison purposes, if your price per therm is different, multiply your price per therm (include minimum charges, taxes, etc.) by the estimated annual energy use for each model. Note that this example is for Central Florida—the inlet temperature for North Florida is approximately 68°F and for South Florida is approximately 76°F.

Types of Available Water Heaters

The following types of water heaters are now on the market: conventional storage, demand, heat pump, tankless coil, indirect, heat recovery unit, and solar. It is also possible to purchase water heaters that can be connected to your home's space-heating system.

Conventional Storage Water Heaters

Ranging in size from 20 to 80 gallons (75.7 to 302.8 liters), storage water heaters remain the most popular type for residential heating needs in the US. A storage heater operates by releasing hot water from the top of the tank when the hot water tap is turned on. To replace that hot water, cold water enters the bottom of the tank, ensuring that the tank is always full. Because the water is constantly heated in the tank, energy can be wasted even when no faucet is on.

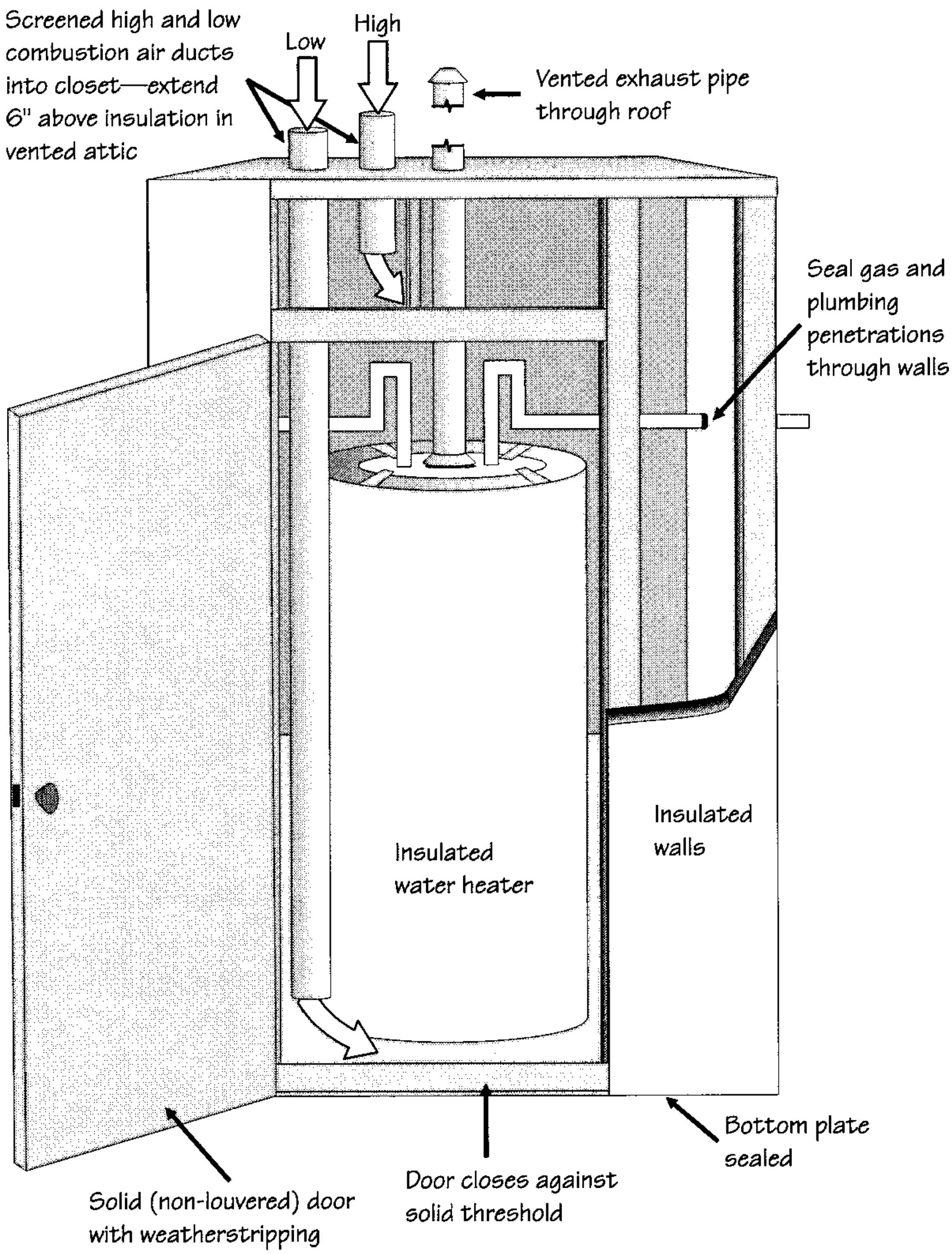
Special Note on Fuel-Fired Water Heaters

Where natural gas is available on site, a gas water heater will usually be life-cycle cost effective relative to an electric model—but check local rates. For safety as well as energy-efficiency reasons, when buying gas-fired water heaters, look for units with sealed combustion or power venting to avoid back-drafting of combustion gases into the building.

If fuel-fired water heaters are located in interior spaces, such as interior mechanical rooms connected to conditioned spaces or laundry rooms, they should include provisions for outside combustion air (Figure 9-3).

More sophisticated energy features found on high efficiency furnaces, such as electronic ignition, flue dampers, and condensing heat exchangers, are being introduced into domestic water heaters.

Figure 9-3
Combustion Closet for Fuel-Fired Water Heater



Demand or Instantaneous (Tankless) Water Heaters

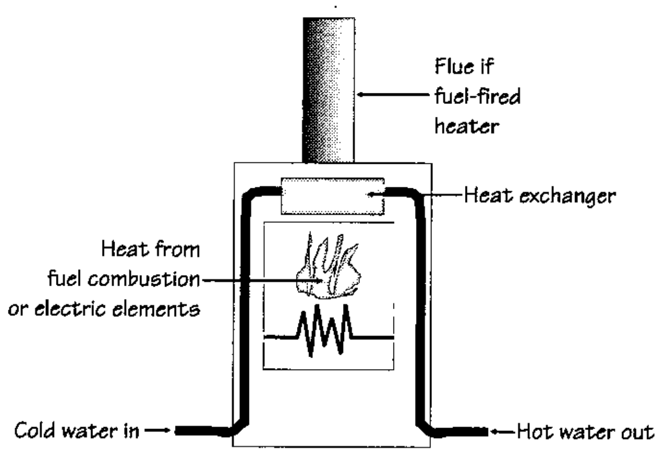
Some homes have bathrooms located away from the kitchen and other bathrooms. This can typically be found in ranch-style homes. The long piping that runs from the centrally located water heater to a distant bathroom contributes to high "transmission" losses. In these cases, a demand or tankless water heater might be recommended (Figure 9-4).

Tankless water heaters are sized in gallons per minute (gpm) of flow. Most provide 2 to 3 gpm of hot water...at most four to five gallons of heated water per minute. Size your unit to meet the peak demand that will be placed on it.

Another thing to consider with tankless heaters is the minimum flow rate required to activate them. Most need a flow rate of about ½ to ¾ gpm to power up; but some are as high as 2 gpm, so they won't heat water unless you turn the water up high.

There is no industry standard for testing and rating the efficiency of tankless water heaters. Electric tankless heaters should save energy compared to electric storage systems, but gas-fired tankless heaters are only available with standing pilot lights, which lower their efficiency.

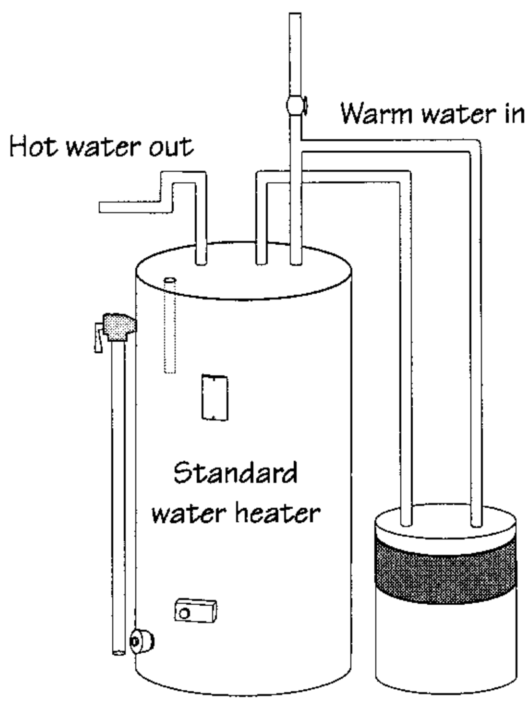
Figure 9-4
Instantaneous Water Heater



HEAT-PUMP WATER HEATER

Unlike the conventional water heater, which uses only resistance heating coils to heat water, the air-source heat pump water heater works by taking heat from the surrounding air and transferring it to the water in the tank. It uses the same principle as refrigerators but in reverse. Heat-pump water heaters have back-up heating coils to ensure ample hot water supply should the heat pump not produce the necessary amount of hot water.

Figure 9-5
Heat Pump Water Heaters



Heat-pump water heaters are available in two styles: self-contained and add-on. A self-contained unit looks like a taller version of a standard electric water heater. This type completely replaces the conventional electric water heater. An add-on heat pump unit can be purchased separately and installed on top of, alongside, or even several feet away from your traditional electric water heater (Figure 9-5). The heat-pump unit (about the size of a window air conditioner) provides the energy, but uses your standard water heater for storage.

They have essentially the same performance as electric resistance storage water heaters, except that efficiencies are typically 2 to 2.5 times higher. Energy Factor (EF) ranges from 1.8 to 2.5, compared to 0.88 to 0.97 for electric resistance systems.

Heat pump water heaters cool and dehumidify the air surrounding the evaporator coil. This can be an advantage where cooling is desirable, a disadvantage when cooling is undesirable. Some heat pump water heaters are designed to recover waste heat from whole house ventilation systems.

Although a heat-pump water heater may have a high initial cost, it can save up to 50% of your water heating bill in moderate climates. They require installation in locations that remain in the 40° to 90°F range year-round. To avoid damaging the equipment, never install a heat pump water heater in areas where the temperature drops below freezing. When operating, they are about as loud as an air conditioner, so do not locate them where noise will be a problem.

Tankless Coil and Indirect Water Heaters

A home's space-heating system can also be used to heat water. Two types of water heaters that use this system are tankless coil and indirect. Tankless coil water heaters use a heating coil installed in the main furnace for water heating. No separate storage tank is needed because water is heated directly inside the boiler in a hydronic (i.e., hot water) heating system. The system is less efficient during warmer months and in warmer climates where the boiler is used less frequently.

Like the tankless coil, the indirect water heater circulates water through a heat exchanger in the boiler. But this heated water then flows to an insulated storage tank. Because the boiler does not need to operate frequently, this system is more efficient than the tankless coil. In fact, when an indirect water heater is used with a highly efficient boiler, the combination may provide one of the least expensive methods of water heating.

Heat Recovery Units

A heat recovery unit (HRU) contains a heat exchanger which captures some of the heat the air conditioning system is removing from the house and transfers it to the water in the water heater. It is installed between the central air conditioner or heat pump and your water heater. A small circulating pump forces water through the heat exchanger while the air conditioner is running. As long as your central system is operating, this "free" heat is used to heat water. A backup electric or gas system provides hot water when the air conditioner is off. This system not only makes free hot water in the summer, but also helps your air conditioner to operate more efficiently by providing an additional place to dump the heat from the house.

If installed on a heat pump, water heating savings can also be realized during the heating season, since the heat pump is 2 to 3 times more efficient than the electric resistance heaters in your water heater. *Note: Check with the manufacturer of the air conditioner if you're considering this option as some super high efficiency models don't accept HRUs very well.*

Solar Water Heaters

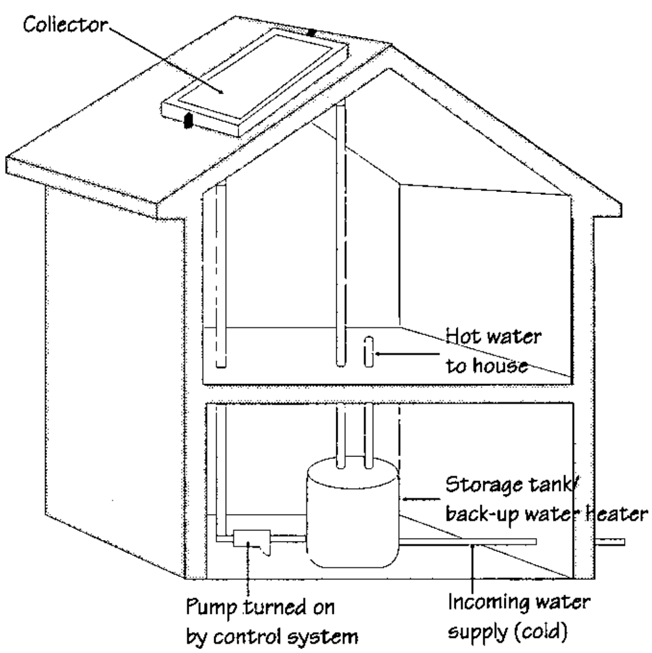
For homes that use a large amount of hot water and receive full sun year-round, solar water heaters may be economical. Most solar water heaters operate by preheating water for a standard water heater. Normally, gas or electric water heaters bring incoming cold water to a desired temperature of about 120°F. A solar water heater uses sunlight to preheat cold water and stores it, often at temperatures well above 120°F.

If the solar-heated water is hot enough, the standard water heater does not need to add more heat. If the water is cooler than needed, the standard water heater will operate as a backup to increase the temperature. Thus, the temperature or availability of hot water is never affected.

Of course, even when the solar-heated water is at temperatures below 120°F, the backup unit will use less energy than it would to heat incoming cold water.

A variety of solar water heaters is available commercially, most of which should last 15 years or longer. They are divided into three categories: active, thermosiphon, and integral collector/storage (ICS)—sometimes referred to as batch. In *active* and *thermosiphon* water heaters, solar panels or collectors trap the sun's heat. Water or other fluid running through the collectors absorbs heat and increases in temperature. The liquid then travels to a storage tank where the heat it gains is stored.

Figure 9-6
Active Solar Water Heating Systems



Active systems use electric pumps to move the water from the collectors to the storage tank (Figure 9-6). Thermosiphon water heaters require no outside power because they use the natural tendency of water to rise as its temperature increases to push water from the collectors to the storage tank, which must be located higher than the collectors.

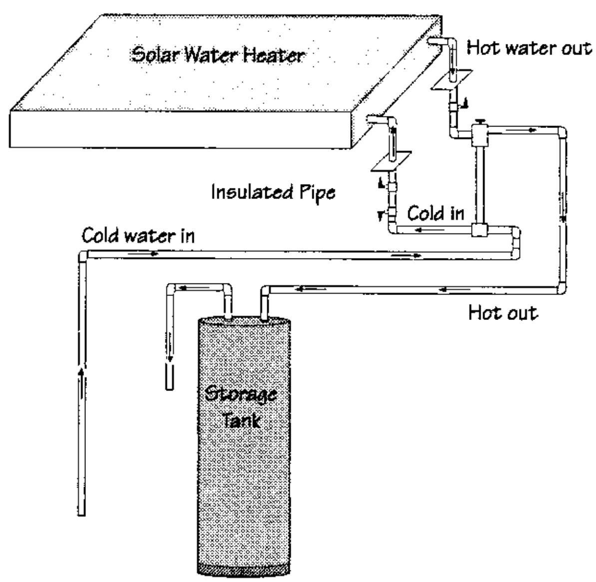
Some solar water heaters use a single, large storage tank that has a backup source of water heating. Other systems use a standard water heater as a backup and a separate solar storage tank. Active and thermosiphon systems cost from $1,500 to $5,000 and supply up to 70 percent of a family's annual hot water needs.

For all shingle and tile roofs in Florida that generally have pitches greater than 3 in 12 (i.e. 14 degrees), collectors should be mounted parallel to the roof. Collectors mounted in this manner are more aesthetically pleasing. However, for flat or very low-sloping roofs, collectors should be titled at an angle (to the horizontal) that is approximately equal in degrees to the local latitude. Florida latitudes range between 25 degrees (in the Florida Keys) to 31 degrees (northern border). Since the sun is lower on the horizon during the winter months, tilting the collector at an angle up to 15 degrees greater than latitude will increase winter performance, which is desirable in most cases.

Solar water heaters must be protected from freezing. Active and thermosiphon systems use nonfreezing fluids or automatic drain systems to prevent freezing.

Another type of solar water heater incorporates the collector and the storage tank into one unit (Figure 9-7). The collector box has insulated sides, one or more clear covers and large tubes that absorb the solar energy and also act as the storage tank. This style of collector typically stores between 30 and 50 gallons of water. The *integral collector/storage (ICS)* solar water heaters (batch) have several advantages. They don't require a pump, which uses electricity and has moving parts that wear out. This typically makes them less expensive than active systems.

Figure 9-7
Batch Solar Water Heating System



On a sunny day, sunlight travels through the glazing of the batch unit and strikes the tanks, which are flat black in color. In most cases, the tanks are covered with a special selective surface coating that readily absorbs sunlight, but reduces heat loss from the tank. When the tanks absorb the sun's energy, the water inside heats up. Local water pressure pushes the solar-heated water into the regular water heater whenever a fixture or appliance, such as a shower or dishwasher, is drawing hot water.

ICS solar heaters are manufactured and sold commercially. Prices range from about $800 to $1,500. However, because of the simplicity of the design, some people build their own.

The collectors for any type of solar water heater should be located as close as possible to the water heater tank to minimize the connecting piping. The glazing should face within 45 degrees of due south.

Collectors are usually located on the roof, but they can be attached to supports on the side of a house or on the ground. Because ICS solar heaters combine collectors, storage tanks, and water they are heavy. Adequate structural support must be provided when they are located on the roof.

Water inside the tanks of an ICS water heater will only freeze on bitterly cold nights. However, the water in the pipes that connect the batch heater to the inside can freeze at temperatures around 32°F. A special *freeze prevention drip valve* should be used on an ICS solar water heater.

Solar water heating can provide year round savings. Households that use a large amount of hot water and can adapt the time when hot water is used to match when it is available will benefit the most. Savings will be greatest if laundry, dishes, and bathing are done between noon and early evening—after the sun has heated the water stored in the tank.

Chapter 10: Appliances and Lighting 157

See Section 415—Lighting

Energy Efficient Appliances

Cooling, hot water, and heating are usually the biggest portion of energy needs in Florida homes. However, the cost of operating major appliances is significant. In the average home, energy bills range from $200 to $400 each year to run refrigerators and freezers, clothes washers and dryers, ranges and ovens, and other appliances.

While most new appliances offer a wide variety of features, many models are not designed to be energy efficient. When choosing appliances, it is important to consider their operating costs—how much energy they require to run—as well as the purchase price and the various features and conveniences they offer.

The National Appliance Energy Conservation Act (NAECA), which upgraded the efficiencies of heating, cooling, and hot water systems, also required improvements in appliance efficiencies. As a result of refrigerator standards that became effective January 1, 1993, a typical refrigerator of today uses less than 800 kilowatt-hours (kWh) per year—less than half of that for a typical 1973 model.

Appliances which operate efficiently may cost more to buy, but the energy savings they provide make them a good investment. For example, running a standard refrigerator over its life of 15 to 20 years costs about three times as much as its purchase price. An energy efficient model can save hundreds of dollars over the life of the appliance. Table 10-1 (next page) shows typical annual energy costs for several appliances.

In addition to saving money on operating costs, energy efficient appliances give off less waste heat than standard models. Therefore, they help keep rooms inside the building cooler during warm weather.

Table 10-1
Typical Energy Costs for Appliances

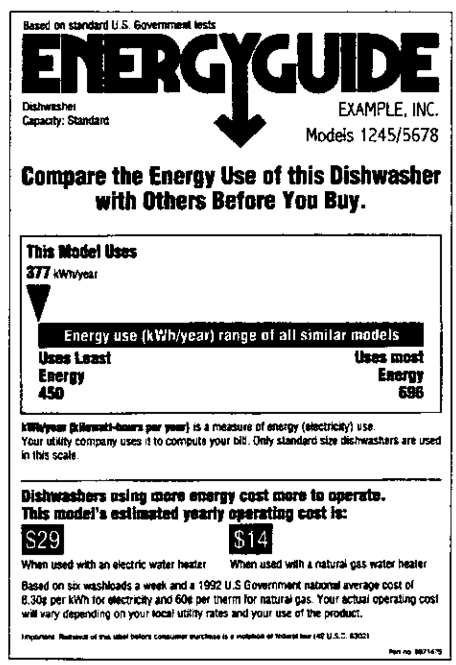
Appliance	Existing	New (NAECA min.)	High Efficiency Model
Refrigerator/freezers	$93	$61	$24
Clothes Washers	$78	$70	$43
Clothes Dryers	$85	$77	$71
Dishwasher	$50	$40	$29
Total	**$306**	**$248**	**$167**
Overall Savings		**19%**	**45% (33%*)**

**compared to NAECA minima.* *Source: Energy Star Homes Builder Guide, 1997*

Energy Star® Appliances

The U.S. EPA has done some of the research for consumers and has labeled certain appliances with the Energy Star® logo (as seen here) that meet their criteria for energy efficiency. An appliance receives the Energy Star® rating if it is significantly more energy efficient than the minimum government standards, as determined by standard testing procedures. The amount by which an appliance must exceed the minimum standards is different for each product rated and depends on available technology. Energy Star® rated products are always among the most efficient available today.

Figure 10-1
EnergyGuide Label



EnergyGuide Label

To compare the energy usage of an appliance, use the *EnergyGuide label* (Figure 10-1). Federal law requires that manufacturers display this label on all new refrigerators, freezers, water heaters, dishwashers, clothes washers, room air conditioners, central air conditioners, heat pumps, furnaces, and boilers.

The EnergyGuide label provides the name of the manufacturer, model number, type of appliance, and capacity. EnergyGuide labels won't tell you which is the best appliance to buy. They will display the estimated annual energy consumption and operating cost of the appliance at a given rate, enabling you to compare the models you're interested in. Make sure you compare similar models with similar capacities—for example, that you're comparing one top-loading clothes washer with another top-loader that handles the same sized batch of laundry. Much like the federal miles-per-gallon ratings for automobiles, the actual amount of energy used and its cost will vary according to local prices and each family's life-style. (Check consumer magazines for other information such as repair history.)

Appliance Shopping Checklist

All appliances

- ❐ Use the EnergyGuide label and Energy Star® symbol, where applicable, to help select unit. Find the savings in operating costs for the more efficient appliance. Divide the savings per year into the extra purchase price to get the payback period. Paybacks of less than five years are generally attractive. See Chapter 2 (*Why Build Efficiently?*) for information on how to determine payback.

Refrigerators

- ❐ The most efficient models are in the 16- to 20-cubic foot range.
- ❐ Side-by-side refrigerator/freezers use more energy than similarly sized models with freezers on top.
- ❐ Features such as automatic icemakers and through-the-door dispensers add somewhat to energy use.
- ❐ Units that are more square, rather than rectangular, also save energy, but may not be as convenient to use.
- ❐ Manual defrost units save considerably more than frost-free units, but create more work for the building occupant.
- ❐ Look for a power-saving switch that turns off a condensation-prevention heater. Keep this switch off unless the unit experiences significant condensation.
- ❐ A new generation of refrigerators not using chlorofluorocarbons (CFCs) exceeds the minimum standards of NAECA by about 30%—the result of the electric utility funded Super Efficient Refrigerator Program (SERP).
- ❐ Try to install the refrigerator in a cooler location—in particular, it should not receive direct sunlight or be positioned near heat-producing appliances.
- ❐ The refrigerator should operate between 36°F and 38°F, and the freezer should be 0°F to 5°F. Correct temperatures that are outside of this range.

Dishwashers

- ❒ Water heating accounts for about 80% of energy use.
- ❒ Should have light, medium, and heavy cycle options.
- ❒ Should have an energy saving "air dry" or "no-heat dry" switch.
- ❒ For most uses, choose a unit that contains a supplemental or booster water heater; then set the building's water heater to 120°F.

Clothes washing machines

- ❒ Water heating accounts for about 90% of energy use.
- ❒ Choose a machine that offers several wash and rinse cycles and several sizes of loads.
- ❒ Front-loading models (horizontal axis) use about 1/3 the hot water of typical top-loading models.
- ❒ New energy efficient top-loading models are also now available.

Clothes dryers

- ❒ Energy-saving switches and models that detect "dryness" and shut off automatically offer considerable energy savings.
    - Some units have moisture sensors in the drum, which save about 15% over standard dryers.
    - Others have a temperature sensor in the dryer exhaust, which saves about 10% over standard units.
- ❒ Higher spin speeds extract more water from clothing, thus reducing the heating requirement of the appliance.
- ❒ If clothes that usually need ironing are removed while slightly damp, they can be hung up to save on dryer and ironing energy use. However, if the building has high humidity problems this is inadvisable.

Cooking

- Convection ovens are about 1/3 more efficient than standard ovens.
- Cooktops vary tremendously. Although energy efficiency is very important, issues such as type of cookware to use, ability to maintain low constant temperature, etc. are also important. Current electric choices include coil, ceramic glass (radiant), halogen, and induction. With regard to energy, induction elements, which use electromagnetic energy to heat the pan, are the most efficient.
- Be careful with large kitchen exhaust fans. While they are important, oversized units can create considerable negative pressures in tight homes and may cause backdrafting of combustion appliances.

Lighting

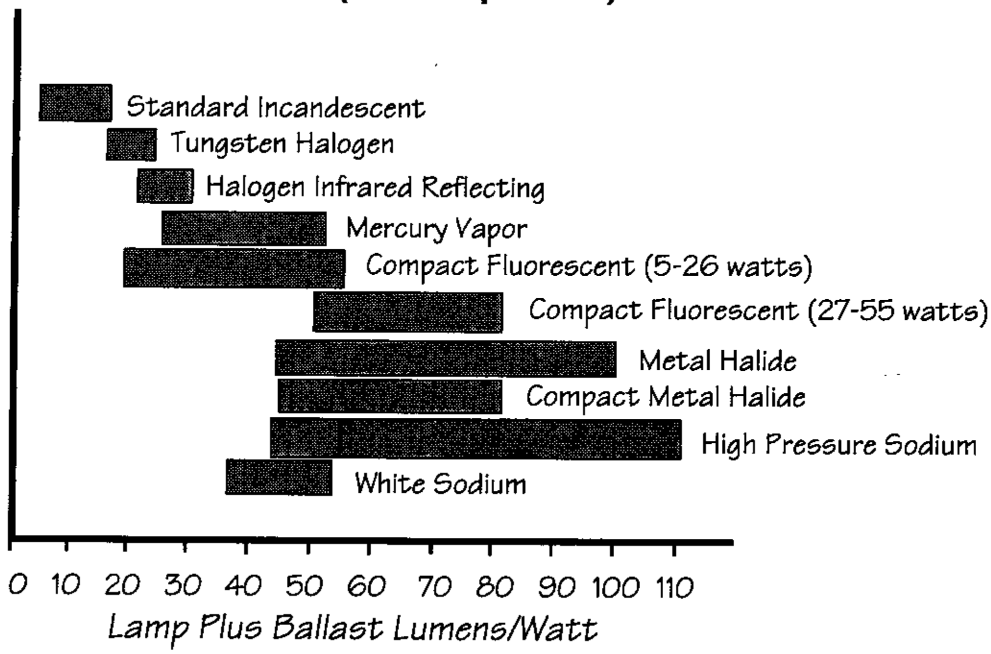
Standard incandescent bulbs are the most common lighting source for homes. However, incandescent lamps are quite inefficient. They convert only 10 percent of the electricity to lighting; the rest produces waste heat. Energy efficient lighting design will not only reduce the lighting portion of utility costs, but can also affect HVAC loads and costs (Table 10-2).

Table 10-2
Standard Versus Energy Efficient Residential Lighting

Standard Lighting Design					**Energy Efficient Design**			
Room	**Type***	**Watts**	**Hours/ day**	**kWh/ year**	**Extra Cost ($)**	**Type**	**Watts**	**kWh/ year**
Kitchen	I	150	8	438	30	F	60	175
Living	I	150	6	328	5	H	135	296
Dining	I	75	5	137	-	I	75	137
Bathrooms (2)	I	200	4	292	-	I	200	292
Hallway	I	150	10	545	30	F	60	219
Bedrooms (3)	I	225	4	328	30	F	90	131
Laundry/ Utility	I	100	4	146	25	F	30	44
Closets (5)	I	300	1	110	-	I	300	110
Porch	I	100	12	438	15	F	30	131
Exterior Floodlight	I	360	12	1,577	100	HPS	150	657
Total Annual Electricity Use (kWh)				4,339				2,192
Annual Lighting Cost ($ @ $.075/kWh)				325				164
Estimated Extra Cost for Energy Efficient Lighting					**$210**			
Payback Period					**1.3 years**			
Rate of Return on Investment					**60%**			

* I=incandescent; F=fluorescent; H=halogen; HPS=high-pressure sodium

Figure 10-2
Energy Efficiencies of Lights
(Lumens per Watt)



Efficiency

A 100-watt lamp does not necessarily provide more illumination than a 75-watt lamp. Watts measure energy use. Lumens measure light output. For example, a 100-watt incandescent bulb provides 1,710 lumens and uses 100 watts of energy. Its efficiency (or efficacy) is 17 lumens per watt (LPW). A compact fluorescent lamp provides similar light output, an average of 1750 lumens and uses 28 watts. Because it provides over 63 lumens per watt, it is much more efficient (Figure 10-2). A federal law passed in 1995 (EPACT) requires all lamp manufacturers to list the lumens and watts on a label.

Lamp Life

Lamp life is also important. Taking the energy savings into account, the higher priced fluorescent lamps cost even less to operate compared to an incandescent bulbs. Using the comparison above, the 100-watt incandescent bulb has an average life of 750 hours and cost about $0.77 or $81 (bulbs + electricity) for 9000 hours of life. The fluorescent lamp has an average life of 10,000 hours and costs $21 or $41 (bulbs + electricity) for 9000 hours of life. The user actually comes out ahead with the fluorescent alternative, even though the fluorescent tube costs more. Table 10-3 provides additional comparisons.

Table 10-3
Purchase and Operating Costs of Different Lighting Products

	Wattage	Typical Purchase Cost ($)	Lumens	Rated Life (Hours)	Efficacy (Lumens/Watt)	Energy Cost for 10,000 hours ($)*
Incandescent and Fluorescent						
Standard	60	0.50	870	1,000	15	48
Energy saving (Halogen)	52	0.79	800	1,000	15	42
Compact fluorescent	15	13.00	720	10,000	48	12
Standard	75	0.50	1,210	1,000	16	60
Energy saving (Halogen)	67	0.79	1,130	1,000	17	54
Compact fluorescent	18	18.00	1,100	10,000	61	14
Compact fluorescent	20	20.00	1,200	10,000	60	16
Standard	100	0.77	1,750	750	17	80
Energy saving (Halogen)	90	0.79	1,620	750	18	72
Compact fluorescent	23-27	20-25	Comparable	10,000	64	20
Torchiere Fixtures						
Halogen	300	20	4,000	2,000	13	240
Compact fluorescent with three, 26-watt lamps	78	80	4,200	10,000	54	62
Room Lighting						
Incandescent fixture with three, 60-watt lamps	180	30	2,610	1,000	15	144
Standard fluorescent fixture with two, 40-watt lamps	92	30	6,300	20,000	68	74
Above fixture with 32-watt lamps/electronic ballast	54	42	5,500	20,000	102	48
Exterior Fixtures (assuming 4 outdoor fixtures)						
Standard PAR lamp (4 lamps/fixture)	1,800	120	20,880	2,000	12	1,440
Tungsten-halogen (4 lamps/fixture)	1,080	144	21,600	2,000	20	864
Mercury Vapor (1 lamp/fixture)	400	65	23,000	24,000	57	320
Metal Halide (1 lamp/fixture)	250	100	20,500	10,000	82	200
High Pressure Sodium (1 lamp/fixture)	200	90	22,000	24,000	110	160

* Electricity cost @ $0.08/kWh

Table 10-4
Characteristics of Several Common Types of Lamps

Type	Watts	Lumens	LPW	CRI	CCT
Incandescent Soft White	100	1710	17.1	95+	2800
Incandescent Double Life	90	1510	16.8	95+	2800
Incandescent Energy Saver	90	1510	16.8	95+	2800
Incandescent Halogen A-Lamp	75	1040	13.9	95+	3050
Incandescent Halogen Flood, 50° Beam Spread	75	1100	14.7	95+	3050
Fluorescent, 48" Tubular T12 Cool White	34	3050	89.7	60+	4200
Fluorescent, 48" Tubular T8 RE730	32	2850	89.1	70+	3000
Fluorescent, 48" Tubular T8 RE830	32	3050	89.7	80+	3000
Compact Fluorescent, Lower Power	13	710	54.6	80+	3000
Compact Fluorescent, Higher Power	27	1620	60	80+	3000

Color Rendering

The color rendering index (CRI) measures the perceived color of objects under artificial light. It is measured on a scale of 0 to 100. Standard incandescent bulbs have a CRI of 95+. A lower CRI means that some colors will look unnatural under the artificial light. The old standard cool white fluorescent lamp has a much lower CRI of 62, which is why people complain that fluorescents give false colors. Today, many kinds of fluorescent lamps have a much higher CRI—80 and above—than the cool white lamp.

Color of the Light

The color correlated temperature (CCT) measures the appearance of the light itself. Color temperature is another common complaint about fluorescent lighting. Often, fluorescent lighting is considered harsh compared to incandescent lighting. People perceive of some light as "warm" and other light as "cool." A low CCT—below 3100 K—is a warm white light. For instance, standard incandescent bulbs have a CCT of 2800. Many fluorescents have a CCT of 3000 and provide the same warm, white light that an incandescent bulb produces. Keep in mind that daylight, the most desired form of light, has a color temperature of 5000 K.

Table 10-4 compares the efficiency, CRI, and CCT of a few of the many kinds of lamps that are available. As this table shows, there are many alternatives. Choose the combination of efficiency, lamp life and cost, color rendering, and color correlated temperature that best fits each application. For the foreseeable future, fluorescents will offer the greatest range of tried and tested alternatives to the standard incandescent or halogen bulb.

Lamps

Fluorescent Lamps

The old complaints about fluorescents—they give false colors, they are too harsh (cool), they buzz, flicker and hum, and they take too long to start—are no longer true. Fluorescent lamps outperform incandescents in energy efficiency. They usually also provide longer lamp life, ranging from 7500 to 20,000 hours. The combination of lower energy use, less heating load, and longer lamp life means that fluorescents usually have a lower total operating cost than incandescent lamps, despite their higher initial cost. Therefore unless there are compelling reasons to the contrary, select a fluorescent alternative.

Fluorescent lamps are normally installed into a luminaire that contains a ballast, either magnetic or electronic. They vary greatly in energy efficiency, lamp life, and color characteristics, all of which will probably be important to your customer. Remember that the label provides the information needed about energy efficiency (lumens and wattage) and lamp life (average rated lamp life). What does T8 RE830 mean? T8 means that the lamp has a diameter of 1 inch because tube diameter is measured in eighths of an inch (T8 = 8/8 inch diameter). RE means that it is a rare earth lamp. The 8 means that the CRI is between 80 and 89. The 30 means that the CCT is 3000 K. This lamp will give good color rendition and the color of the light itself is almost the same as that of an incandescent lamp.

Fluorescent lamps come in a wide array of shapes, sizes, and lengths. Linear fluorescents are the standard long, straight tube lamp. They are usually the least expensive to buy. However, they *are* long and straight, which does not lend itself to some situations—a pull-down lamp over a table, for example. U-shaped fluorescents are simply a long tube bent into a "U." Circline fluorescents are a long tube bent into a circle. Compact fluorescents come in many sizes and shapes and are designed to be used in applications which normally take an incandescent or halogen lamp.

Screwbase compact fluorescent lamps can replace standard incandescent lamps since, as their name suggests, they are a "screw-in" lamp. They come in two forms, one a combined lamp and ballast, the other a separate ballast and lamp. Units with separate ballast and lamps are preferable because ballasts last much longer than lamps. In the combined type the consumer must replace—and pay for—the ballast every time the lamp burns out.

Screwbase fluorescents with diffusers and reflectors are also available, and may be worth their extra cost in some applications. Lamps with diffusers, like tubular fluorescents, shed light in all directions. However, the diffuser does just what it says—diffuses the light. This effect can be important—in a pull-down light over a table, for example. Reflectors aim the light. Again, this can be important in some situations, such as accent lighting on a piece of artwork. In general, select these more expensive alternatives only when other fluorescents cannot produce the desired result.

Remember CRI and CCT. The traditional "cool white" or "warm white" fluorescent lamps do not give good color characteristics. The newer rare earth fluorescents are much better. In places where color does not matter—such as the garage—the very inexpensive traditional fluorescent lamps will usually be fine. In a living room or bathroom, on the other hand, color is important. Choose a lamp with good color characteristics: a CRI of more than 80 and a CCT of 3000 K or less.

Ballasts

Except for screwbase compact fluorescents, fluorescent luminaires come with either magnetic or electronic ballasts. Electronic ballasts are more energy efficient than magnetic ballasts. For many applications, you can select between three start-up modes—preheat, rapid start and instant start. Preheat starts cause the lamp to flicker a few times before it starts, a feature that may be unacceptable to many clients for most indoor residential uses. In the rapid start mode, there is a delay of 1 to 2 seconds before the lamp starts, but there is no flickering. In the instant start mode, there is no delay or flickering. Most electronic ballasts are instant start.

Incandescent Lamps

Reduced wattage and long-life bulbs may or may not save energy or money and the savings are usually not great. Compare a 100-watt soft white bulb to a 90-watt "energy saving" alternative. Remember that it is LPW (lumens per watt), not watts themselves that matter. The 100-watt standard bulb provided 1710 lumens, or 17.1 LPW while the 90-watt alternative provided only 1510 lumens, or only 16.8 LPW. Another lamp, a 100-watt long life bulb, provided even fewer lumens, only 1500 or 15 LPW. The long life bulbs do last longer, 1500 hours instead of 750 to 1000 for the standard or reduced wattage bulb in our comparison.

Reflectors

Standard incandescent bulbs emit light in all directions. Reflector bulbs, often called PAR lights, direct light in one direction. This means that you can often use a lower wattage reflector bulb and still provide adequate light. Lamp life is comparable to long-life standard incandescent lamps. Nonetheless, reflector bulbs are not nearly as energy efficient as fluorescent lamps. However, they do provide one way of reducing energy use in situations where only an incandescent lamp will meet the lighting need. A luminaire with a reflective surface will also permit you to use a lower wattage incandescent lamp. Note that there are reflectors for compact fluorescents also on the market. Check with a distributor.

Halogen Bulbs

Halogen bulbs are slightly more energy efficient than incandescent lamps. Table 10-3 shows a 90-watt halogen that provided 1620 lumens, or 18 LPW with a cost of $72 for 10,000 hours. However, concern has grown over the potential for fire hazard from halogen bulbs, especially if the occupants are not aware of where they should be placed.

High Intensity Discharge (HID)

Consider high intensity discharge (HID) lamps if frequent outdoor night illumination is desired. HID lamps use an electric arc to produce intense light and can save 75% to 90% compared to incandescent lamps. They have ballasts and take a few seconds to produce light when first turned on, because the ballast needs time to establish the arc. The most energy efficient types are metal halide and high pressure sodium. HIDs provide ample illumination, but have very poor color rendition. However, this is rarely an issue for the applications where HIDs are used, such as parking lots or playing fields.

Lighting Needs

There is great opportunity for originality and ingenuity in residential lighting design. A home combines more functions and needs than most other buildings, yet energy efficient lighting can be achieved at minimal cost. Common needs are listed below:

- *Ambient lighting* provides illumination for performing routine daily activities—such as watching television—and safety—in a hallway, for example. Low light levels are usually fine for ambient lighting.
- *Indirect lighting*, or *uplighting*, where light is directed to the ceiling and upper part of the walls, is a specific technique commonly used to provide ambient lighting or lighting where glare can be a problem. It provides a very evenly distributed light and helps prevent reflected glare from glossy surfaces, such as televisions.
- *Activity lighting* provides illumination for a specific task, such as reading or woodworking. The light needed will vary by task and by how long the task is performed. Sewing for a few minutes does not require as much light as sewing for an extended period of time, for example.
- *Accent lighting* focuses light on an object or an area in the room to emphasize it. Accent light is used to draw attention to artwork or interesting architectural details.
- *Wall washing* is similar to accent lighting because it, too, draws attention. It can also provide ambient lighting because the light is reflected off the wall.
- *Special purpose lighting* refers to such uses as medicine cabinets and under- cabinet lighting in the kitchen.

Treatments and Luminaires

Once the amount of lumens that are needed is determined, choose a luminaire (the lamp plus the fixture) that uses the fewest watts. In designing a lighting plan, consult with knowledgeable professionals about optimum lighting levels and different types of fixtures and lamps. Table 10-5 shows sizing guidelines for fluorescent lighting systems. Different treatments and types of luminaires can be used to meet each lighting need (Table 10-6).

Table 10-5
Fluorescent Lighting Guidelines

Type of Room	Size of Room	Amount of Light Needed
Living room, bedrooms, family, or recreation room	under 150 sq ft	40 to 60 watts
	150 to 250 sq ft	60 to 80 watts
	over 250 sq ft	0.33 watt/sq ft
Kitchen, laundry, or workshop	75 sq ft	55 to 70 watts
	75 to 120 sq ft	60 to 80 watts
	over 120 sq ft	0.75 watt/sq ft

Ceiling-Mounted

Ceiling-mounted luminaires are the standard fixture attached to the ceiling. There are two types: diffusers and track or adjustable heads. Since these luminaires are not recessed, they can be installed where plenum space is limited above the ceiling or where there are obstructions, such as ducts, that prevent installing recessed fixtures. However, one luminaire in the middle of even a medium-sized living room causes glare with typical furniture arrangements.

Suspended

Suspended luminaires hang from the ceiling. They can be more flexible than many other kinds of luminaires if fixtures with retractable cords or chains are chosen so that their height can be adjusted as required. They work well in rooms with high ceilings, but may be a poor choice for rooms with low ceilings.

Recessed

Recessed lighting can be used for almost every lighting need. However, these fixtures are installed into the ceiling and are notorious for air leakage, which can greatly increase heating and cooling costs. Some argue that it is virtually impossible to install a recessed fixture so that it does not leak air. Make sure that the housing (or "can") does not have perforations in it. These perforations are a direct pathway for losing heated or cooled air. Look for a housing that meets the energy code air infiltration standards.

Table 10-6
Lighting Need and Types of Luminaires to Use

Type of Luminaire		Ambient	Indirect	Activity	Accent	Wall Wash	Special Purpose
Ceiling-Mounted	Diffuse	✓					
"	Track or Adjustable Head		✓	✓	✓	✓	✓
Suspended	Downlight	✓		✓	✓		✓
"	Uplight	✓	✓				
"	Uplight/Downlight	✓		✓			
"	Chandelier	✓		✓			
"	Ceiling Fan	✓	✓				
Recessed	Troffer and "Luminous Ceiling"	✓		✓			
"	Downlight	✓		✓			✓
"	Wall Wash					✓	✓
"	Accent				✓		✓
Architectural	Cove	✓	✓				✓
"	Soffit	✓		✓		✓	
"	Valence	✓	✓	✓		✓	✓
Wall-Mounted	Sconce or Diffuser	✓	✓				✓
"	Vanity Lights						✓
Cabinet-Integrated	Medicine Cabinet						✓
"	Under-Cabinet or Furniture			✓			✓

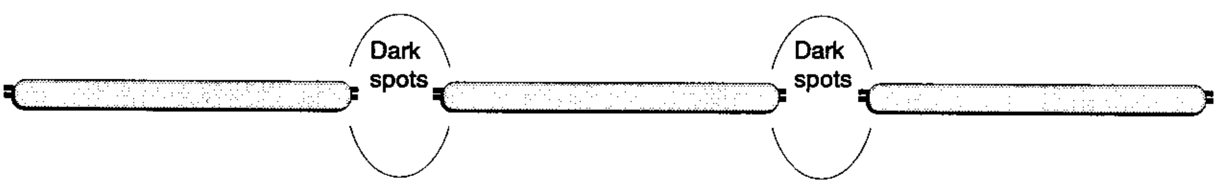
Further, many recessed fixtures cannot have insulation touching them. Look for a housing rated airtight "IC," meaning that it can be covered by insulation. (Refer to Chapter 5, *Insulation Materials and Techniques*, for more information.) Additionally, install a luminaire that uses fluorescent lamps to further reduce energy use. Long lasting (10 year) compact fluorescent lamps are convenient for recessed cans that are difficult to reach in cathedral ceilings. Many recessed luminaires require at least 8 inches of space in the plenum.

Architectural

Coves, soffits and valances can meet almost any lighting need, although the soft, diffuse light they provide may require additional lighting for some tasks, such as reading. They are an energy-efficient alternative because they use fluorescent tubes. Unlike recessed lighting, they do not require penetrating the ceiling and risking air leakage. Coves and valances are good choices for rooms with high ceilings and can provide dramatic effects in rooms with cathedral or vaulted ceilings (Figure 10-3). A valance mounted lower on the wall can provide overhead light above the bed. Soffits can be used in rooms with low ceilings and often are very useful in rooms, such as bathrooms, with very limited ceiling height. Soffits can provide counter lighting in kitchens by adding a strip of wood that extends downward from the upper cabinet to hide the lamp and prevent glare.

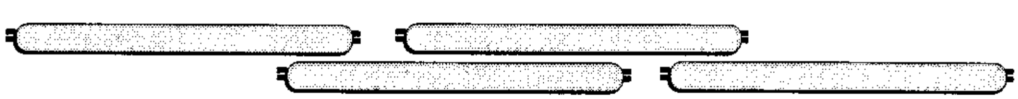
Figure 10-3
Tips for installing architectural luminaires

When installing architectural luminaires, avoid producing dark spots or "scallops" on the wall by putting tubes end to end.



Instead, overlap the ends of the fluorescent tubes where a single row of tubes is installed.

Stagger the ends of the tubes were two rows are installed.



Wall-Mounted

Wall-mounted luminaires provide ambient and indirect lighting and are often used for special purpose lighting. They work with any ceiling height. However, be careful where you place them. They can create a glare problem when they are in the line of view of the occupant. Take height, shielding, and aiming angle into account to help prevent this problem. They also offer little opportunity to rearrange the room when used for accent or activity lighting.

Furniture or Cabinet-Integrated

There are many kinds of furniture or cabinet-integrated lighting, including the lighting on many appliances such as range hoods or microwave ovens. One recurring problem with these luminaires is that the switches are located in hard-to-reach places. This encourages people to leave the lights on for long periods of time, even when not needed. Make sure that switches are easily accessible. Remember that people in wheel chairs cannot reach switches located more than 4 feet above the floor. Providing good access to switches on medicine cabinets or cabinets for these people is even more difficult.

In designing a lighting plan, consultation with a knowledgable professional or supplier can be a sound investment, enabling the builder to make effective use of the broad range of luminaires and lamps available today.

Chapter 11: Siting and Passive Design Features

A site is an ecosystem. Careful siting can help reduce the impacts of construction on soils, water, and the plant and animal community. Site features such as topography can also make a building more energy efficient. Simple building structures, such as overhangs and awnings, take advantage of the natural setting to reduce energy use. These features also affect the value of the building. A building that blends into its surroundings can have a higher value than buildings that do not. You can help your clients make wise decisions by pointing out the total savings over a ten- or twenty-year period that will result from good siting and passive design features.

KEY FACTORS IN FLORIDA
- Access to solar radiation
- Ventilation

In Florida, there are two principal factors in siting and passive design: access to solar radiation and ventilation.

Solar Radiation

Let's look at solar radiation first. The impact of solar radiation is a critical issue because heating and cooling account for a large part of the energy use in both residential and commercial buildings in Florida (Figures 11-1 and 11-2). Exposure to the sun is required only during the winter months in hot, humid regions where heating requirements are small. Shading and air movement are the most important factors during the rest of the year.

Figure 11-1
Typical Residential Energy Use in Florida

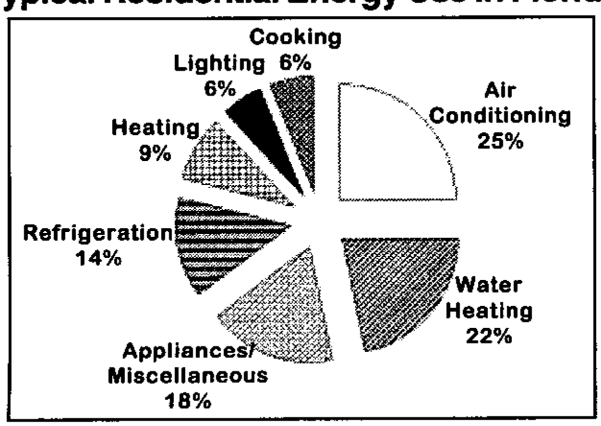
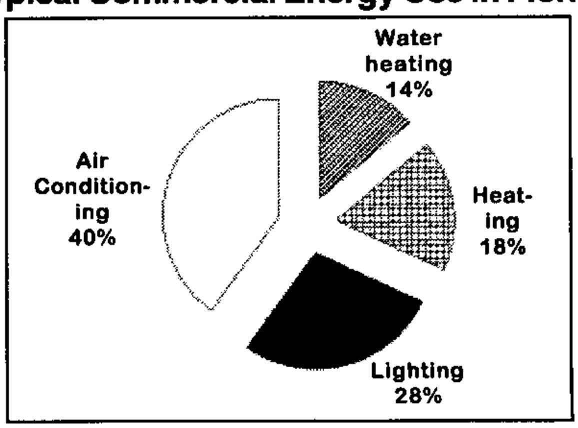


Figure 11-2
Typical Commercial Energy Use in Florida



ORIENTATION
Long side faces south and length is within 15° of the east-west axis.

This reduces overheating because the short east and west sides are exposed to the sun for most of the day during the summer. The long side of the building is exposed to the low-angle rays of the winter sun. Calculate the east-west axis from true north. True north is shown on topographic maps, but not by a compass. Compasses point toward magnetic north, which can vary as much as 20° from true north.

CONFIGURATION
In most cases, buildings should be at least one and one-half times as long as they are wide.

The configuration of the building is important because the amount of heat the building loses increases with surface area. Compact shapes lose less heat through the skin than narrow or elongated shapes. The correct configuration of a building therefore depends on the regional climate. It also depends on the degree to which passive cooling systems are used and on the kind of passive cooling that is used. A combination of active and passive cooling systems are usually used in Florida. In this case, a building should be at least one and one-half times as long as it is wide with the longer side of the building oriented to make maximum use of solar radiation.

In homes, kitchens and dining rooms should be on the north or east sides or in the center of the building. Primary living spaces, such as living and family rooms, should be on the south side of homes to provide for year-round moderate temperature control where low sun angles can provide passive solar heating. Closets, utility rooms and storage rooms can act as insulating buffers to the living spaces. Kitchens and dining rooms on the north or east sides or in the center of a home help prevent heat from cooking being added to the heat from solar radiation on the west side.

FLOOR PLAN FOR HOMES
- Primary living spaces on the south side
- Kitchens and dining rooms on the north or east side, or center of house
- Closets, utility rooms and storage rooms as buffers to living spaces

Predominant window areas of a building should face north or south to reduce heat gain from solar radiation during the summer. One 6 × 8 foot clear glass area on a west wall can require more air conditioning to offset heat gain than all the rest of the wall. Glass areas should not exceed about 10% of the wall area in single-story houses and about 6% in two-story houses. Solar screens or tinted windows can reduce heat gain from glass areas significantly. Clear glass has a shading coefficient of 1. A solar screen or film with a shading coefficient of 0.2 would reduce direct solar radiation by 80%. Double-pane windows are better insulators against cold and heat than single-pane glass.

GLASS AREAS

- Predominant window areas on the north or south
- Unshaded/untinted glass areas 10% or less of wall area in single story homes
- Unshaded/untinted glass areas 6% or less of wall area in two-story homes
- Solar screens or tinted windows
- Double-pane or storm windows

Storm windows are another alternative. Their depth depends on the site's latitude. You need to know the sun's pattern over the site and the height of the window-to-roof line to determine the correct overhang depth.

VEGETATION

- Deciduous vegetation in north Florida
- Evergreen vegetation in central and south Florida

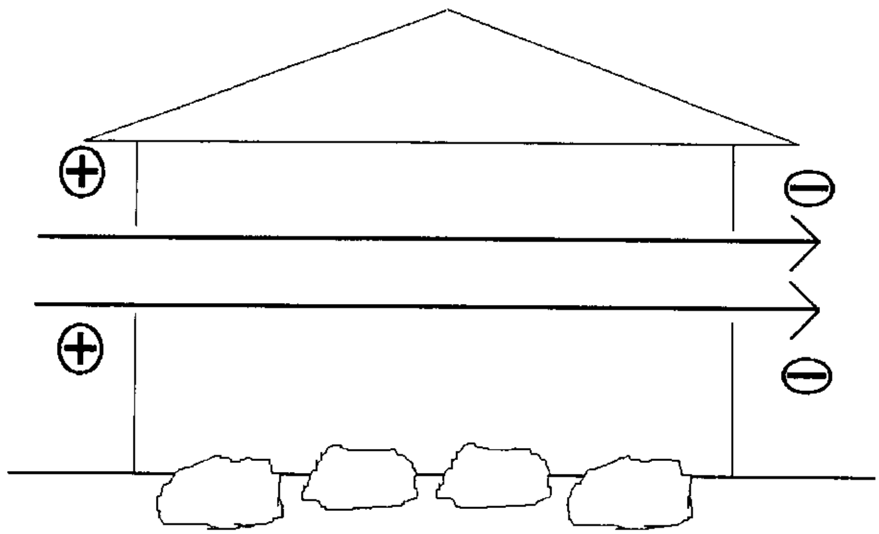
In many areas, the best trees are those that have a dense canopy in the summer and an open, leafless canopy in the winter. For example, deciduous trees on the east, west, and south sides of a building provide shading in the summer, reducing cooling bills by as much as 40%. Yet, they still allow the sun's rays to penetrate in the winter. In South Florida, where winters are very mild and short, evergreens are better because they provide shading year-round. *Enviroscaping to Conserve Energy: A Guide to Microclimate Modification* provides information on species selection and landscape design. This publication can be found at your local County Extension Service Office or through the University of Florida's Web site at http://edis.ifas.ufl.edu/scripts/htmlgen.exe?DOCUMENT_EH143.

Thermal mass is a building component that stores heat well and has a tendency to lose and gain heat slowly. It moderates the impact of outside temperature extremes because it absorbs the sun's energy during periods when the building is exposed to the sun and releases the energy to the inside when the solar radiation is absent. Thermal mass reduces the load on heating and cooling systems, which in turn reduces energy use. Thermal mass must be combined with proper insulation (R-6 or better), shading, and proper orientation to increase a building's energy efficiency.

Greenhouses or sunspaces can be used as exterior spaces to trap solar radiation and transfer heat to a thermal mass. The mass separates the greenhouse or sunspace from the inside of the building. However, the greenhouse or sunspace must be a separate thermal zone from the rest of the building because they are subject to extreme temperatures. Well insulated and sealed doors and windows between them and the building are critical. When heating from these spaces is desired, vents allow warm air to flow into the building. These vents should be placed both high and low on the thermal mass that separates the sunspace from the inside of the building. Overheating of the sunspace in the summer can be prevented by shading and by placing vents near the top of the sunspace.

Ventilation

Figure 11-3
Cross ventilation depends on using prevailing winds



Now let's look at the second important factor, ventilation. Natural ventilation brings in outdoor air, which passes directly over people to increase cooling from evaporation on the skin. However, a completely passive system is rarely possible even where this is the main cooling strategy because it requires consistent, relatively high wind velocities with low humidity (see Figure 11-3), conditions not found in most of Florida. Nonetheless, buildings that permit maximum use of natural ventilation during the fall and spring reduce air conditioning needs significantly.

Natural ventilation is most appropriate when indoor temperatures and humidity are above the outdoor level. Natural ventilation is not recommended if the outside dew point temperature exceeds 60°F. It will only increase the humidity indoors and contribute to the growth of mold and mildew. Well-designed buildings use the prevailing wind direction to cool in the summer, but protect buildings from winter winds. The meteorological station at the nearest airport can give you information about local wind patterns so that you can judge how well a building in the area is designed to take advantage of natural ventilation.

GREENHOUSES AND SUNSPACES

- Separated from the rest of the building by a thermal mass
- Well insulated and sealed doors and windows between them and the building
- Vents both high and low on the thermal mass

> Buildings can be oriented to take advantage of prevailing winds during the fall and spring.

Ideal orientation for solar access and ventilation sometimes conflict. ***Solar radiation is more important*** because it affects the heating and cooling of the building more. Protecting against prevailing north winds during the winter is important in cooler parts of the state. A long south side is desirable not only to prevent excessive heat gain from solar radiation, but also to promote cross-ventilation for incoming breezes from the north.

> Take advantage of natural topographic features to protect buildings.

Topographic features can also help make buildings more energy efficient. Hills can protect buildings from cold winter winds in cooler regions. Natural topographic features can also be used to reduce danger of flooding and to increase the kinds of vegetation in the landscape.

> FLOOR PLAN
> - Fewer interior partitions
> - Transoms above doors

More open plans are better than plans with many interior partitions because partitions resist air flow and decrease total ventilation. Transoms—windows above doors—allow for some cross-ventilation and yet maintain privacy between adjacent rooms.

Cross ventilation allows air to flow from a strong positive pressure area to a negative pressure area in the opposite wall (Figure 11-3). Therefore, correct window placement depends on the prevailing wind direction and cross ventilation is less successful where there is no strong prevailing wind direction. Window areas should be split about equally between the windward and leeward sides of a building for good cross ventilation. Window area should be about 15% of the floor area to both maximize cross ventilation and to prevent excessive heat gain when using air conditioning. Windows low on the wall allow viewing while sitting or standing. If the occupants will be sitting most of the time, the windows should be about 3 feet above the floor, ending no higher than 6.5 feet from the floor.

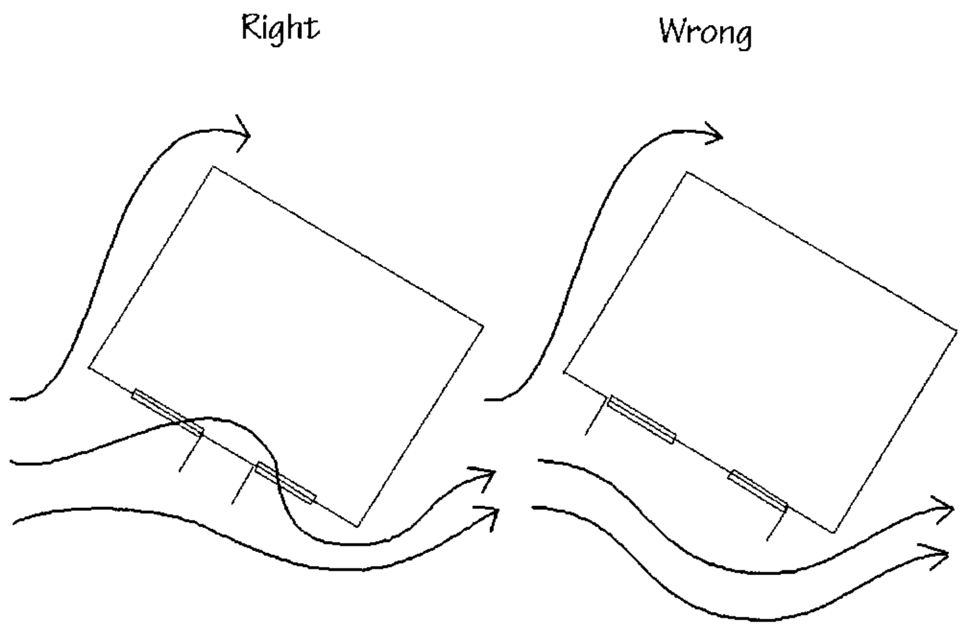
> WINDOWS
> - Window placement to allow cross ventilation from prevailing winds
> - Window areas split about equally between the windward and leeward sides of a building
> - Window area of about 15% of the floor area
> - Correct window height to direct air toward occupants

A low window is especially important when hoppers or jalousies are used because they tend to deflect air upward. *Casement or pivoting windows* deflect the air stream from side to side. They can act as fin walls when they swing outwards. *Hoppers* or *jalousies* deflect wind vertically. They can be used to deflect rain while still admitting air. However, they may also direct the air over the occupants' heads. *Horizontal or strip windows* are often the best choice to ventilate large areas.

Fin walls on walls with windows direct air into the building.

Fin walls can greatly increase the air that enters a building from windows on the *same wall.* They are used when the wall does not directly face into the prevailing winds. Fin walls must be placed correctly, as seen in Figure 11-4, to be effective. They keep air from entering the room if they are placed incorrectly.

Figure 11-4
Correct and incorrect placement of fin walls



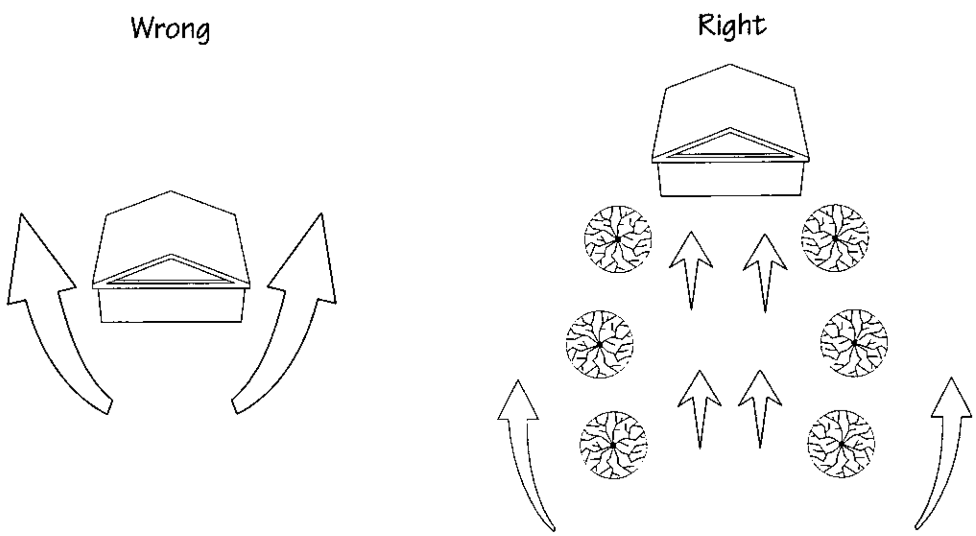
Roof vents and cupolas can help ventilate buildings.

Roof vents and cupolas can lower attic temperatures and help ventilate buildings if the wind speed in an area is adequate. The vacuum produced by wind blowing across the cupola will exhaust the rising hot air from the house.

Wind is a liability in the winter. Both wind speed and flow affect heat transmission through the building envelope. Vegetation and other barriers can reduce wind speed and flow at sites where *reducing* heat loss is important. Or, they can be used to *increase* heat loss at sites where excessive heat buildup is the more important problem. Trees, for example, can be a windbreak or they can funnel cool breezes into a building. Plants near buildings can help prevent cool winds from easily escaping around the sides of the building (Figure 11-5).

Hurricanes Andrew and Hugo showed that some trees resist wind damage better than others. One of the most durable is the Florida state tree, the Sabal Palm. Most palm trees are very resistant to high winds. Other wind-resistant trees include hickory, pecan, live oak, bluff oak, bald cypress, and American ash. Trees that resist wind poorly include laurel oak, water oak, sweet gum, sugarberry, cherry laurel, and pine. Place these species well away from buildings to avoid possible damage.

Figure 11-5
Vegetation can help prevent breezes from escaping around the sides of the building



VEGETATION

- Trees and shrubs or walls that protect the building from cooling winds in the winter
- Trees and shrubs or walls that direct breezes toward the building where cooling is critical
- Wind resistant trees, especially near buildings

Appendix I:
Mortgage Rate Tables 181

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 × 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	14.86

Interest Rate

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
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

Interest Rate

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
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 II: Fingertip Facts

This section contains statistical energy information—conversion factors, R-values, fuel prices, and energy efficiency recommendations. 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)

1º F	one degree Fahrenheit	**cf**	cubic foot
MMBtu	million Btu	**cfm**	cubic foot per minute
kWh	kilowatt-hour	**bbl**	barrel
kW	kilowatt	**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 heating/cooling	=	12,000 Btu/hour

Fuel Units

1 cf of natural gas	=	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 × 4 ft × 8 ft)
1 cord dried oak	=	23.9 MMBtu
1 cord dried pine	=	14.2 MMBtu

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.

Material	R-value
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	
Fiberboard sheathing (noninsulating blackboard)	2.6
Expanded polystyrene (beadboard)	4.0
Extruded polystyrene	5.0
Polyisocyanurate and polyurethane	7.2
Building Materials	
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	2.0
Filled with vermiculite/perlite	4.0 to 6.0
Filled with cement mortar	1.8
Dead Air Spaces	**R-value of air space**
½-inch	.75
¾-inch	.77
3½-inch	.80
3½-inch, reflecting surface on one side	1.6
3½-inch, reflecting surface both sides	2.2

Appendix III: Energy Code Excerpts 189

A STUDY GUIDE FOR THE 1997 EDITION OF FLORIDA'S ENERGY EFFICIENCY CODE FOR BUILDING CONSTRUCTION

PREFACE

In response to a federal requirement of the Energy Policy and Conservation Act (Public law 94-163), the 1977 Florida Legislature passed two laws which required local governments to adopt energy efficient building standards. In effect, this precipitated the local adoption of an energy code for certain categories of buildings for which building permits were issued after March 15, 1979. The two laws enacted by the Florida Legislature were the "Florida Thermal Efficiency Code" (Ch. 553.900, Florida Statutes) and the "Florida Lighting Efficiency Code" (Ch. 553.908, Florida Statutes), which were combined in 1980 as the Florida Model Energy Efficiency Code for Building Construction.

Originally, this state law referenced minimum standards for construction to meet or exceed national standards such as those of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE 90-75). However, nationally recognized energy codes or standards such as ASHRAE were designed primarily for climates where heating is more important than cooling. The Florida Energy Efficiency Code for Building Construction was developed to be climate-specific for Florida and is not readily applicable for use in other parts of the nation.

The Florida Legislature, through Chapter 81-226, Laws of Florida, and Chapter 553, Part VII, Florida Statutes, established the Florida Energy Efficiency Code as the statewide uniform standard for energy efficiency in the thermal design and operation of all buildings in the State of Florida (with certain exemptions; see Section 101.3(g)2). As such, the Energy Code is a uniform code and may not be made more stringent or lenient by local government. Any changes to the Code will be made through the Administrative Procedures Act process.

The Florida Department of Community Affairs (DCA) was given the responsibility for administering, modifying, revising, updating and maintaining this Energy Code. DCA was also made responsible for at least triennially determining cost-effective, energy-saving equipment and techniques available and updating the Code to incorporate such equipment and techniques.

Prior to issuing any building permit, certification of Code compliance, using forms identified within the body of the Code, must be submitted to the local building official.

Purpose Of This Manual

This manual is intended to be used as a study guide to important Energy Code information needed to take construction industry licensing tests. It is not intended to take the place of the Florida Energy Efficiency Code for Building Construction. It is comprised of excerpts taken from the Energy Code, but is by no means inclusive of all Code requirements. Design and construction professionals should own and refer to a current edition of the Energy Code book.

Code Format

Commercial buildings and residential buildings greater than 3 stories comply by Chapter 4 of the Code, which is broken out into four compliance methods: Method A (the Whole Building Performance Method), Method B (the Component Performance Method), Method C (the Limited and Special Use Buildings Prescriptive Method) and Method D (the Renovations and Systems Prescriptive Method). Residential buildings of 3 stories or less comply by Chapter 6, which is broken out into three compliance methods: Method A (the Whole Building Performance Method), Method B (the Component Prescriptive Method), and Method C (the Limited Applications Prescriptive Method).

Requirements for major categories of building elements are then lumped together: **Building Envelope Systems, Mechanical Systems, Plumbing Systems and Electrical Systems**. Each component has its own section.

ADMINISTRATION AND ENFORCEMENT

100 GENERAL

100.1 TITLE.

This Code shall be known as the Florida Energy Efficiency Code For Building Construction, and may be cited as such. It will be referred to herein as "the Code" or "this Code".

100.2 INTENT.

The provisions of this Code shall regulate 1) the design of building envelopes for adequate thermal resistance and low air leakage and 2) the design and selection of mechanical, electrical, and illumination systems and equipment which will enable the effective use of energy in new building construction, additions, alterations or any change in building configuration.

It is intended that these provisions provide flexibility to permit the use of innovative approaches and techniques to achieve effective utilization of energy. These provisions are structured to permit compliance with the intent of this Code by the following design paths as applicable for the type of construction and date permitted.

1. Chapter 4, Commercial Building Compliance Methods

2 Chapter 6, Residential Building Compliance Methods.

Compliance with these paths meets the intent of this Code as allowed by sections 101.1 and 101.2 of this Code.

This Code is not intended to abridge any safety or health requirements mandated under any other applicable codes or ordinances.

101 SCOPE

101.0 General.

This Code is a statewide uniform code and shall not be made more stringent or lenient by local government. The Code provides for a uniform standard of energy efficiency by, at a minimum, setting forth minimum requirements for exterior envelopes, lighting, electrical distribution, and selection of heating, lighting, ventilating, air conditioning and service water heating systems. It shall apply to all new buildings, to additions to existing buildings and manufactured homes, to renovations to existing buildings, both public and private, with certain exceptions, to changes of occupancy type, to the site-installed components and features of manufactured homes at their first set-up, and to the installation or replacement of building systems and components with new products for which thermal efficiency standards are set by this Code. New buildings, with the exception of those exempted below, and in accordance with the specific exceptions of individual sections shall be designed to comply with Chapter 4 or 6 of this Code.

101.1 Commercial Buildings.

101.1.1 New Construction.

Chapter 4, Commercial Building Compliance Methods. Commercial buildings of any size and multifamily residential buildings greater than three stories shall comply with Chapter 4 of the Code. This chapter contains four compliance methods:

Method A: Whole Building Performance Method

Method B: Component Performance Method

Method C: Limited Applications Prescriptive Method

Method D: Renovations and Systems Prescriptive Method

101.1.2 Additions.

Additions to existing commercial buildings are considered new building construction and shall comply with Chapter 4 of this Code as allowed in section 101.1.1.

Additions to existing non-residential buildings that are unable to comply with Code requirements for the addition alone may comply with the Code by bringing the entire building into compliance with the requirements for new buildings.

101.1.3 Renovations.

Renovated commercial buildings shall, when applicable (see section 202, Renovations), comply with the prescriptive requirements contained in Form 400D or with Method B of Chapter 4 for insulation, HVAC systems, lighting, water heating systems and exterior envelope components being retrofitted or replaced.

101.1.4 Buildings With Multiple Occupancy Types.

When a building contains more than one occupancy type, each portion of the building shall conform to the requirements for the occupancy housed therein.

EXCEPTIONS:

1. Where minor occupancy use does not occupy more than 5 percent of the floor area of the building, the major use shall be considered the building occupancy.

2. Residential dwelling units such as congregate living facilities that are part of a larger commercial occupancy type and are three stories or less may comply with Chapter 4 of this Code.

101.1.5 Limited or Special Use Buildings.

Buildings determined by the Department of Community Affairs to have a limited energy use potential based on size, configuration or time occupied, or to have a special use requirement shall be considered Limited or Special Use Buildings and shall comply with the Code by Method C of Chapter 4. Code compliance requirements shall be adjusted by the Department to handle such cases when warranted.

101.1.6 Shell Buildings.

Non-residential buildings that are permitted prior to design completion or which will be finished in sections at a time after construction of the shell shall comply with Method B of Chapter 4 of the Code prior to granting of a permit to build. All assumptions made about features not installed until later that are not on the building plans shall be listed and appended to the Form 400B submitted to the Building Department. Unless the building is completed as per all assumptions made in the original Code compliance submittal, a revised Code submittal(s) using Methods A, B or C shall be submitted when completion of the building (or part of the building) is permitted.

101.2 Residential Buildings.

101.2.1 New Construction.

New residential construction shall comply with this Code by using the following compliance methods.

Chapter 4, Commercial Buildings Compliance Methods. Multifamily buildings greater than three stories shall comply by Chapter 4 of the Code.

Chapter 6, Residential Buildings Compliance Methods. Single family residential buildings and multifamily buildings of three stories or less shall comply with this chapter of the Code. This Chapter contains three compliance methods:

Method A: Whole Building Performance Method

Method B: Component Prescriptive Method

Method C: Limited Applications Prescriptive Method

101.2.2 Additions.

Additions to existing residential buildings shall be considered new building construction and shall comply with the requirements of either Method A, Method B, or Method C of Chapter 6, as applicable. Additions to residential buildings over three stories shall comply by Chapter 4.

Additions to existing residential buildings that are unable to comply with Code requirements for the addition alone may comply with the Code by bringing the entire building into compliance with the requirements for new buildings given in section 101.4.2.

101.2.3 Renovations

Renovated buildings shall, when applicable (see section 202, Renovations), meet the prescriptive requirements contained in Method C of Chapter 6 for residential applications of the Code for insulation, HVAC systems, lighting, water heating systems and exterior envelope for those components being retrofitted or replaced.

101.2.4 Manufactured Homes.

Site-installed components of manufactured homes and residential manufactured buildings shall meet the prescriptive requirements contained in Method C of Chapter 6 for those components.

101.2.5 Buildings Permitted Together.

101.2.5.1 Residences in which two buildings are permitted together that are not connected by conditioned space shall be considered separate residences for the purposes of compliance with this Code if the following conditions apply:

1. The secondary building has its own bathroom and kitchenette or bar; and
2. The secondary building is heated and/or cooled by a separate heating and/or cooling system.

101.2.5.2 Conditioned workrooms, exercise rooms, play rooms, pool rooms and similar types of rooms that are separated from the main residence and do not meet the conditions in section 101.2.5.1 shall use Chapter 4 to demonstrate compliance with this Code.

EXCEPTION:

If a workroom or other room is separated from the main residence only by enclosed unconditioned space and is heated or cooled by the same system(s) as the primary building, it shall comply with this Code as part of the primary building.

101.3 Changes of Occupancy Type.

101.3.1 Buildings having a change of occupancy type that were permitted prior to March 15, 1979, shall meet the requirements for renovations in section 101.1.3 or section 101.2.3, as appropriate, for those components which are being retrofitted or replaced.

101.3.2 Buildings having a change of occupancy that were permitted after March 15, 1979, shall comply with the requirements of Chapter 4 for commercial applications and multifamily residential buildings greater than three stories or Chapter 6 for residential applications of three stories or less. Where the efficiency of a building component is unknown, it shall be determined in accordance with the criteria specified in section 101.4.2.1.

101.4 Existing Buildings

101.4.1 Existing Buildings Not Previously Conditioned.

101.4.1.1 Previously unconditioned existing buildings which were permitted prior to March 15, 1979 to which heating or cooling systems are added shall meet the prescriptive requirements contained in Method B of Chapter 4 for commercial applications and Method C of Chapter 6 for residential applications of the Code for insulation, HVAC system(s), water heating system and/or exterior envelope for those components which are being retrofitted or replaced.

101.4.1.2 Existing buildings which were permitted after March 15, 1979 as unconditioned space to which comfort conditioning is added shall be considered additions and shall be brought into full compliance with this Code.

101.4.2 Non-Exempt Existing Buildings.

Existing buildings not exempt from the provisions of this Code (see section 101.5.1), for either the entire building or an addition to the building, that are unable to meet one or more current prescriptive Code minimum requirements may be exempt from those minimum requirements if the entire building is brought into compliance with the following chapters and the assumptions in section 101.4.2.1 are used:

1. Commercial buildings and residential buildings greater than three stories: Method A of Chapter 4.

2 Single-family residential buildings and multifamily buildings of three or less stories: Method A of Chapter 6.

101.4.2.1 Assumptions for Existing Building Efficiencies.

The following restrictions apply if the entire building is used to demonstrate Code compliance:

1. The owner shall demonstrate to the building department's satisfaction that all R-values and equipment efficiencies claimed are present. If the building was built after 1980, the original Energy Code submittal may be used to demonstrate efficiencies.

2 If it is apparent from inspection that no insulation is present in the existing walls, floors or ceilings, or if inspection is not possible, an R-value of zero (0) shall be used for that component in the calculation. If as part of the addition and renovation project, insulation or equipment in the existing structure is upgraded, the new values may be used in the calculation. Multipliers for insulation levels not on Form 600A may be found in sec. 2.0 of Appendix C.

3. If, upon inspection, insulation is found but the R-value is unknown, then an R-value shall be determined by an energy audit utilizing current acceptable practice based on insulation thickness, density and type.

4. Equipment efficiencies shall be demonstrated, either from manufacturer's literature or certified equipment directories, or by the procedure provided in section 407.1.ABC.3 or section 607.1.ABC.3 based on system capacity and total on-site energy input. Equipment to be added shall meet the applicable minimum equipment efficiency from Tables 4-3 through 4-9 for commercial occupancies and from Tables 6-3 through 6-9 for residential occupancies. Equipment efficiencies not meeting the values given in Tables 4-3 through

4-9 or 6-3 through 6-9, shall utilize the cooling or heating system multipliers provided by FLA/COM for commercial occupancies and Table 6-13 of Appendix C for residential occupancies complying by Chapter 6. Residential ducts with less than R-4.2 insulation shall use the multipliers provided in Tables 6-15 to 6-17 in Appendix C.

5. Any non-vertical roof glass shall be calculated as horizontal glazing.

101.5 Exempt Buildings. Buildings exempt from compliance with this Code include those described in sections 101.5.1 through 101.5.8.

101.5.1 Existing buildings except those considered renovated buildings, changes of occupancy type, or previously unconditioned buildings to which comfort conditioning is added.

101.5.2 Any building or portion thereof whose peak design rate of energy usage for all purposes is less than 1 watt (3.4 British thermal units per hour) per square foot of floor area for all purposes.

101.5.3 Any building which is neither heated nor cooled by a mechanical system designed to control or modify the indoor temperature and powered by electricity or fossil fuels. Such buildings shall not contain electrical, plumbing or mechanical systems which have been designed to accommodate the future installation of heating or cooling equipment.

101.5.4 Any building for which federal mandatory standards preempt state energy codes.

101.5.5 Any historical building as described in Section 267.021, Florida Statutes.

101.5.6 Any state building that must conform to the "Florida Energy Conservation Act of 1974", and amendments thereto, implemented by rules of the Department of Management Services, State of Florida, including the use of life-cycle analysis (FLEET).

101.5.7. Any building of less than 1,000 square feet whose primary use is not as a principal residence and which is constructed and owned by a natural person for hunting or similar recreational purposes; however, no such person may build more than one exempt building in any 12 month period.

101.5.8 Any building where heating or cooling systems are provided which are designed for purposes other than general space comfort conditioning. Buildings included in this exemption include:

1. Buildings containing a system(s) designed and sold for dehumidification purposes only and controlled only by a humidistat. No thermostat shall be installed on systems thus exempted from this Code.

2. Commercial service areas where only ceiling radiant heaters or spot coolers are to be installed which will provide heat or cool only to a single work area and do not provide general heating or cooling for the space.

3. Buildings heated with a system designed to provide sufficient heat only to prevent freezing of products or systems. Such systems shall not provide heating above 50°F.

4 Pre-manufactured freezer or refrigerated storage buildings and areas where the temperature is set below 40°F and in which no operators work on a regular basis.

5. Electrical equipment switching buildings which provide space conditioning for equipment only and in which no operators work on a regular basis.

101.6 Building Systems. Thermal efficiency standards are set for the following building systems where new products are installed or replaced in existing buildings, and for which a permit must be obtained. Such systems shall meet the minimum efficiencies allowed for that system on Form 400D for commercial buildings and on Form 600C for residential buildings.

1. Heating, ventilating or air conditioning systems;

2. Service water or pool heating systems;

3. Electrical systems and motors;

4. Lighting systems.

EXCEPTIONS:

1. Where part of a functional unit is repaired or replaced. For example, replacement of an entire HVAC system is not required because a new compressor or other part does not meet Code when installed with an older system.

2. Where existing components are utilized with a replacement system, such as air distribution system ducts or electrical wiring for lights, such components or controls need not meet Code if meeting Code would require that component's replacement.

3. Replacement equipment that would require extensive revisions to other systems, equipment or elements of a building where such replacement is a like-for-like replacement, such as through-the-wall condensing units and PTACs, chillers, and cooling towers in confined spaces.

4. HVAC Equipment sizing calculations are not required for systems installed in existing buildings not meeting the definition of renovation in section 202.

102 MATERIALS AND EQUIPMENT

102.1 Efficiency and Maintenance Information. An operating and maintenance manual shall be provided to the building owner for all commercial buildings. The manual shall include basic data relating to the design, operation and maintenance of HVAC systems and equipment. Required routine maintenance actions shall be clearly identified. Where applicable, HVAC controls information such as diagrams, schematics, control sequence descriptions, and maintenance and calibration information shall be included. Operations manuals shall be available for inspection by the building official upon request. See section 414.1.ABC.4.

102.2 Alternate Materials - Method of Construction, Design or Insulating Systems. The provisions of this Code are not intended to prevent the use of any material, method of construction, design or insulating system not specifically prescribed herein, provided that such construction, design, or insulating system has been approved by the Building Official and the Department of Community Affairs as meeting the intent of the Code. This clause shall not allow disregard of any provision(s) of the Code by building departments, nor shall it prevent uniform statewide implementation of the Code as required by Florida law (Section 553.901, Florida Statutes).

102.3 Air Conditioners Sold or Installed in Florida. All air conditioners installed in new or renovated buildings in the State of Florida shall comply with requirements set forth in Chapters 4 or 6, as applicable.

103 CODE COMPLIANCE AND PERMITTING

103.0 General. Code compliance for all buildings shall be certified by use of approved forms for the compliance method chosen that are specific to the climate zone in which the building will be located. See Figure 1-1.

The only software approved for determining compliance with this Code shall be the software developed and maintained by the Department or its designated representative.

Worst case calculations may be submitted for identical buildings facing different cardinal directions; however, original Code certification signatures shall be provided for each building.

103.1 Certification of Compliance. Code compliance for non-residential and multifamily residential applications (except for duplexes, townhouses, or other buildings identified in Sections 481.229 and 471.003, Florida Statutes) shall be certified by the owner, project architect (registered in the State of Florida), or other officially designated agent allowed in section 103.2.

103.1.1 Code Compliance Preparation.

The person preparing the compliance calculation shall certify that the plans and specifications covered by the calculation, or amendments thereto, are in compliance with the Florida Energy Efficiency Code for Building Construction.

103.1.1.1 Commercial Applications

Completion of procedures demonstrating compliance with this Code for commercial buildings shall be signed and sealed by an architect or engineer licensed to practice in the State of Florida, with the exception of buildings excluded by Section 481.229, Florida Statutes, or Section 471.003, Florida Statutes. Calculations for buildings falling within the exception of Section 471.003, Florida Statutes, may be performed by air conditioning or mechanical contractors licensed in accordance with Chapter 389, Florida Statutes, or under any special act or ordinance.

Design professionals responsible under Florida law for the design of lighting, electrical, mechanical, and plumbing systems and the building shell, shall certify compliance of those building systems with the Code by signing and providing their professional registration number on the Energy Code form provided as part of the plans and specifications to the building department.

EXCEPTION:

Typed names and registration numbers may be provided in lieu of a signature where all relevant information has been included on signed and sealed plans.

103.1.1.2 Residential Applications

103.1.1.2.1 Single-Family Residential, Duplexes, Townhouses. No license or registration is required to prepare the Code compliance form for single-family residential dwellings, duplexes and townhouses.

103.1.1.2.2 Multifamily Residential. Form preparation for multifamily dwellings except duplexes and townhouses shall be signed and sealed by an architect or engineer registered in the State of Florida, with the exception of buildings excluded by Section 481.229, Florida Statutes, or Section 471.003, Florida Statutes. Calculations for buildings falling within the exception of Section 471.003, Florida Statutes, may be performed by air conditioning or mechanical contractors licensed in accordance with Chapter 489, Florida Statutes, or under any special act or ordinance.

103.1.2 Code Compliance Certification.

The building's owner, the owner's architect, or other authorized agent legally designated by the owner shall certify that the building is in compliance with the Code, as per Section 553.907, Florida Statutes, prior to receiving the permit to begin construction or renovation.

If, during the building's construction or renovation, alterations are made in the building's design or in materials or equipment installed in the building which would diminish it's energy performance, an amended copy of the compliance certification shall be submitted to the building official on or before the date of final inspection by the building owner or his/her legally authorized agent.

103.2 Details, Plans and Specifications. Plans and specifications shall be submitted with each application for a building permit. Energy Code calculations shall be made a part of the plans and specifications of the building. The Building Official shall require, subject to the exceptions in Section 481.229, Florida Statutes, and Section 471.003, Florida Statutes, that plans and specifications be prepared by an engineer or architect licensed to practice in the State of Florida. The plans and specifications, including the Energy Code calculations, shall show, in sufficient detail, all pertinent data and features of the building and the equipment and systems as herein governed including, but not limited to: design criteria, exterior envelope component materials, U values of the envelope systems, R-values of insulating materials, size and type of apparatus and equipment, equipment and systems controls and other pertinent data to indicate conformance with the requirements of the Code.

103.3 Building Permits. Prior to receiving the permit to begin construction or renovation, owners, or an agent duly designated by the owner, of all buildings shall certify Energy Code compliance to the designated local enforcement agency. If, during the building construction or renovation, alterations are made in the design, materials, or equipment which would diminish the energy performance of the building, an amended copy of the compliance certifications shall be submitted to the local enforcement agency on or before the date of final inspection by the building owner or his agent.

Building officials or their officially designated representatives shall assure that the compliance forms are complete and without gross errors.

104 INSPECTIONS

104.1 General. All construction or work for which a permit is required shall be subject to inspection by the Building Official or his/her officially designated representative.

104.2 Approvals Required. No work shall be done on any part of the building or structure beyond the point indicated in each successive inspection without first obtaining the written approval of the Building Official. No construction shall be concealed without inspection approval.

104.3 Inspections Required. There shall be a final inspection for Code compliance on all buildings when completed and ready for occupancy.

104.4 Information Cards Required.

104.4.1 Energy Performance Level (EPL) Display Card. The building official shall require that an *Energy Performance Level Display Card* be completed and certified by the builder to be accurate and correct before final approval of the building for occupancy. Florida law (Section 553.9085) requires the EPL Display Card to be included as an addendum to each sales contract executed after January 1, 1994, for both pre-sold and non-presold residential buildings.

The *Energy Performance Level (EPL) Display Card* contains information indicating the energy performance level and efficiencies of components installed in a dwelling unit. The building official shall verify that the *EPL Display Card* completed and signed by the builder accurately reflects the plans and specifications submitted to demonstrate Code compliance for the building.

104.4.2 HVAC Efficiency Card. The building official shall require that a completed HVAC Efficiency Card signed by a representative of the heating and cooling equipment contractor be posted in a prominent location on the cabinet of the indoor air handler or furnace of each heating or heating and cooling system installed in the building at the time of installation. Where single package units are installed, the card shall be posted on the unit itself. The card shall be durable, readable and shall contain the following information:

1 Manufacturer's name(s);

2. Brand name(s);

3. Model numbers of the furnace, compressor unit, and air handler (and evaporator coil, if the air handler can be equipped with more than one coil) for each system installed;

4. Efficiency ratings of the combined equipment for each system actually installed;

5. Name and address of the heating and or cooling company installing the equipment;

6. Signature line and date line, preceded by the statement "With the authorization of the installing contractor I certify that the information entered on this card accurately represents the system installed."

7. Signature line and date line, preceded by the statement "As the Building Official or the representative of the Building Official I certify that the information entered on this card accurately represents the system installed."

EXCEPTIONS:

1. If the information required above has been previously submitted and is included on the plans required at the building site, the HVAC Efficiency Card need not be provided. However, the plans shall be signed by a representative of the heating and cooling company installing the equipment and shall be available for inspection by building inspectors and by prospective buyers until the time of title transfer.

2. The Federal Trade Commission's Energy Guide Label may be used to fulfill this requirement.

104.4.3 Insulation Certification Card. In cases where the R-value of insulation installed in either walls, ceilings or floors is not readily apparent, the local building official shall require that an R-Value Certification Card signed by the insulation contractor be posted in a prominent location at the time of installation. The card shall contain, at a minimum, the following information:

1. Insulation manufacturer's name;

2. Insulation type;

3. R-value of insulation installed;

4. Thickness of insulation installed;

5. Location of insulation installed;

6. Indication that the installation has been checked and does not block attic ventilation.

7. Name and address of the contractor installing the insulation;

8. Date of installation.

104.4.4 Energy Guide Labels. *Energy Guide* Labels required by the U.S. Federal Trade Commission for heating and cooling systems, water heaters and other appliances covered by federal law shall remain on those appliances until time of title transfer.

104.4.5 Fenestration Energy Rating Labels. Energy performance values (i.e., U-value, Shading Coefficient, Solar Heat Gain Coefficient) of fenestration products (i.e., windows, doors and skylights) shall be determined by an accredited, independent laboratory and labeled and certified by the manufacturer. Such certified and labeled fenestration energy ratings shall be accepted for the purposes of determining compliance with the building envelope requirements of this Code.

Where the specified energy performance (U-value, Solar Heat Gain Coefficient or Shading Coefficient) of the fenestration product is not labeled nor readily apparent, the default procedures outlined in section 3.1 of Appendix B shall be used to determine Code compliance. Product features must be verifiable for the product to qualify for the default value associated with those features. Where the existence of a particular feature cannot be determined with reasonable certainty, the product shall not receive credit for that feature. Where a composite of materials from two different product types are used, the product shall be assigned the worst value.

U-values (thermal transmittances) of fenestration products (windows, doors and skylights) shall be determined by an accredited, independent laboratory in accordance with National Fenestration Rating Council 100: *Procedure for Determining Fenestration Product Thermal Properties.* The Solar Heat Gain Coefficient (SHGC) for glazed fenestration products (windows, glazed doors and skylights) shall be determined in accordance with National Fenestration Rating Council 200: *Procedure for Determining Fenestration Product Solar Heat Gain Coefficients at Normal Incidence.* Where a Shading Coefficient (SC) for fenestration is to be used to determine Code compliance, it may be determined by converting the product's Solar Heat Gain Coefficient, as determined in accordance with NFRC 200, to a Shading Coefficient, by dividing the product's SHGC by 0.87.

105 REPORTING

105.0 Reporting to the Department of Community Affairs. A reporting form shall be submitted to the local building department by the owner or owner's agent with the submittal certifying compliance with this Code. Reporting forms shall be a copy of the front page of the form applicable for the Code chapter under which compliance is demonstrated.

105.1 Reporting Schedule. It shall be the responsibility of the local Building Official to forward the reporting section of the proper form to the Department of Community Affairs on a quarterly basis as per the reporting schedule in Table 1-1.

Table 1-1
Reporting Schedule

	Group I*	Group II*	Group III*
Quarter 1	12/31	1/31	2/28
Quarter 2	3/31	4/30	5/31
Quarter 3	6/30	7/31	8/31
Quarter 4	9/30	10/31	11/30

**See Appendix A for Group designations.*

105.2 Jurisdiction Numbers.

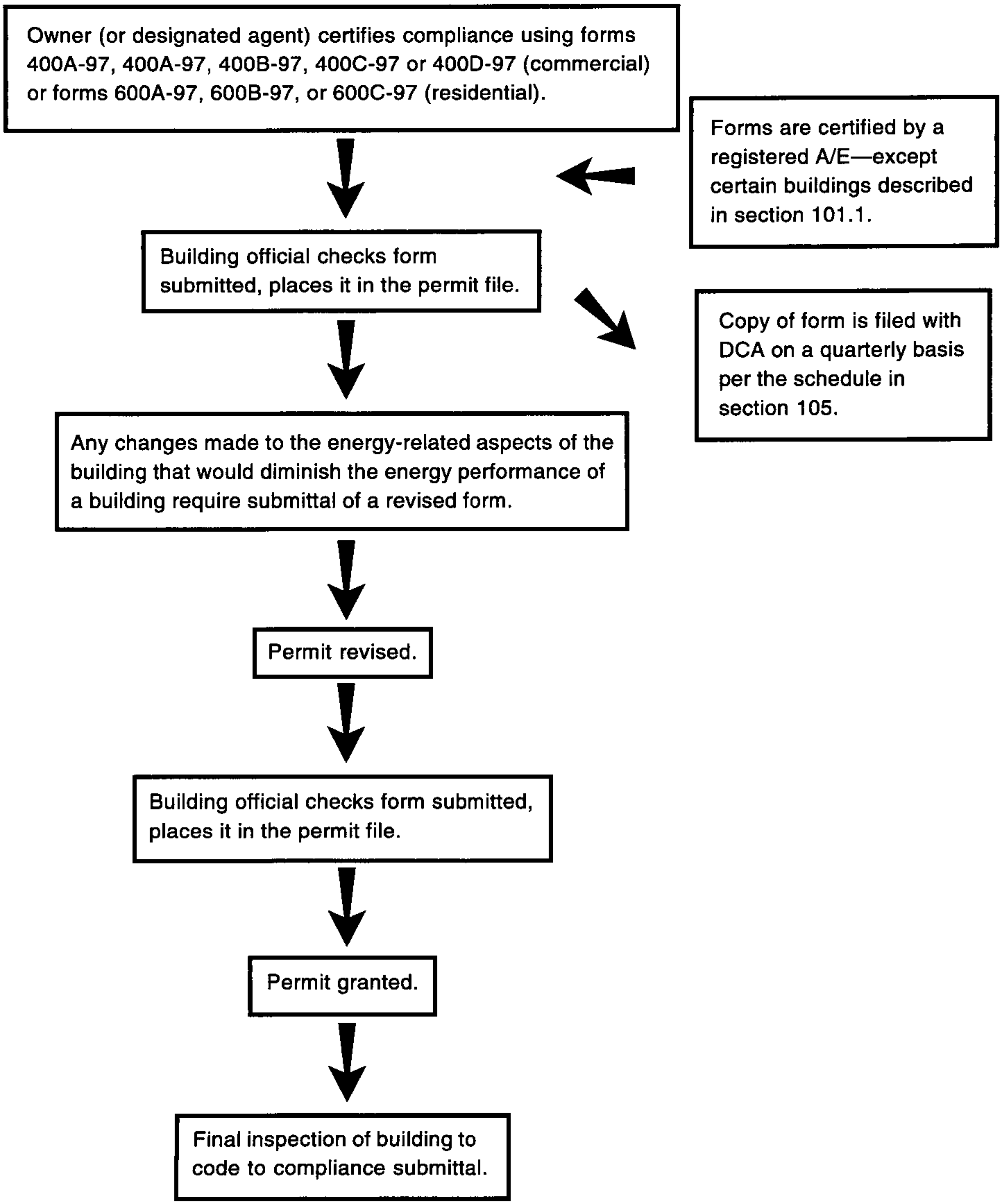
For data collection purposes, all permitting jurisdictions in the State of Florida have been assigned a six digit jurisdiction number. The jurisdiction number is required on all Energy Code forms. Jurisdiction numbers are listed by county in Appendix A.

106 VALIDITY

106.0 Validity.

If any section, subsection, sentence, clause, or phrase of this Code is, for any reason, held to be invalid for any reason, such decision shall not affect the validity of the remaining portions of this Code.

Figure 1-1
Code Compliance Flow Chart



COMMERCIAL BUILDING COMPLIANCE METHODS

400 ADMINISTRATION

400.0 General. The provisions of this Chapter apply to all new commercial occupancy buildings, additions to existing commercial occupancy buildings, and multifamily residential buildings over three stories in height. Building type classifications shall be those defined in Chapter 2 of this Code under "Occupancy Classification". This Chapter provides three Methods by which commercial buildings may be brought into compliance with this Code.

Method A, the Whole Building Performance Method. This is a computer-based annual energy performance calculation. Under this method, energy performance is calculated for the entire building based on the envelope and major energy-consuming systems specified in the design and simultaneously for a Baseline building of the same configuration, but with baseline systems. Compliance calculations are described in the sections called Performance Calculation Procedures. The ratio of the total points for the As-Built Building to the total points calculated for the Baseline building shall be 1.0 or less to comply with this Code. Basic prescriptive requirements described in the sections called Prescriptive Requirements must also be met.

Method B, the Component Performance Method. This is a computer-based calculation methodology. Under this method, components of building systems must meet minimum performance standards, as described in the sections called Performance Calculation Procedures. Basic prescriptive requirements described in the sections called Prescriptive Requirements must also be met. Shell buildings shall comply by Method B of this Chapter.

Method C, the Limited and Special Use Buildings Prescriptive Method. This method requires that a list of prescriptive requirements specified for a given building type be met or exceeded to comply with this Code. The following building types may comply by Method C of this Chapter:

1. Detached commercial buildings of less than 200 sq ft area.
2. Skyboxes or sports stadiums.
3. Traffic safety control towers.
4. Convenience stores <5,000 sq ft.
5. Restaurants <5,000 sq ft
6. Retail stores <5,000 sq ft

7. Office buildings <5,000 sq ft
8. School buildings <5,000 sq ft
9. Storage buildings <5,000 sq ft

Method D, the Renovated Buildings and Systems Method. This method requires that a list of prescriptive requirements specified for one or more building components be met or exceeded to comply with this Code. Renovated buildings shall, when applicable (see section 202), meet the efficiencies listed on Form 400D for components being changed or shall comply with the envelope or systems criteria in Method B of FLA/COM for the components being changed. Existing buildings not meeting the definition of a renovation in which new heating, cooling, water heating, electrical or lighting systems are installed shall meet the minimum efficiencies listed in Form 400D for the system(s) being changed.

400.0.ABCD Compliance Criteria. Commercial buildings demonstrating compliance with this Code by Methods A or B shall meet all of the criteria given in the text as specific to the chosen method of compliance for 1 - 4 below . Commercial buildings utilizing Method C or D for Code compliance shall meet all criteria specified for that Method C occupancy type or building configuration for 1, 3 and 4 below.

1. Prescriptive Requirements.
2. Performance Calculation Procedure.
3. Certification of Compliance.
4. Reporting

400.1 Prescriptive Requirements. Basic Prescriptive Requirements shall be met for all buildings. The section number followed by the combined number and letters ".1.ABCD" indicates these Basic Prescriptive Requirements (i.e., prescriptive requirements that shall be met by buildings complying by either Method A, B, C, or D) in sections 401 through 415. Prescriptive Requirements specific to Method A, B, C, or D (i.e. ".1.B" is specific to Method B) shall be met when complying with the Code by that method. Where a Prescriptive Requirement specific to a method is more stringent than the Basic Prescriptive Requirement, the more stringent requirement shall be met.

400.2 Performance Calculation Procedures. The calculation procedures contained in the personal computer-based program entitled FLA/COM shall be used to demonstrate Code compliance of the design for commercial buildings complying by Method A or Method B of this Chapter. The building components' efficiency levels specified in the performance compliance calculation (or amended copy submitted to the building department) are the minimum efficiencies allowed to be installed in the building.

400.2.A.1 Additions. Additions to existing buildings shall follow the same Method A calculation procedure as new construction with the following qualifications:

1. Calculations shall be conducted using only the components of the addition itself, including those pre-existing components which separate the addition from other spaces.
2. Efficiencies for heating and cooling systems shall be assumed to be the minimum efficiency allowed by the Code for that type and size of equipment unless new equipment is installed to replace existing equipment or to service the addition specifically or higher equipment efficiencies can be documented.

400.3 CERTIFICATION OF COMPLIANCE.

400.3.ABCD.1 Code Compliance Preparation. The FLA/COM Performance Calculation Procedures demonstrating Code compliance for Methods A and B, and Forms 400C and 400D demonstrating Code compliance for Methods C and D shall be prepared, signed and sealed by an architect or engineer registered in the State of Florida, with the exception of buildings excluded by Section 481.229, Florida Statutes, or Section 471.003, Florida Statutes. Calculations for buildings falling within the exception of Section 471.003, Florida Statutes, may be performed by air conditioning or mechanical contractors licensed in accordance with Chapter 489, Florida Statutes, or under any special act or ordinance.

The person preparing the compliance calculation shall certify that the calculation, or amendments thereto, is true and accurate and demonstrates that the building is in compliance with the Florida Energy Efficiency Code For Building Construction.

400.3.ABCD.2 Code Compliance Certification. The building's owner, the owner's architect, or other authorized agent legally designated by the owner shall certify to the building official that the building is in compliance with the Energy Efficiency Code For Building Construction prior to receiving the permit to begin construction or renovation.

If, during the building's construction or renovation, alterations are made in the building's design or in materials or equipment installed in the building which would diminish it's energy performance, an amended copy of the compliance certification shall be submitted to the building official on or before the date of final inspection by the building owner or his/her legally authorized agent.

The certified FLA/COM calculation printout or Form 400C shall be a part of the plans and specifications submitted for permitting.

The party responsible under Subsections 471.003 and 481.228 and Chapter 489, Florida Statutes, for the design and specification of each building system shall certify that the plans and specifications for that system comply with the requirements of the Florida Energy Efficiency Code for Building Construction. See also section 103.2.

400.3.ABCD.3 Forms. Forms referenced in Table 4-1 shall be used to demonstrate Code compliance with this Chapter.

Table 4-1
Index to Commercial Code Compliance Forms

Method		Form Number
Method A	Whole Building Performance	*Form 400A-97* (FLA/COM Computer printout)
Method B	Component Performance Method	*Form 400B-97* (FLA/COM Computer printout)
Method C	Limited and Special Use Buildings	*Form 400C-97* (separate forms for North, Central, and South Florida)
Method D	Renovated Buildings and Systems Method	*Form 400D-97* (all climate zones)

400.3.A Method A Forms. An accurately completed Form 400A-97 (generated by the FLA/COM-97 computer program) demonstrating that Code compliance has been achieved shall be submitted to the building official for Method A compliance. Calculations shall be performed for the climate zone in which the building will be located and according to the procedures specified for Method A in this Chapter.

400.3.B Method B Forms. An accurately completed Form 400B-97 (generated by the FLA/COM-97 computer program) demonstrating that Code compliance has been achieved shall be submitted to the building official for Method B compliance. Calculations shall be performed for the climate zone in which the building will be located and according to the procedures specified for Method B in this Chapter.

400.3.C Method C Forms. An accurately completed Form 400C-97 demonstrating that Code compliance has been achieved shall be submitted to the building official for Method C compliance. The form submitted shall be specific for the climate zone in which the building will be located.

400.3.D Method D Forms. An accurately completed Form 400D-97 demonstrating Code compliance shall be submitted to the building official for Method D compliance.

400.4.ABCD Reporting. A copy of the front page of the 400 series form submitted to demonstrate Code compliance shall be sent by the building official to the Department of Community Affairs on a quarterly basis for reporting purposes.

401 FENESTRATIONS (GLAZING)

401.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D.

401.1.ABCD.1 Window Leakage. All exterior windows shall be designed to limit air leakage into and from the building envelope. Manufactured windows shall have air infiltration rates not exceeding those shown in Table 4-2 (see section 406.1). Site constructed windows shall be sealed in accordance with the requirements of section 406.1.

Table 4-2
Air Leakage for fenestrations and Doors
Maximum Allowable Infiltration Rate

Component	CFM/FT^2 of Area Finished window opening in the plane of the wall
Fenestration	
Operable	0.3
Jalousie	1.2
Sliding glass doors	0.3
Doors	
Wood	0.3
Commercial entrance doors	1.2
Residential swinging doors	0.5
Wall Sections	
Aluminum	0.1

402 WALLS

402.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D

402.1.ABCD.1 Thermal Resistance Requirements for Adjacent Walls. All opaque portions of walls separating conditioned spaces and interior unconditioned spaces shall be insulated and for the following shall have an insulation R-value of at least:

Climate Zone	Insulation
1,2 and 3	R-5
4,5 and 6	R-2.5
7,8 and 9	R-1.6

404 ROOFS/CEILINGS

404.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D

404.1.ABCD.1 Roof/Ceiling Thermal Envelopes. The roof or ceiling which functions as the building's thermal envelope shall be insulated to a R-value of at least R-10.

404.1.ABCD.2 Cavities Used as Plenums. Cavities beneath a roof deck which will be used as supply or return plenums shall have an insulated roof. The insulation shall have a R-value of at least R-19.

404.1.ABCD.3 Vented Cavities above Dropped Ceilings. Where cavities beneath a roof deck are not sealed from the outside environment, the ceiling shall be treated as the exterior thermal and pressure envelopes of the building.

406 AIR INFILTRATION

406.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D. The requirements of this section shall apply only to those locations that separate interior building conditioned space from the outdoors or from unconditioned space or crawl spaces. Compliance with the criteria for air leakage through building components shall be determined by tests conducted in accordance with ASTM E283-91.

406.1.ABCD.1 Minimum Infiltration Levels Allowed.

406.1.ABCD.1.1 Exterior Doors and Windows. All exterior doors and windows shall be designed to limit air leakage into or from the building envelope. Manufactured doors and windows shall have air infiltration rates not exceeding those shown in Table 4-2. These rates shall be determined from tests conducted at a pressure differential of 1.567 lb/ft^2, which is equivalent to the impact pressure of a 25 mph wind. Compliance with the criteria of air leakage shall be determined by testing to AAMA/NWWDA 101/I.S. 2-97 or ASTM E283-91, as appropriate. Site constructed doors and windows shall be sealed in accordance with the requirements of this section.

406.1.ABCD.1.2 Exterior Joints in the Envelope. All exterior joints, cracks and holes in the building envelope shall be caulked, gasketed, weatherstripped or otherwise sealed.

Such joints shall include, but not be limited to, the following:

1. Around window or door frames;
2. Between walls and foundations;
3. Between walls and roof/ceilings;
4. Through wall panels and top and bottom plates in exterior walls;
5. At penetrations of utility services or other service entry through walls, floors and roofs;
6. Between wall panels, particularly at corners and changes in orientation;
7. Between wall and floor where the floor penetrates the wall;
8. Around penetrations of chimneys, flue vents, or attic hatches; and
9. Walls bounding building cavities between floor/ceilings and ceilings/roof decks.

406.1.ABCD.1.3 Apertures in The Building Envelope. Any intentional apertures or openings in walls, ceilings or floor between conditioned and unconditioned space (such as hydrostatic openings in stairwells for coastal buildings) shall have dampers which limit air flow between the spaces.

406.1.ABCD.1.4. Building Cavities.

406.1.ABCD.1.4.1 Where vented dropped ceiling cavities occur over conditioned spaces, the ceiling shall be considered to be both the upper thermal envelope and pressure envelope of the building and shall contain a continuous air barrier between the conditioned space and the vented unconditioned space that is also sealed to the air barrier of the walls. IMPORTANT NOTE: See the definition of air barrier in section 202.

Where unvented dropped ceiling cavities occur over conditioned spaces that do not have an air barrier between the conditioned and unconditioned space (such as T-bar ceilings), they shall be completely sealed from the exterior environment (at the roof plane) and adjacent spaces by a continuous air barrier that is also sealed to the air barrier of the walls. In that case, the roof assembly shall constitute both the upper thermal envelope and pressure envelope of the building.

Unconditioned spaces above separate tenancies shall contain dividing partitions between the tenancies to form a continuous air barrier that is sealed at the ceiling and roof to prevent air flow between them.

406.1.ABCD.1.4.2 Building cavities designed to be air distribution system components shall be sealed according to the criteria for air ducts, plenums, etc. in section 410.1.ABCD.3.6.

407 SPACE COOLING SYSTEMS

407.0 Applicability. This section covers the determination of minimum cooling system design requirements and efficiencies. The requirements of this section apply to equipment and mechanical component performance of all air conditioning systems installed in new and renovated buildings including, but not limited to: unitary (central) cooling equipment (air-cooled, water-cooled and evaporatively cooled); the cooling mode of unitary (central) and packaged terminal heat pumps (air source and water source); packaged terminal air conditioners; roof air conditioners; room air conditioners; and heat-operated cooling equipment such as absorption equipment, engine-driven equipment and turbine-driven equipment.

EXCEPTIONS: Special applications, including, but not limited to, hospitals, laboratories, thermally sensitive equipment rooms, and computer rooms may be exempted from the requirements of section 407 when approved by the Building Official.

407.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D

407.1.ABCD.1 Sizing. A cooling load calculation shall be performed for newly installed units as per criteria of section 5.1 of Appendix B. This calculation shall be attached to the Code compliance form submitted to the building department when the building is permitted or, in the event the mechanical permit is obtained at a later time, the sizing calculation shall be submitted with the application for the mechanical permit.

EXCEPTIONS:

1. Where mechanical systems are designed by an engineer registered in the State of Florida, a signed and sealed summary sheet may be submitted in lieu of the complete sizing calculation(s). Such summary sheet shall include the following (by zone):

   - Project name/owner
   - Project address
   - Sizing method used
   - Area in sq.ft.
   - Total heating required with outside air
   - Total sensible gain
   - Total latent gain
   - Total cooling required with outside air
   - Grains water (difference)
   - Outdoor dry bulb used
   - Outdoor wet bulb used
   - Relative humidity
   - Indoor dry bulb

2. Systems installed in existing buildings not meeting the definition of renovation in section 202.

407.1.ABCD.1.1 HVAC systems and equipment shall be sized to provide no more than the space and system loads calculated in accordance with section 407.1.ABCD.1. A single piece of equipment providing both cooling and heating shall satisfy this provision when the cooling function meets the provisions of section 407.1.ABCD.1, and the heating function is sized as small as possible to meet the load within available equipment options.

EXCEPTIONS:

1. When the equipment selected is the smallest size needed to meet the load within available options of the desired equipment line.
2. Stand-by equipment provided with controls and devices that allow such equipment to operate automatically only when the primary equipment is not operating.
3. Multiple units of the same equipment type with combined capacities exceeding the design load and are provided with controls that sequence or otherwise optimally control the operation of each unit based on load.

407.1.ABCD.1.2 Buildings which contain assembly occupancies shall have equipment sized or controlled to prevent continuous space cooling or heating of such spaces with peak capacity equipment by the following options:

1. Equipment is staged to include cooling or heating to the space and stages are controlled by an electronically controlled energy management system.
2. A separate cooling or heating system is utilized to provide cooling or heating to the assembly occupancy.
3. A variable speed compressor is utilized to provide incremental cooling or heating to the assembly occupancy.

407.1.ABCD.2 Controls

407.1.ABCD.2.1 Simultaneous Heating and Cooling. Zone thermostatic and humidistatic controls shall be capable of operating in sequence the supply of heating and cooling energy to the zone. Such controls shall prevent:

1. Reheating of spaces and cooling supply air volumes;
2. Recooling of spaces and heating supply air volumes;
3. Mixing or simultaneous supply of air that has been previously mechanically heated and air that has been previously cooled by mechanical refrigeration and
4. Other simultaneous operation of heating and cooling systems to the same zone.

EXCEPTIONS:

a. Variable-air-volume systems that, during periods of occupancy, are designed to reduce the air supply volume to each zone to a minimum before heating, recooling, or mixing takes place. This minimum volume shall be no greater than the larger of: 30% of the peak supply volume; the minimum required to meet minimum ventilation requirements of ASHRAE Standard 62-1989; 0.4 cfm/ft^2 of zone conditioned floor area; or 300 cfm.

b. Zones where special pressurization relationships or cross-contamination requirements are such that variable air volume systems are impractical, such as isolation and operating rooms of hospitals, and laboratories.

c. At least 75% of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered (including heat recovery on water-source heat pumps) or site-solar energy source.

d. Zones where specified humidity levels are required to satisfy process needs, such as computer rooms and museums.

e. Zones with a peak supply air quantity of 300 cfm or less.

f. Systems that are designed and dedicated to condition only the outdoor ventilation air stream to meet the requirements of ASHRAE Standard 62. Such systems shall be controlled so that they do not allow overcooling of the building. Any building utilizing this exception that has a system that requires reheat, other than reclaimed waste heat, shall comply by Method A of this Code.

407.1.ABCD.2.2 TEMPERATURE CONTROLS.

407.1.ABCD.2.2.1 Systems. Each HVAC system shall include at least one temperature control device.

407.1.ABCD.2.2.1.1 Temperature Reset for Air Systems. Air systems supplying heated or cooled air to multiple zones shall include controls which automatically reset supply air temperatures by representative building loads or by outside air temperature. Temperature shall be reset by at least 25% of the design supply-air-to-room-air temperature difference. Zones which are expected to experience relatively constant loads, such as interior zones, shall be designed for the fully reset supply temperature.

EXCEPTIONS:

Systems which comply with section 407.1.ABCD.2.1 without using reheat or mixing of previously conditioned air.

407.1.ABCD.2.2.1.2 Hydronic Systems, Reset Controls. Systems supplying heated and or chilled water to comfort conditioning systems shall include controls which automatically reset supply water temperatures by representative building loads (including return water temperature) or by outside air temperature. Temperature shall be reset by at least 25% of the design supply-to-return water temperature difference.

EXCEPTIONS:

1. Systems for which supply temperature reset controls cannot be implemented without causing improper operation of heating, cooling, humidification or dehumidification systems.

2. Systems with less than 600,000 Btu/h design capacity.

407.1.ABCD.2.2.2 Zones. The supply of heating and cooling energy to each zone shall be controlled by individual thermostatic controls responding to temperature within the zone. For the purposes of this section, a dwelling unit is considered a zone.

EXCEPTION:

Independent perimeter systems that are designed to offset only envelope heat losses or gains or both may serve one or more zones also served by an interior system when the perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one orientation for at least 50 contiguous feet and the perimeter system heating and cooling supply is controlled by thermostat(s) located within the zone(s) served by the system.

407.1.ABCD.2.2.2.1 Where used to control comfort cooling, zone thermostatic controls shall be capable of being set locally or remotely by adjustment or selection of sensors up to 85°F or higher.

407.1.ABCD.2.2.2.2 Where used to control both comfort heating and cooling, zone thermostatic controls shall be capable of providing a temperature range or deadband of at least 5°F within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

EXCEPTIONS:

1. Special occupancy or special usage conditioning approved by the building official.

2. Thermostat controls that require manual changeover between heating & cooling modes.

407.1.ABCD.2.3 Humidity Control. Systems equipped with a means for adding moisture to maintain specific humidity levels in a zone or zones shall have a humidistat provided capable of being set to prevent the use of fossil fuel or electricity to provide relative humidities in excess of 30% for comfort purposes.

Where purchased energy reheat is utilized for comfort dehumidification, the system shall be equipped with a humidistat capable of being set to prevent the use of fossil fuel or electricity to reduce relative humidities below 60%.

407.1.ABCD.2.4 Off-Hour Controls

407.1.ABCD.2.4.1 Automatic Setback or Shutdown Controls. HVAC systems shall be equipped with automatic controls capable of accomplishing a reduction of energy use through control setback or equipment shutdown.

EXCEPTIONS:

1. Systems serving areas expected to operate continuously.
2. Equipment with full-load demands not exceeding 2 kW controlled by readily accessible manual off-hour controls.

407.1.ABCD.2.4.2 Shutoff Dampers. Outdoor air supply and exhaust systems shall be provided with motorized or gravity dampers or other means of automatic volume shutoff or reduction.

EXCEPTIONS:

1. Systems serving areas expected to operate continuously.
2. Individual systems which have a design air flow rate of 3000 cfm or less.
3. Gravity and other non-electrical ventilation systems may be controlled by readily accessible manual damper controls.
4. Where restricted by health and life safety codes.

407.1.ABCD.2.4.3 Zone Isolation. Systems that serve zones which can be expected to operate non-simultaneously for more than 750 hours per year shall include isolation devices and controls to shut off or set back the supply of heating and cooling to each zone independently. Isolation is not required for zones expected to operate continuously or expected to be inoperative only when all other zones are inoperative.

For buildings where occupancy patterns are not known at the time of system design, such as shell buildings, isolation areas may be predesignated.

The grouping of zones on one floor into a single isolation area shall be permitted when the total conditioned floor area does not exceed 25,000 square feet per group.

407.1.ABCD.2.5 Controls Testing. HVAC control systems shall be tested to assure that control elements are calibrated, adjusted, and in proper working condition.

407.1.ABCD.3 EQUIPMENT PERFORMANCE STANDARDS

407.1.ABCD.3.1 Equipment Ratings. Cooling system efficiencies shall be rated as follows:

1. Central air conditioning equipment under 65,000 Btu/h capacity, both split-system and single-package equipment, single- or three-phase, shall be rated with a *Seasonal Energy Efficiency Ratio* (SEER). Three phase units may also be rated with an Integrated Part Load Value (IPLV).

2. Packaged terminal air conditioners and heat pumps shall be rated with an *Energy Efficiency Ratio* (EER).

3. Room air conditioners shall be rated by an *Energy Efficiency Ratio* (EER).

4. Central air conditioning equipment over 65,000 Btu/h shall be rated with an *Energy Efficiency Ratio* (EER).

5. Water-cooled and evaporatively cooled central systems under 135,000 Btu/h shall be rated with an *Energy Efficiency Ratio* (EER).

6. Air-cooled, evaporatively-cooled and water source unitary air conditioning systems over 65,000 Btu/h may also be rated with an *Integrated Part-Load Value* (IPLV).

7. Heat-operated cooling equipment such as gas driven heat pumps shall be rated with a *Coefficient of Performance* (COP)-cooling.

407.1.ABCD.3.1.1 Matched Equipment. Equipment efficiency ratings shall be obtained from a nationally recognized certification program directory or from a manufacturer's rating certified with an approved Department of Energy (DOE) or Air-conditioning and Refrigeration Institute (ARI) rating procedure. Equipment efficiencies shall be based on the Standard Rating Conditions contained in the test standard referenced in Chapter 3 that is appropriate for that equipment. The procedure for determining the Integrated Part-Load Value (IPLV) for a piece of equipment shall be the one provided in the appropriate ARI test standard for the type of equipment referenced. Ratings for products covered under the National Appliance Energy Conservation Act of 1987 shall be those determined for the Federal Trade Commission's required appliance labeling.

407.1.ABCD.3.1.2 Mix-Matched Equipment. Ratings for unitary central air conditioning and heat pump systems less than 65,000 Btu/h, using evaporator/(condenser) coils manufactured by independent companies, shall meet all requirements of either section 407.1.ABCD.3.1.2.1 or 407.1.ABCD.3.1.2.2. Equipment components manufactured by the same company that are not designed and tested for operation together shall also meet these requirements.

407.1.ABCD.3.1.2.1 Companies whose equipment is certified under a nationally recognized certification program or rating procedure where sample units are tested on a regular basis and efficiencies are published in a directory may rate their equipment in accord with the requirements of that program.

407.1.ABCD.3.1.2.2 Companies whose equipment is not certified under a nationally recognized testing and certification program shall publish equipment efficiencies not greater than the efficiency rating of the condensing unit (cooling mode) or outdoor unit (heating mode) manufacturer's most commonly sold condensing unit-evaporator coil or outdoor unit-indoor coil combination.

The evaporator/ (condenser) coil manufacturer shall submit computer simulated equipment efficiency ratings to demonstrate predicted equipment efficiencies. Where simulated efficiencies are less than the condensing unit or outdoor unit manufacturer's most commonly sold combination efficiency, a rating not to exceed the simulated rating shall be used. Published simulated equipment efficiency rating submittals shall identify any enhancement features included to attain claimed ratings.

Computer simulated equipment efficiency ratings submitted shall be based on the condensing unit manufacturer's tested combination (as listed in the current ARI Directory and identified by the model numbers of both the condensing unit and coil or outdoor unit and indoor coil as listed by ARI) and the independent coil manufacturer's evaporator/(condenser) coil performance data. Such simulated ratings shall be certified, signed and dated by a Florida-registered professional engineer, or, for the cases of a secondary original equipment manufacturer (OEM) and a company manufacturing component parts specifically for mix-matched cooling or heating equipment, the president or chairman of the board of the manufacturing company and a professional engineer registered in the state of manufacture, and shall show that the unit, identified by model number, meets the minimum Code requirements. The certification shall attest to the accuracy of the input data, the validity of the calculation procedure utilized and that the results of the simulation are in accordance with the DOE approved methodology. Simulated equipment efficiency rating certifications shall identify any enhancement features included to attain claimed ratings. A full set of input data utilized to arrive at the rating shall be available as documentation on request.

When challenged, computer simulated ratings shall not exceed 105 percent of the SEER, EER, HSPF or COP rating, as appropriate, of the actual tested performance for that condensing unit evaporator coil configuration. Unsubstantiated claims for such equipment shall be dropped from publication.

407.1.ABCD.3.1.3 Field-Assembled Equipment and Components. Air conditioning and heat pump systems with capacities of 65,000 Btu/h or greater where components such as indoor or outdoor coils are used from more than one manufacturer, shall be rated by a calculated total system Energy Efficiency Ratio (EER). Component efficiencies shall be specified based on data provided by the component manufacturers. Calculations documenting how the efficiency rating was derived shall be submitted with the appropriate Code compliance form and shall be signed and sealed by a registered professional engineer.

Total on-site energy input to the equipment shall be determined by combining inputs to all components, elements and accessories, such as compressor(s) internal circulating pump(s), condenser-air fan(s), evaporative-internal circulating pump(s), purge devices, viscosity control heaters, and controls.

407.1.ABCD.3.2 Minimum Efficiencies for Cooling Equipment

407.1.ABCD.3.2.1 Electrically Operated, Cooling Mode. These requirements apply to air-conditioning equipment installed in buildings covered by this code including but not limited to: unitary (central) cooling equipment (air-cooled, water-cooled and evaporatively cooled); the cooling mode of unitary (central) and packaged terminal heat pumps (air source and water source); packaged terminal air conditioners; roof air conditioners; and room air conditioners.

EXCEPTION:

> Existing systems in existing buildings which must comply with this code are exempt from minimum efficiency requirements.

407.1.ABCD.3.2.1.1 HVAC system equipment of less than 65,000 Btu/h, whose energy input in the cooling mode is entirely electric, shall have a Seasonal Energy Efficiency Ratio (SEER), Energy Efficiency Ratio (EER), may have an Integrated Park-Load Value (IPLV), as applicable for that piece of equipment (see section 407.1.ABCD.3.1), of not less than the values shown in Table 4-3.

Table 4-3
Electrically Driven Cooling Equipment
Capacities: <65,000 BTU/H
Minimum Performance Efficiencies[1,2]

Type of Equipment, Capacities, Standard Rating Conditions (°F)	EER	SEER	IPLV[2]
Central Units			
Air-Cooled—Seasonal Rating[3]			
Split-system		10.0	
Single-package		9.7	
Evaporatively Cooled			
Standard Rating (80db/67wb indoor 95db/75wb outdoors)	9.3		
Int. Part Load Value (80db/67wb out)			8.5
Water-Cooled			
Water-Source Heat Pump (80db/67wb indoor)			
Standard Rating (85 entering water)	9.3		
Low Temp. Rating (75 entering)	10.2		
Ground-Water Heat Pump			
Standard Rating (70 entering)	11.0		
Low Temp. Rating (50 entering)	11.5		
Ground Source Heat Pump			
77° Entering brine	10.0		
70° Entering brine	10.4		
Unitary Air Conditioners (80db/67wb indoor)			
Standard Rating (85 entering)	9.3		
Int. Part Load Value (75 entering)			8.3
Packaged Terminal Units (PTAC & PTHP)			
Standard Rating (95db outdoor)			
≤7,000	8.9		
7,001-8,000 Btu/h	8.8		
8,001-9,000 Btu/h	8.6		
9,001-10,000 Btu/h	8.5		
10,001-11,000 Btu/h	8.3		
11,001-12,000 Btu/h	8.2		
12,001-13,000 Btu/h	8.0		
13,001-14,000 Btu/h	7.8		
14,001-15,000 Btu/h	7.7		
>15,000 Btu/h	7.6		
Room Units[3]			
Without reverse cycle			
<6,000 Btu/h	8.0		
6,000-7,999 Btu/h	8.5		
8,000-13,999 Btu/h (with louvers)	9.0		
14,000-20,000 Btu/h (with louvers)	8.8		
20,000 Btu/h (with louvers)	8.2		
8,000-20,000 BTU/H (without louvers)	8.5		
>20,000 Btu/h (without louvers)	8.2		
With reverse cycle (with louvers)	8.5		
With reverse cycle (without louvers)	8.0		

[1] *Test procedures for equipment referenced shall be in accordance with the applicable standard listed in Chapter 3.*

[2] *Products covered by the 1992 Energy Policy act have no efficiency requirements at other than standard rating conditions for products manufactured after 1/1/94.*

[3] *To be consistent with National Appliance Energy Conservation Act of 1987, P.L. 100-12.*

407.1.ABCD.3.2.1.2. HVAC system equipment with capacities between 65,000 Btu/h and 135,000 Btu/h whose energy input in the cooling mode is entirely electric, shall show an Energy Efficiency Ratio (EER) and/or Integrated Part-Load Value (IPLV), as applicable for that piece of equipment (see section 407.1.ABCD.3.1), of not less than values shown in Table 4-4.

Table 4-4
Electrically Driven Cooling Equipment
Capacities: ≥ 65,000 BTU/H <135,000 BTU/H
Minimum Performance Efficiencies

Type of Equipment, Capacities, Standard Rating Conditions (°F)	EER	IPLV[2]
Central Units		
Air-Cooled		
Standard Rating (95db outdoor)	8.9	
Int. Part Load Value (80db outdoor)		8.3
Evaporatively Cooled		
Standard Rating (80db/67wb indoor, 95 db/75 wb outdoor)	10.5	
Int. Part Load Value (80db/67wb outdoor)		9.7
Water-Cooled		
Water-Source Heat Pump (85° entering water)		
Standard Rating (80db/67wb indoor)	10.5	
Groundwater-Cooled Heat Pump[3]		
Standard Rating (70° entering)	11.0	
Low Temperature Rating (50° entering)	11.5	
Ground Source Heat Pumps[3]		
77° Entering brine	10.0	
70° Entering brine	10.4	
Unitary Air-Conditioners (80db/78wb)		
Standard Rating (85° entering)	10.5	

[1] *Reference standards for equipment testing are specified in Chapter 3.*

[2] *Products covered by the 1992 Energy Policy Act have no efficiency requirements at other than standard rating conditions for products manufactured after 1/1/94.*

[3] *Rating for groundwater-cooled, ground source heat pumps applies to all units under 135,000 Btu/h.*

407.1.ABCD.3.2.1.3. HVAC system equipment with capacities equal to or greater than 135,000 Btu/h whose energy input in the cooling mode is entirely electric, shall show an Energy Efficiency Ratio (EER), and/or Integrated Part-Load Value (IPLV), as applicable for that piece of equipment (see section 407.1.ABCD.3.1), of not less than the values shown in Table 4-5.

Table 4-5
Electrically Driven HVAC System Components[1]
Capacity: ≥ 135,000 BTU/H
Minimum Performance Efficiencies

Types of Equipment, Capacities Standard Rating Conditons (F°)	EER	COP	IPLV
Large Unitary Air Conditioners and Heat Pumps			
Air Conditioners[2]			
Air-cooled < 760,000 Btu/h	8.5		7.5
Air-cooled > 760,000 Btu/h	8.2		7.5
Water/evaporative cooled	9.6		9.0
Heat Pumps[2]			
Air-cooled < 760,000 Btu/h	8.5		7.5
Air-cooled> 760,000 Btu/h	8.2		7.5
Condensing Units			
Air-cooled	9.9		11.0
Water/evaporative cooled	12.9		12.9
Water Chilling Packages			
Water-cooled with screw, scroll, or centrifugal compressor			
> 300 tons		5.2[3]	5.3[3]
>150 tons, < 300 tons		4.2	4.5
< 150 tons		3.8	3.9
Water-cooled, with reciprocating compressor		3.8	3.9
Air-cooled with condenser			
> 150 tons		2.5	2.5
< 150 tons		2.7	2.8
Air-cooled, condenserless		3.1	3.2

[1] *When tested to the Standard Rating Conditions contained in the test standard referenced in Chapter 3 that is appropriate for that equipment.*

[2] *Units that have an integral gas, oil or hydronic heating assembly that was not present when the unit efficiency was determined may deduct 0.2 from all required EERs and IPLVs.*

[3] *Where R-22 or CFC refrigerants with ozone depletion factors less than or equal to those for R-22 are used, these requirements are reduced to 4.7 COP and 4.8 IPLV.*

407.1.ABCD.3.2.2 Heat Operated, Cooling Mode. These requirements apply to cooling equipment installed in buildings covered by this code including but not limited to: absorption equipment, engine-driven equipment and turbine-drive equipment.

EXCEPTION:

Existing systems in existing buildings which must comply with this code are exempt from minimum efficiency requirements.

Heat-operated cooling equipment shall show a COP-cooling not less than the values shown in Table 4-6. Electrical auxiliary inputs shall be excluded from the COP-cooling calculation.

407.1.ABCD.3.2.3. Other Air-Conditioning Systems. Air-conditioning systems not identified in Tables 4-3 through 4-6 of this Code shall meet at least the lowest efficiency rating on the appropriate table for that size of equipment.

Table 4-6
Heat-Operated[1] Cooling Equipment
Minimum Performance Efficiencies

Heat Source Minimum	COP[2]
Direct-fired (gas, oil)	0.48
Indirect-fired (steam, hot water)	0.68

[1] *Standard rating conditions at sea level.*

[2] *Minimum COP =* $\frac{\textit{Net Cooling Output}}{\textit{Total Heat Input (electrical auxiliary excluded)}}$

407.1.ABCD.3.3 Condensing Coils Installed in Cool Air Stream of Another Air-Conditioning Unit. The condensing coil of one air-conditioning unit shall not be installed in the cool air stream of another air-conditioning unit.

EXCEPTIONS:

1. Where condenser heat reclaim is used in a properly designed system including enthalpy control devices to achieve requisite humidity control for process, special storage or equipment spaces and occupant comfort within the criteria of Standard ASHRAE Standard 55-92. Such systems shall result in less energy use than other appropriate options.

2. For computer or clean rooms whose location precludes the use of systems which would not reject heat into conditioned spaces.

408 SPACE HEATING EQUIPMENT

408.0 Applicability. This section covers the determination of minimum heating system design requirements and efficiencies. The requirements of this section apply to equipment and mechanical component performance of all heating systems installed in new and renovated buildings including, but not limited to: unitary central heat pumps, either air or water source in the heating mode; water source (hydronic) heat pumps as used in multiple unit hydronic HVAC systems; packaged terminal heat pumps and room air conditioner heat pumps in the heating mode; and all gas- and oil-fired warm air furnaces, boilers and direct heating equipment.

EXCEPTIONS:

> Special applications, including, but not limited to, hospitals, laboratories, thermally sensitive equipment rooms, and computer rooms may be exempted from the requirements of section 407 when approved by the Building Official.

408.1.ABCD Basic Prescriptive Requirements for Methods A, B,C, and D

408.1.ABCD.1 Sizing. Heating equipment and systems shall be sized to provide no more than the space and system loads calculated in accordance with section 407.1.ABCD.1, with exceptions.

408.1.ABCD.2 Controls. Heating equipment and systems shall meet all applicable prescriptive requirements for controls in section 407.1.ABCD.2.

408.1.ABCD.2.1 Where used to control comfort heating, zone thermostatic controls shall be capable of being set locally or remotely by adjustment or selection of sensors down to 55°F or lower.

408.1.ABCD.3 Equipment Performance Standards

408.1.ABCD.3.1 Equipment Ratings. Heating system efficiencies shall be rated as follows:

1. Central electric heat pumps under 65,000 Btu/h capacity, both split-system and single-package equipment, single- or three-phase, shall be rated with a *Heating Seasonal Performance Factor* (HSPF).

2. Packaged terminal heat pumps shall be rated with a *Coefficient of Performance* (COP).

3. Air source heat pumps of 65,000 Btu/h or larger and water-source heat pumps shall be rated with a *Coefficient of Performance* (COP).

4. Gas- and oil-fired warm air furnaces under 225,000 Btu/h and boilers under 300,000 Btu/h shall be rated with an *Annual Fuel Utilization Efficiency* (AFUE).

5. Gas - and oil-fired warm air furnaces and unit heaters of 225,000 Btu/h and over and boilers of 300,000 Btu/h or greater shall be rated with a *steady-state combustion efficiency*, E_t/E_c.

6. Gas- and oil-fired direct heating equipment shall be rated with an *Annual Fuel Utilization Efficiency* (AFUE).

7. Central gas driven heat pumps shall be rated with a Coefficient of Performance (COP).

408.1.ABCD.3.1.1. Matched Equipment. Equipment efficiency ratings shall be obtained from a nationally recognized certification program directory, from a manufacturer's rating certified to be in compliance with an approved Department of Energy (DOE) or an Air-conditioning and Refrigeration Institute (ARI) rating procedure. Equipment efficiencies shall be based on the Standard Rating Conditions contained in the test standard referenced in Chapter 3 that is appropriate for that equipment. Ratings for products covered under the National Appliance Energy Conservation Act of 1987 shall be those determined for the Federal Trade Commission's required appliance labeling.

408.1.ABCD.3.1.2 Mix-Matched Equipment. Ratings for unitary central heat pump systems less than 65,000 Btu/h, using evaporator/ (condenser) coils manufactured by independent companies, shall meet all requirements of either section 407.1.ABCD.3.1.2.1 or 407.1.ABCD.3.1.2.2. Equipment components manufactured by the same company that are not designed and tested for operation together shall also meet these requirements.

408.1.ABCD.3.1.3 Field-Assembled Equipment and Components. Heat pump systems with capacities of 65,000 Btu/h or greater where components such as indoor or outdoor coils are used from more than one manufacturer, shall be rated by a calculated total system Coefficient of Performance (COP). The rate of net heat output used in the COP calculation is the change in the total heat content of the air entering and leaving the equipment, not including supplementary heat. Component efficiencies shall be specified based on data provided by the component manufacturers. Calculations documenting how the overall system efficiency rating was derived shall be submitted with the appropriate Code compliance form and shall be signed and sealed by a registered professional engineer.

Total on-site energy input to the heat pump shall be determined by combining the energy input to all elements, except supplementary heaters, of the heat pump, including, but not limited to, compressor(s), compressor pump heater(s), pump(s), supply-air fan(s), return-air fan(s), outdoor air fan(s), cooling-tower fan(s), and the HVAC system equipment control circuit.

408.1.ABCD.3.2 MINIMUM EFFICIENCIES FOR HEATING EQUIPMENT.

408.1.ABCD.3.2.1 Heat Pump - Heating Mode. These requirements apply, but are not limited to: unitary central electric or gas driven heat pumps, either air or water source in the heating mode; water source (hydronic) heat pumps as used in multiple unit hydronic HVAC systems; and packaged terminal heat pumps and room air-conditioner heat pumps in the heating mode.

408.1.ABCD.3.2.1.1 Minimum Efficiencies. Heat pumps whose energy input is entirely electric shall have a Heating Seasonal Performance Factor (HSPF) or Coefficient of Performance (COP), as applicable (see section 408.1.ABCD.2), in the heating mode of not less than the values shown in Table 4-7.

408.1.ABCD.3.2.1.2 SUPPLEMENTARY HEAT.

408.1.ABCD.3.2.1.2.1 Heat pumps having supplementary heaters shall have controls that prevent heater operation when the heating load can be met by the heat pump. Supplemental heater operation is permitted during outdoor coil defrost cycles not exceeding 15 minutes.

EXCEPTION:

> Heat pumps that incorporate a control system that allows auxiliary electric resistance heat to operate above the balance point are permitted, providing the use of all resistance heat is included in the determination of the HSPF for that heat pump and the HSPF meets the minimum efficiency requirements as shown in Table 4-7.

408.1.ABCD.3.2.1.2.2 Tempering of indoor air during defrost cycles shall be controlled so as to minimize use of supplemental heat.

408.1.ABCD.3.2.1.2.3 Where manual controls are provided for activating the supplementary heat source on an emergency basis an indicator shall be provided to show the control status.

408.1.ABCD.3.2.1.2.4 Supplementary heat on heat pumps that is provided by electric resistance heaters shall meet the following conditions:

1. Supplementary electric resistance heat greater than 10 KW shall be divided into at least two stages and controlled by outdoor thermostats, multi-stage indoor thermostats, or combinations thereof, to operate only when the system's refrigerating capacity plus previous strip heat stages cannot meet the heating load of the building.
2. Supplementary electric resistance heat plus refrigeration cycle heating capacity shall not exceed 120 percent of the design load calculated at the 99 percent design dry bulb temperature.

Table 4-7
Electric Driven Heating Equipment
Heat Pumps
Minimum Performance Efficiencies

Category and Rating Conditions Outdoor Temperatures (° F)		Minimum COP	Minimum HSPF
Electric Heat Pumps			
Packaged Terminal (PTHP)			
Standard Rating (47db/43wb)			
<10,000 Btu/h		2.7	
10,000-13,000 Btu/h		2.6	
>13,000 Btu/h		2.5	
Central Systems			
Air Source			
<65,000 Btu/h- Season Rating[2]			
Split-system			6.8
Single-package			6.6
>65,000 Btu/h			
High Temp. Rating (47db/43wb)		3.0	
Low Temp Rating (17db/15wb)		2.0	
>135,000 Btu/h			
High Temp. Rating (47db/43wb)		2.9	
Low Temp. Rating (17db/15wb)		2.0	
Water Source[3]			
Standard Rating	75°F Entering water	3.9	
	70°F Entering water	3.8	
Ground Source[3]			
	32°F Entering water	2.5	
	41°F Entering water	2.7	
Groundwater Source[3]			
High Temp. Rating	70 °F Entering water	3.4	
Low Temp. Rating	50°F Entering water	3.0	

[1] *Equipment testing reference standards are specified in Chapter 3.*

[2] *To be consistent with the National Appliance Energy Conservation Act of 1987.*

[3] *Ratings for water source, ground source, and ground water source heat pumps apply to all units under 135,000 Btu/h.*

[4] *Products covered by the 1992 Energy Policy Act have no efficiency requirements at other than standard rating conditions for products manufactured after 1/1/94.*

408.1.ABCD.3.2.2 Central Electric Furnaces. Central electric furnaces greater than 10 kW shall be divided into at least two stages and controlled by an outdoor thermostat, multi-stage indoor thermostats or combination thereof.

408.1.ABCD.3.2.3 Combustion Heating Equipment

408.1.ABCD.3.2.3.1 All gas and oil-fired furnaces and boilers (as defined in 10 CFR Part 430) shall have an Annual Fuel Utilization Efficiency (AFUE) or steady-state combustion efficiency E_t, as applicable (see section 408.1.ABCD.3.1.1), of not less than the values shown in Table 4-8.

Table 4-8
Gas- and Oil-Fired Heating Equipment
Rating Conditions and Minimum Performance Efficiencies[1]

Types of Equipment, Rating Conditions	E_t/E_c (%)[2]	AFUE(%)
Warm Air Furnaces		
<225,000 Btu/h[3] (Seasonal Rating)		
Gas-fired		78
Oil-fired		78
≥225,000 Btu/h (Steady-State)		
Gas-fired		
Max. Rating Capacity	80	
Min. Rated Capacity	78	
Oil-fired		
Max. Rated Capacity	81	
Min. Rated Capacity	81	
Warm Air Duct Furnaces		
Gas-fired		
Max. Rated Capacity	78	
Min. Rated Capacity	75	
Unit Heaters		
Gas-fired		
Max. Rated Capacity	78	
Min. Rated Capacity	74	
Oil-fired		
Max. Rated Capacity	81	
Min. Rated Capacity	81	
Boilers		
<300,000 Btu/h (Seasonal Rating)		
Gas-fired except steam boilers		80
Gas-fired steam boilers		75
Oil-fired		80
≥300,000 Btu/h (Steady-State)		
Gas-fired		
Max. Rated Capacity	80	
Min. Rated Capacity	80	
Oil-fired		
Max. Rated Capacity	83	
Min. Rated Capacity	83	
Oil-fired (Residual)		
Max. Rated Capacity	83	
Min. Rated Capacity	83	

1 *Reference standards for equipment testing are specified in Chapter 3.*

2 *Combustion efficiency E_c and thermal efficiency E_t constitute 100 percent minus flue losses in percent of heat input. See the reference standard in Chapter 3 for more information.*

3 *To be consistent with the National Appliance Energy Conservation Act of 1987, Appendix M to Subpart B, 10 CPR Part 430.*

408.1.ABCD.3.2.3.2 All gas-fired direct heating equipment shall have an Annual Fuel Utilization Efficiency (AFUE) of not less than the values shown in Table 4-9.

408.1.ABCD.3.2.4 Other Heating Systems. Heating systems not identified in Tables 4-7 through 4-9 of this Code shall meet at least the lowest efficiency rating on the appropriate table for the size of equipment.

408.1.ABCD.3.2.5 Heating Systems Having Additional Functions. Space heating equipment used to provide additional functions (e.g. service water heating) as part of a combination (integrated) system shall comply with minimum performance requirements for the appropriate space heating equipment category. Service water heating equipment used to provide additional functions (e.g. space heating) as part of a combination (integrated) system shall, as a minimum, meet the minimum performance requirements for water heating equipment in section 412.1.ABCD.

Table 4-9
Gas-Fired Direct Heating Equipment
Minimum Performance Efficiencies

Types of Equipment, BTU/H Heating Capacity	AFUE (%)
Wall	
Fan Type	
Up to 42,000	73
Over 42,000	74
Gravity Type	
Up to 10,000	59
Over 10,000 up to 12,000	60
Over 12,000 up to 15,000	61
Over 15,000 up to 19,000	62
Over 19,000 up to 27,000	63
Over 27,000 up to 46,000	64
Over 46,000	65
Floor	
Up to 37,000	56
Over 37,000	57
Room	
Up to 18,000	57
Over 18,000 up to 20,000	58
Over 20,000 up to 27,000	63
Over 27,000 up to 46,000	64
Over 46,000	65

409 VENTILATION

409.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D.

409.1.ABCD.1 Air Quality. Sources of pollutants within the conditioned space shall be minimized or eliminated, if possible, in order to minimize the outside air intake required for dilution. Concentrated sources shall be controlled at the source by containment, local exhaust systems, or both.

409.1.ABCD.1.1 Ventilation systems shall be designed to be capable of reducing the supply of outdoor air to the minimum ventilation rates required by section 6.1.3 of ASHRAE Standard 62-89. Systems may be designed to supply outside air quantities exceeding minimum levels, but they shall be capable of operating at no more than minimum levels through the use of return ducts, manually or automatically operated control dampers, fan volume controls , or other devices.

EXCEPTION:

Minimum outdoor air quantities may be greater if required to make up air exhausted for source control of contaminants or if required by process systems or local codes.

409.1.ABCD.2 Controls. Each mechanical ventilation system (supply and exhaust) shall be equipped with a readily accessible switch or other means for shut-off or volume reduction and shut-off when ventilation is not required. Automatic or manual dampers installed for the purpose of shutting off ventilation systems shall be designed with tight shut-off characteristics to minimize air leakage.

EXCEPTIONS:

Manual dampers may be used for outdoor air intakes in the following cases:

1. For multifamily residential buildings
2. When the fan system capacity is less than 5000 cfm.

409.1.ABCD.3 Non-residential Kitchen Spaces. Non-residential kitchen space and areas in dining rooms or open malls where a kitchen exhaust hood is required by NFPA 96 shall comply with the following requirements:

1. Be designed with an exhaust air and make up air balance such that the space is never under a positive pressure, and never under a negative pressure exceeding .02" w.g. relative to all indoor spaces surrounding the kitchen space, during all cooking hours.

2. All exhaust and makeup air system components (fans, dampers, etc.) shall be interlocked in such a way that the balance prescribed in #1 above is maintained throughout all cooking hours, and all variations of cooking operations.

410 AIR DISTRIBUTION SYSTEMS

410.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D

410.1.ABCD.0 Zoning

410.1.ABCD.0.1 Zones with special process temperature requirements, humidity requirements, or both, shall be served by air distribution systems separate from those serving zones requiring only comfort conditioning. The central cooling and heating systems for these special process zones shall be separate from the primary cooling and heating systems to allow off-hours control of the primary cooling and heating system specified in section 407.1.ABCD.2.4.

EXCEPTION:

> Zones requiring only comfort heating or comfort cooling that are served by a system primarily used for process temperature and humidity control need not be served by a separate system if the total supply air to these comfort zones is no more than 25% of the total system supply air or the total conditioned floor area of the zones is less than 1000 square feet.

410.1.ABCD.0.2. Zones having substantially different heating or cooling load characteristics, such as perimeter zones in contrast to interior zones, shall not be served by a single multiple zone air distribution system.

410.1.ABCD.0.3. Perimeter zone systems which reheat air provided by interior zone systems for ventilation or other purposes shall utilize heat pumps or other heat reclaim systems for heating at least those air quantities provided by the interior system.

EXCEPTION:

> Climate regions where only morning warm-up is required and controls are provided to limit operation of the resistance heat to mornings not to exceed two hours duration.

410.1.ABCD.1 Sizing and Design Criteria

410.1.ABCD.1.1 Fan System Design. All HVAC fan systems used for any combination of comfort heating, ventilating, or air conditioning shall meet the design criteria of this section. For the purposes of this section, the energy demand of a fan system is the sum of the demand of all fans which are required to operate at design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it back to the source or exhaust it to the outdoors. Fan system energy demand shall not include the additional power required by air treatment or filtering systems with final pressure drops over 1 inch wc.

EXCEPTIONS:

1. Systems with total fan system motor horsepower of 10 hp or less.
2. Unitary equipment for which the energy used by the fan is considered in the efficiency ratings of sections 407.1.ABCD.3.1 and/or 408.1.ABCD.3.1.

410.1.ABCD.1.1.1 Constant Volume Fan Systems. For fan systems which provide a constant air volume whenever the fans are operating, the power required by the motors for the combined fan system at design conditions shall not exceed 0.8 W/cfm of supply air.

410.1.ABCD.1.1.2 Variable Air Volume (VAV) Fan Systems.

410.1.ABCD.1.1.2.1 For fan systems which are able to vary system air volume automatically as a function of load, the power required by the motors for the combined fan system shall not exceed 1.25 W/cfm of supply air at design conditions.

410.1.ABCD.1.1.2.2 Individual VAV fans with motors 75 hp and larger shall include controls and devices necessary for the fan motor to demand no more than 50% of design wattage at 50% of design air volume, based on manufacturer's test data.

410.1.ABCD.1.2 Duct Sizing and Design. Duct systems shall be sized and designed through the use of ASHRAE, ACCA or other nationally recognized design procedure.

410.1.ABCD.2 Air Distribution System Insulation. All air distribution system components which move or contain conditioned air including, but not limited to, air filter enclosures, air ducts and plenums that are located in or on buildings shall be thermally insulated in accordance with the criteria of sections 410.1.ABCD.2.1 through 410.1.ABCD.2.4.

410.1.ABCD.2.1 Insulation Required. The minimum installed thermal resistance for air distribution system components shall be as specified in Table 4-10.

Table 4-10
Minimum Insulation Levels
Air Distribution System Components[1]

Location	R-Value	
Exterior of building	R-8	
Attic with ceiling insulation	R-6	
Dropped ceiling cavity with roof insulation:[1]		
Climate zones 1,2,3	Roof ≥R-16: R-4.2	Roof <R-16: R-6
Climate zones 4,5,6	Roof ≥R-14: R-4.2	Roof <R-14: R-6
Climate zones 7,8,9	Roof ≥R-12: R-4.2	Roof <R-12: R-6
Unconditioned interior spaces	R-4.2	
Conditioned interior spaces	None	

[1] *Roof R-value specified is of the insulation only.*

EXCEPTIONS:

1. Air distribution system components, except air handling units, that are located in enclosed unconditioned space with a Temperature Difference (TD) greater than 40°F shall be insulated to at least R-6. TD is the temperature difference between the space within which the duct is located and the temperature of the air leaving the heating or cooling unit.

2. Air distribution system component insulation (except where required to prevent condensation) is not required in the following cases:

   a Ducts located directly in the heated and/or cooled space.

   b. Exhaust air ducts.

   c. Factory-installed plenums, casings, or ductwork furnished as a part of HVAC equipment tested and rated in accordance with section 407.1.ABCD.3 or 408.1.ABCD.3.

   d. Return air ducts meeting all the requirements of section 410.1.ABCD.3.6 for building cavities which will be used as return air plenums.

410.1.ABCD.2.2 R-Value Determination. All duct insulation and factory-made ducts shall be labeled with R-values based on flat sections of insulation only at installed thickness and excluding any air film resistance. The thermal resistance (R) shall be determined using the relationship R=t/k where t (inches) is the installed thickness and k (Btu-in/hr·ft^2°F) is the measured apparent thermal conductivity at 75°F mean temperature and at installed thickness tested in accordance with ASTM C-518 or ASTM C-177.

The installed thickness of duct insulation used to calculate R-values shall be determined as follows:

1. Duct board, duct liner and factory-made rigid ducts not normally subjected to compression shall use the nominal insulation thickness.

2. Duct wrap shall have an assumed installed thickness of 75% of nominal thickness (25% compression).

3. Factory-made flexible air ducts shall have the installed thickness and calculated R-values determined in accordance with Paragraph 3.4, of the 1996 Edition of The Air Diffusion Council Standard, Flexible Duct Performance & Installation Standards, Third Edition.

410.1.ABCD.2.3 Condensation Control. Additional insulation with vapor barrier shall be provided where the minimum duct insulation requirements of 410.1.ABCD.3.1 are determined to be insufficient to prevent condensation.

410.1.ABCD.2.4 Fibrous Glass Duct Liner. Fibrous glass duct liner shall be fabricated and installed in accordance with the provisions of the NAIMA Fibrous Glass Duct Liner Standard, 1994.

410.1.ABCD.3 Air Distribution System Construction and Installation. Ducts shall be constructed, braced, reinforced and installed to provide structural strength and durability. All transverse joints, longitudinal seams and fitting connections shall be securely fastened and sealed in accordance with the applicable standards of this section.

As an alternative to compliance with specific criteria of sections 410.1.ABCD.3.0.4 through 410.1.ABCD.3.2.1, 410.1.ABCD.3.3.1 through 410.1.ABCD.3.3.2, and 410.1.ABCD.3.3.6, air ducts and duct systems complying with the applicable requirements of the following standards shall be deemed as meeting the intent of this Code. Where these standards do not address the specific closure details of the Code, in the manner required by the subsequent sections of this Code, the requirements of the Code shall govern.

1. SMACNA HVAC Duct Construction Standards, Metal and Flexible.

2. NAIMA Fibrous Glass Duct Construction Standards.

3. ADC Flexible Duct Performance and Installation Standards.

4. ASHRAE Handbook - HVAC Systems and Equipment.

5. UL 181.

6. UL181A: Part I; Part II; Part III.

7. UL 181B: Part I; Part II.

410.1.ABCD.3.0 General. All enclosures which form the primary air containment passageways for air distribution systems shall be considered ducts or plenum chambers and shall be constructed and sealed in accordance with the applicable criteria of this section.

410.1.ABCD.3.0.1 Mechanical Fastening. All joints between sections of air ducts and plenums, between intermediate and terminal fittings and other components of the air distribution system, and between subsections of these components shall be mechanically fastened to secure the sections independently of the closure system(s).

410.1.ABCD.3.0.2 Sealing. Air distribution system components shall be sealed to 100 percent closure with approved closure systems.

410.1.ABCD.3.0.3 Space Provided. Sufficient space shall be provided adjacent to all mechanical components located in or forming a part of the air distribution system to assure adequate access for 1) construction and sealing in accordance with the requirements of section 410.1.ABCD.3 of this Code, 2) inspection and 3) cleaning and maintenance. A minimum of 4" is considered sufficient space around air handling units.

410.1.ABCD.3.0.4 Product Application. Closure products shall be applied to the air barriers of air distribution system components being joined in order to form a continuous barrier or they may be applied in accordance with the manufacturer's instructions or appropriate industry installation standard where more restrictive.

410.1.ABCD.3.0.5 Surface Preparation. The surfaces upon which closure products are to be applied shall be clean and dry in accordance with the manufacturer's installation instructions.

410.1.ABCD.3.0.6 Approved Mechanical Attachments. Approved mechanical attachments for air distribution system components include screws, rivets, welds, inter-locking joints crimped and rolled, staples, twist in (screw attachment), and compression systems created by bend tabs or screws tabs and flanges or by clinching straps. Mechanical attachments shall be selected to be appropriate to the duct system type.

410.1.ABCD.3.0.7 Approved Closure Systems. The following closure systems and materials are approved for air distribution construction and sealing for the applications and pressure classes prescribed in sections 410.1.ABCD.3.1 through 410.1.ABCD.3.8:

1. Metal Closures.

   a. Welds applied continuously along metal seams or joints through which air could leak.

   b. Longitudinal grooved metal seams and snaplock seams that are rolled and crimped by the manufacturer.

2. Gasketing material placed between mated surfaces which are mechanically fastened with sufficient force to compress the gasket and to fill all voids and cracks through which air leakage would otherwise occur.

3. Mastics Closures. Mastics shall be placed over the entire joint between mated surfaces. Mastics shall not be diluted. Approved mastics include the following:

   a. Mastic or mastic-plus-embedded fabric systems applied to fibrous glass ductboard that are listed and labeled in accordance with UL 181A, Part III.

   b. Mastic or mastic-plus-embedded fabric systems applied to non-metal flexible duct that are listed and labeled in accordance with UL 181B, Part II.

4. Tapes. Tapes shall be applied such that they extend not less than 1 inch onto each of the mated surfaces and shall totally cover the joint. When used on rectangular ducts, tapes shall be used only on joints between parallel rigid surfaces and on right angle joints. Approved tapes include the following:

   a. Pressure-sensitive tapes.

      1) Pressure-sensitive tapes applied to fibrous glass ductboard that are listed and labeled in accordance with UL 181A, Part I.

      2) Pressure-sensitive tapes applied to non-metal flexible duct that are listed and labeled in accordance with UL 181B, Part I

   b. Heat-activated tapes applied to fibrous glass ductboard that are listed and labeled in accordance with UL 181A, Part II.

410.1.ABCD.3.1 Metal Duct, Rigid and Flexible. All transverse joints, longitudinal seams and duct wall penetration of ducts and joints with other air distribution system components shall be mechanically attached and sealed to 100 percent closure using approved closure systems for that pressure class as specified in section 410.1.ABCD.3.1.1 or section 410.1.ABCD.3.1.2.

410.1.ABCD.3.1.1 Pressures Less Than 1 Inch Water Gauge, Approved Closure Systems. The following closure systems are approved for rigid metal duct designed to be operated at pressures less than 1" w.g. when they conform to the approved closure and mechanical attachment requirements of section 410.1.ABCD.3.0:

1. Continuous welds.
2. Longitudinal grooved seams, Pittsburgh lock and snaplock seams.
3. Mastic or mastic-plus-embedded fabric systems.
4. Gaskets.
5. Pressure-sensitive tape.

410.1.ABCD.3.1.2 Pressures 1 Inch Water Gauge or Greater, Approved Closure Systems. The following closure systems are approved for rigid metal duct designed to be operated at pressures 1" w.g. or greater when they conform to the approved closure and mechanical attachment requirements of section 410.1.ABCD.3.0:

1. Continuous welds.
2. Mastic or mastic-plus-embedded fabric systems.
3. Gaskets.

410.1.ABCD.3.1.3 High Pressure Duct Systems. High pressure duct systems designed to operate at pressures greater than 3 inches water gauge (4 inches water gauge pressure class), shall be tested in accordance with the SMACNA HVAC Air Duct Leakage Test Manual. The tested duct leakage class, at a test pressure equal to the design duct pressure class rating, shall be equal to or less than Leakage Class 6. Leakage testing may be limited to representative sections of the duct system but in no case shall such tested sections include less than 25 percent of the total installed duct area for the designated pressure class.

410.1.ABCD.3.2 Fibrous Glass Duct, Rigid. All rigid fibrous glass ducts and plenums shall be constructed and erected in accordance with the provisions of the NAIMA Fibrous Glass Duct Construction Standards, 1993.

All joints, seams and duct wall penetrations including, but not limited to, the joints between sections of duct and the joints between duct and other distribution system components shall be mechanically attached and sealed to 100 percent closure using approved closure systems as specified in section 410.1.ABCD.3.2.1.

410.1.ABCD.3.2.1 Approved Closure Systems. The following closure systems are approved for rigid fibrous glass duct when they meet the approved closure and mechanical attachment requirements of section 410.1.ABCD.3.0:

1. Heat-activated tapes.
2. Pressure-sensitive tapes.
3. Mastics or mastic-plus-embedded fabric systems.

410.1.ABCD.3.3. Flexible Duct Systems, Non-Metal. Flexible non-metal ducts shall be joined to all other air distribution system components by either terminal or intermediate fittings. All duct collar fittings shall have a minimum 5/8 inch integral flange for sealing to other component and a minimum 3 inch shaft for insertion into the inner duct core.

Flexible ducts having porous inner cores shall not be used.

EXCEPTION:

> Ducts having a non-porous liner between the porous inner core and the outer jacket. Fastening and sealing requirements shall be applied to such intermediate liners.

All joints of flexible ducts to fittings and fittings to other air distribution system components shall be mechanically attached and sealed as specified in sections 410.1.ABCD.3.3.1 through 410.1.ABCD.3.3.6.

410.1.ABCD.3.3.1 Duct Core to Duct Fitting, Mechanical Attachment. The reinforced core shall be mechanically attached to the duct fitting by a drawband installed directly over the wire-reinforced core and the duct fitting. The duct fitting shall extend a minimum of 2 inches into each section of duct core. When the flexible duct is larger than 12 inches in diameter or the design pressure exceeds 1 inch water gauge, the drawband shall be secured by a raised bead or indented groove on the fitting.

410.1.ABCD.3.3.2 Duct Core to Duct Fitting, Approved Closure Systems. The reinforced core shall be sealed to the duct fitting using one of the following sealing materials which conforms to the approved closure and mechanical attachment requirements of section 410.1.ABCD.3.0:

1. Gasketing.
2. Mastic or mastic-plus-embedded fabric systems.
3. Pressure-sensitive tape.

410.1.ABCD.3.3.3 Duct Outer Jacket to Duct Collar Fitting. The outer jacket of a flexible duct section shall be secured at the juncture of the air distribution system component and intermediate or terminal fitting in such a way as to prevent excess condensation. The outer jacket of a flexible duct section shall not be interposed between the flange of the duct collar fitting and the flexible duct, rigid fibrous glass duct board, or sheet metal to which it is mated.

410.1.ABCD.3.3.4 Duct Collar Fittings to Rigid Duct, Mechanical Attachment. The duct collar fitting shall be mechanically attached to the rigid duct board or sheet metal by appropriate mechanical fasteners, either screws, spin-in flanges, or dovetail flanges.

410.1.ABCD.3.3.5 Duct Collar Fitting to Rigid Duct, Approved Closure Systems. The duct collar fitting's integral flange shall be sealed to the rigid duct board or sheet metal using one of the following closure systems/materials which conforms to the approved closure and mechanical attachment standards of 410.1.ABCD.3.0:

1. Gasketing.
2. Mastic or mastic-plus-embedded fabric.
3. Pressure-sensitive tape.

410.1.ABCD.3.3.6 Flexible Duct Installation and Support. Flexible ducts shall be configured and supported so as to prevent the use of excess duct material, prevent duct dislocation or damage, and prevent constriction of the duct below the rated duct diameter in accordance with the following requirements:

1. Ducts shall be installed fully extended. The total extended length of duct material shall not exceed 5 percent of the minimum required length for that run.
2. Bends shall maintain a center line radius of not less than one duct diameter.
3. Terminal devices shall be supported independently of the flexible duct.
4. Horizontal duct shall be supported at intervals not greater than 5 feet. Duct sag between supports shall not exceed ½ inch per foot of length. Supports shall be provided within 1.5 feet of intermediate fittings and between intermediate fittings and bends. Ceiling joists and rigid duct or equipment may be considered to be supports.
5. Vertical duct shall be stabilized with support straps at intervals not greater than 6 feet.
6. Hangers, saddles and other supports shall meet the duct manufacturer's recommendations and shall be of sufficient width to prevent restriction of the internal duct diameter. In no case shall the material supporting flexible duct that is in direct contact with it be less than 1-½ inch.

410.1.ABCD.3.4 Terminal and Intermediate Fittings. All seams and joints in terminal and intermediate fittings, between fitting subsections and between fittings and other air distribution system components or building components shall be mechanically attached and sealed to 100 % closure using approved closure systems for that joining application as specified in section 410.1.ABCD.3.4.1 or sec. 410.1.ABCD.3.4.2.

410.1.ABCD.3.4.1 Fittings and Joints Between Dissimilar Duct Types, Approved Closure Systems. Approved closure systems shall be as designated by air distribution system component material type in section 410.1.ABCD.3.

EXCEPTION:

When the components of a joint are fibrous glass duct board and metal duct, including collar fittings and metal equipment housings, the closure systems approved for fibrous glass duct shall be used.

410.1.ABCD.3.4.2 Terminal Fittings and Air Ducts to Building Envelope Components, Approved Closure Systems. Terminal fittings and air ducts which penetrate the building envelope shall be mechanically attached to the structure and sealed to the envelope component penetrated and shall use one of the following closure systems/materials which conform to the approved closure and mechanical application requirements of section 410.1.ABCD.3.0:

1. Mastics or mastic-plus-embedded fabrics.
2. Gaskets used in terminal fitting/grille assemblies which compress the gasket material between the fitting and the wall, ceiling or floor sheathing.

410.1.ABCD.3.5 Air Handling Units. All air handling units shall be mechanically attached to other air distribution system components. Air handling units located outside the conditioned space shall be sealed to 100 percent closure using approved closure systems conforming to the approved closure and mechanical application requirements of section 410.1.ABCD.3.1.

410.1.ABCD.3.5.1 Approved Closure Systems. Systems conforming to the product and application standards of section 410.1.ABCD.3.0 may be used when sealing air handling units.

410.1.ABCD.3.6 Cavities of the Building Structure. Cavities in framed spaces, such as dropped soffits and walls, shall not be used to deliver air from or return air to the conditioning system unless they contain an air duct insert which is insulated in accordance with section 410.1.ABCD.2 and constructed and sealed in accordance with the requirements of section 410.1.ABCD.3 appropriate for the duct materials used.

EXCEPTION:

Return air plenums.

Cavities designed for air transport such as mechanical closets, chases, air shafts, etc. shall be lined with an air barrier and sealed in accordance with section 410.1.ABCD.3.7 and shall be insulated in accordance with section 410.1.ABCD.2.

Building cavities which will be used as return air plenums shall be lined with a continuous air barrier made of durable non-porous materials. All penetrations to the air barrier shall be sealed with a suitable long-life mastic material.

EXCEPTION:

> Surfaces between the plenum and conditioned spaces from which the return/mixed air is drawn.

Building cavities beneath a roof deck that will be used as return air plenums shall have an insulated roof with insulation having an R-value of at least R-19.

410.1.ABCD.3.7 Mechanical Closets. The interior surfaces of mechanical closets shall be sheathed with a continuous air barrier as specified in section 410.1.ABCD.3.7.1 and shall be sealed to 100 percent closure with approved closure systems as specified in section 410.1.ABCD.3.7.2. All joints shall be sealed between air barrier segments and between the air barriers of walls and those of the ceiling, floor and door framing. All penetrations of the air barrier including but not limited to those by air ducts, service lines, refrigerant lines, electrical wiring, and condensate drain lines shall be sealed to the air barrier with approved closure systems.

EXCEPTION:

> Air passageways into the closet from conditioned space that are specifically designed for return air flow.

Through-wall, through-floor and through-ceiling air passageways into the closet shall be framed and sealed to form an airtight passageway using approved air duct materials and approved closure systems.

Duct penetrations through any part of the ceiling, walls or floor of a mechanical closet shall have sufficient space between surrounding ceiling, walls or floor and any duct or plenum penetration to allow for sealing of the penetration and inspection of the seal.

Clothes washers, clothes dryers, combustion water heaters and atmospheric combustion furnaces shall not be located in mechanical closets used as return air plenums.

410.1.ABCD.3.7.1 Approved Air Barriers. The following air barriers are approved for use in mechanical closets:

1. One-half inch thick or greater gypsum wallboard;

2. Other panelized materials having inward facing surfaces with an air porosity no greater than that of a duct product meeting section 22 of UL 181 which are sealed on all interior surfaces to create a continuous air barrier.

410.1.ABCD.3.7.2 Approved Closure Systems. The following closure systems are approved for use in mechanical closets:

1. Gypsum wallboard joint compound over taped joints between gypsum wallboard panels.

2. Sealants complying with the product and application standards of section 410.1.ABCD.3.2.1 for fibrous glass ductboard;

3. A suitable long-life caulk or mastic compliant with the locally adopted mechanical code for all applications.

410.1.ABCD.3.8 Enclosed Support Platforms. Enclosed support platforms located between the return air inlet(s) from conditioned space and the inlet of the air handling unit or furnace, shall contain a duct section constructed entirely of rigid metal, rigid fibrous glass duct board, or flexible duct which is constructed and sealed according to the respective requirements of section 410.1.ABCD.3 and insulated according to the requirements of section 410.1.ABCD.2.

The duct section shall be designed and constructed so that no portion of the building structure, including adjoining walls, floors and ceilings, shall be in contact with the return air stream or function as a component of this duct section.

The duct section shall not be penetrated by a refrigerant line chase, refrigerant line, wiring, pipe or any object other than a component of the air distribution system.

Through-wall, through-floor and through-ceiling air passageways into the duct section shall contain a branch duct which is fabricated of rigid fibrous glass duct board or rigid metal and which extends to and is sealed to both the duct section and the grille side wall surface. The branch duct shall be fabricated and attached to the duct insert in accordance with section 410.1.ABCD.3.2 or section 410.1.ABCD.3.1 for the duct type used.

410.1.ABCD.4 Testing, Adjusting, and Balancing. Air distribution systems shall be tested, adjusted, and balanced by a company or individual holding a current certification from a recognized testing and balancing agency or comparable certification approved by the authority having jurisdiction.

EXCEPTIONS:

1. Buildings with cooling or heating system capacities of 15 tons or less per system may be tested and balanced by a mechanical contractor licensed to design and install such system(s).

2. Buildings with cooling or heating system capacities of 65,000 Btu/h or less per system are exempt from the requirements of this section.

IMPORTANT NOTES:

1. Building envelope pressurization should be either neutral or positive to prevent infiltration of excess latent load.

2. Commercial kitchen hood exhaust cfm should be sized to prevent significant depressurization.

410.1.ABCD.4.1 Air system balancing shall be accomplished in a manner to first minimize throttling losses, then fan speed shall be adjusted to meet design flow conditions. Balancing procedures shall be in accordance with the National Environmental Balancing Bureau (NEBB) Procedural Standards (1991), the Associated Air Balance Council (AABC) National Standards (1989), or equivalent procedures.

EXCEPTION:

Damper throttling may be used for air system balancing with fan motors of 1 hp or less, or if throttling results in no greater than 1/3 hp fan horsepower draw above that required if the fan speed were adjusted.

411 PUMPS AND PIPING

411.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D.

411.1.ABCD.1 Pumping System Design Criteria.

411.1.ABCD.1.1 General. The following design criteria apply to all HVAC pumping systems used for comfort heating, comfort air conditioning, or both. For the purposes of this section, the energy demand of a pumping system is the sum of the demand of all pumps which are required to operate at design conditions to supply fluid from the heating or cooling source to the conditioned space(s) or heat transfer devices(s) and return it back to the source.

EXCEPTION:

Systems with total pump system motor horsepower of 10 hp or less.

411.1.ABCD.1.2 Friction Rate. Piping systems shall be designed at a friction pressure loss rate of not more than 4.0 feet of water per 100 equivalent feet of pipe.

NOTE: Lower friction rates may be required for proper noise or corrosion control.

411.1.ABCD.1.3 Variable Flow. HVAC pumping systems used for comfort heating and/or comfort air conditioning that serve control valves designed to modulate or step open and closed as a function of load shall be designed for variable fluid flow and capable of reducing system flow to 50% of design flow or less.

EXCEPTIONS:

1. Systems where a minimum flow greater than 50% of the design flow is required for the proper operation of equipment served by the system, such as chillers.
2. Systems that serve no more than one control valve.
3. Systems with a total pump system horse power < 10 hp.
4. Systems that include supply temperature reset controls in accordance with section 407.1.ABCD.2.2.1.1, without exception.

411.1.ABCD.2 Piping Insulation. All HVAC system piping, including the vapor line of HVAC refrigerant piping, shall be thermally insulated in accordance with Table 4-11.

Table 4-11
Minimum Pipe Insulation (in.)[1]

Type of System	Fluid Design Operating Temperature	Insulation Conductivity		Nominal Pipe Diameter				
	Range,°F	Conductivity Range Btu·in/(h·ft³·°F)	Mean Temperature Rating	Run-outs[2] Up to 2	1 and Less	1-¼ to 2	2-½ to 4	5 to 6
Heating Systems (Steam, Steam Condensate, and Water)	> 350	0.32-0.34	250	1.5	2.5	2.5	3.0	3.5
	251-350	0.29-0.31	200	1.5	2.0	2.5	2.5	3.5
	201-250	0.27-0.30	150	1.0	1.5	1.5	2.0	2.0
	141-200	0.25-0.29	125	0.5	1.5	1.5	1.5	1.5
	105-140	0.24-0.28	100	0.5	1.0	1.0	1.0	1.5
Domestic and Service Hot Water Systems[3]	≥105	0.24-0.28	100	0.5	1.0	1.0	1.5	1.5
Cooling Systems (Chilled Water, Brine, and Refrigerant)[4]	40-55	0.23-0.27	75	0.5	0.5	0.75	1.0	1.0
	< 40	0.23-0.27	75	1.0	1.0	1.5	1.5	1.5

[1] *For insulation outside the stated conductivity range, the minimum thickness shall be determined in accordance with Equation 4-2 in section 1.1.ABCD.2.1*

[2] *Runouts to individual terminal units not exceeding 12' in length.*

[3] *Applies to circulating sections of service or domestic hot water systems and first 8' from storage thank for non-circulation systems.*

[4] *The required minimum thickness does not consider water vapor transmission and condensation. Additional insulation, vapor retarders, or both, may be required to limit water vapor transmission and condensation.*

EXCEPTIONS:

1 Factory-installed piping within HVAC equipment tested and rated in accordance with 407.1.ABCD.3 and 408.1.ABCD.3.

2. Piping that conveys fluids which have a design operating temperature range between 55°F and 105°F.

3. Piping that conveys fluids which have not been heated or cooled through the use of fossil fuels or electricity.

411.1.ABCD.2.1 Alternative Insulation Types. Insulation thicknesses in Table 4-11 are based on insulation with thermal conductivities within the range listed for each fluid operating temperature range, rated in accordance with ASTM C 335-89 at the mean temperature listed in the table. For insulation that has a conductivity outside the range shown in Table 4-11 for the applicable fluid operating temperature range at the mean rating temperature shown (when rounded to the nearest 0.01 Btu·in./(h·°F·ft²), the minimum thicknesses shall be determined in accordance with Equation 4-2:

EQUATION 4-2

$$T = PR\,[(1 + t/PR)^{K/k} - 1]$$

Where:

T	=	Minimum insulation thickness for material with conductivity K, in.
PR	=	Pipe actual outside radius, in.
t	=	Insulation thickness from Table 4-11, in.
K	=	Conductivity of alternate material at the mean rating temperature indicated in Table 4-11 for the applicable fluid temperature range, Btu·in/(h·ft²·°F)
k	=	The lower value of the conductivity range listed in Table 4-11 for the applicable fluid temperature range, Btu·in/(h·ft²·°F)

411.1.ABCD.4 Hydronic System Testing, Adjusting, and Balancing. Hydronic systems shall be tested, adjusted and balanced by a company holding a current certification from a nationally recognized testing and balancing organization.

Hydronic systems shall be balanced by adjusting pump speed or by trimming the impeller to meet design flow requirements. Valve throttling alone may be used for final balancing in the following cases:

1. For pumps with pump motors of 10 hp or less.

2. If valve throttling results in no greater than 3 hp pump horsepower draw above that required if the impeller were trimmed.

3. To reserve additional pump pressure capability in open circuit piping systems subject to fouling. Valve throttling pressure drop shall not exceed that expected for future fouling.

412 WATER HEATING SYSTEMS

412.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D

412.1.ABCD.1 Water Heater Sizing and Design. Service water heating system design loads for the purpose of sizing and selecting systems shall be determined in accordance with the procedures described in Chapter 45 of ASHRAE Handbook, 1995 HVAC Applications, or a similar computation procedure.

412.1.ABCD.2 Controls.

412.1.ABCD.2.1 Storage Water Heaters

412.1.ABCD.2.1.1 Temperature Controls. Service water heating systems shall be equipped with automatic temperature controls capable of adjusting storage temperatures from at least 90° F to a temperature setting compatible with the intended use. The temperature setting range shall be in accordance with Table 3 in Chapter 45 of the ASHRAE Handbook, 1995 HVAC Applications.

EXCEPTION:

> Service water heating systems serving residential dwelling units may be equipped with controls capable of adjustment down to 110°F only.

Where temperatures higher than 120°F are required at certain outlets for a particular intended use, separate remote heaters or booster heaters shall be installed for those outlets.

412.1.ABCD.2.1.2 Shut Down Switch/Valve. A separate switch or a clearly marked circuit breaker shall be provided to permit the power supplied to electric service systems to be turned off. A separate valve shall be provided to permit the energy supplied to the main burner(s) of combustion types of service water heating systems to be turned off.

412.1.ABCD.2.1.3 Heat Traps. Storage water heaters not equipped with integral heat traps and having vertical pipe risers shall be installed with insulated heat traps on both the inlet and outlets. The heat trap shall be installed directly or as close as possible to the outlet fittings.

EXCEPTION:

> Water heaters that are used to supply circulating systems. These systems shall comply with section 412.1.ABCD.3.2.

412.1.ABCD.2.2 Circulating Hot Water Systems and Heated Pipes. Systems designed to maintain usage temperatures in hot water pipes, such as circulating hot water systems, shall be equipped with automatic time switches or other controls that can be set to turn OFF the system when use of hot water is not required.

412.1.ABCD.2.3 Water Flow Rate Controls.

412.1.ABCD.2.3.1 Showers. Showers used for other than safety reasons shall be equipped with flow control devices to limit the water discharge to a maximum of 2.5 gpm per shower head at a distribution pressure of 80 psig when tested in accordance with the procedures of ANSI A112.18.1M-1989. Flow restricting inserts used as a component part of a showerhead shall be mechanically retained at the point of manufacture.

412.1.ABCD.2.3.2 Lavatories or Restrooms of Public Facilities. Lavatories or restrooms of public facilities shall:

1. Be equipped with outlet devices which limit the flow of hot water to a maximum of 0.5 gpm or be equipped with self-closing valves that limit delivery to a per cycle maximum of 0.25 gallons of hot water for recirculating systems and to a maximum of 0.50 gallons for non-recirculating systems.

   EXCEPTION:

   Separate lavatories for physically handicapped persons shall not be equipped with self-closing valves.

2. Be equipped with devices which limit the outlet temperature to a maximum of 110°F.

3. Meet the provisions of 42 CFR 6295 (k), Standards for Water Closets and Urinals.

412.1.ABCD.2.4 Swimming Pool and Spa Temperature Controls

412.1.ABCD.2.4.1 On-Off Switch Required. All pool and spa heaters shall be equipped with an ON-OFF switch mounted for easy access to allow the heater to be shut off without adjusting the thermostat setting and to allow restarting without relighting the pilot light.

412.1.ABCD.2.4.2 Covers Required. Spas and heated swimming pools shall be equipped with a cover designed to minimize heat loss.

EXCEPTION:

Outdoor pools deriving over 70 percent of the energy for heating (computed over an annual operating season) from site-recovered or site-solar energy.

412.1.ABCD.2.4.3 Time Switches on Private Pools. Time switches shall be installed on all swimming pool pumps and all electric swimming pool heaters. These switches shall allow for the shutdown of heating devices during hours of peak utility demand and for the minimum peak period operation of pumps necessary to maintain water in a clear and sanitary condition in keeping with applicable public health standards.

EXCEPTIONS:

1. Where public health standards require 24 hour operation of pumps.

2. Pumps required to operate solar or waste heat recovery pool heating systems.

412.1.ABCD.3 Equipment Performance Standards

412.1.ABCD.3.1 Electric Water Heater Efficiencies.

412.1.ABCD.3.1.1 Storage Capacities Of 120 Gallons Or Less. All automatic electric storage water heaters having a storage capacity of 120 gallons or less and an input rating of 12 kw or less shall, when tested in accordance with the DOE Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Appendix E to Subpart B, 10 CFR Part 430, meet the performance minimums listed in Table 4-12.

Table 4-12
Minimum Performance Standards
Water Heating Equipment: Fired Storage Water Heaters
Minimum Energy Factors (EF)

Type/ Volume	Tank Volume (Gallons)								
	20	30	40	50	65	75	80	100	120
Electric: Up to 120 gal or 12kW input	.90	.89	.88	.86	.84	—	.82	.80	.77
Gas: Up to 100 gal or 75,000 Btu/h input	.58	.56	.54	.52	.50	.48	—	.43	—
Oil: Up to 50 gal or 75,000 Btu/h input	—	.53	.51	.50	—	—	—	—	—

412.1.ABCD.3.1.2 Storage Capacities Greater Than 120 Gallons. Performance minimums for electric storage water heaters with capacities greater than 120 gallons or an input rate greater than 12 KW shall have a standby loss of $.30+27/V_T$ percent/hour or less, where V_T is the tested storage volume in gallons.

412.1.ABCD.3.2 Gas- and Oil-fired Water Heater Efficiencies.

412.1.ABCD.3.2.1 Tanks With Input Ratings Of 75,000 Btu/h or Less (Gas) or 105,000 Btu/h or Less (Oil). All gas- and oil-fired automatic storage water heaters with capacities of 100 gallons or less and an input rating of 75,000 Btu/h or less (gas) or 105,000 Btu/h or less (oil) shall, when tested in accordance with the DOE Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Appendix E to Subpart B, 10 CFR Part 430, meet the performance minimums listed in Table 4-12.

412.1.ABCD.3.2.2 Tanks With Input Ratings Greater Than 75,000 Btu/h (Gas) or Greater Than 105,000 Btu/h (Oil). All gas-fired storage water heaters with input ratings greater than 75,000 Btu/h but less than or equal to 155,000 Btu/h, and all oil-fired storage water heaters with input ratings greater than 105,000 Btu/h but less than or equal to 155,000 Btu/h shall have a steady state combustion efficiency E_t of .78 or more and a standby loss of $1.30+114/V_T$ (in percent/hour) or less, where V_T is the tested storage volume in gallons.

All gas- and oil-fired storage water heaters with input ratings greater than 155,000 Btu/h shall have a steady-state combustion efficiency, E_t, of .78 or more and a standby loss of no more than $1.30+95/V_T$, where V_T is the tested storage volume in gallons.

412.1.ABCD.3.3 Unfired Storage Tanks. All unfired storage tanks shall have a standby loss of 6.5 Btu/h/ft^2 or less, based on an 80° water-air temperature difference.

412.1.ABCD.3.4 Combination Service Water Heating and Space Heating Equipment. Combination space and service water heating equipment may only be used when at least one of the following conditions is met:

1. The annual space heating energy is less than 50% of the annual service water heating energy.
2. The energy input or storage volume of the combined boiler or water heater is less than twice the energy input or storage volume of the smaller of the separate boilers or water heaters otherwise required.
3. Where the input to the combined boiler is less than 150,000 Btu/h.

412.1.ABCD.3.4.1 Service water heating equipment used to provide additional functions (e.g. space heating) as part of a combination (integrated) system shall comply with minimum performance requirements for water heating equipment.

412.1.ABCD.3.4.2 Combination water and space heating systems with input ratings of less than 105,000 Btu/h shall utilize a water heater listed by the Gas Appliance Manufacturer's Association (GAMA). Changeouts of burners to increase capacity shall not be made unless the unit has been listed at that capacity by GAMA.

412.1.ABCD.3.5 Pool and Spa Heaters. All gas- and oil-fired pool heaters when tested in accordance with ANSI Z21.56-1989 shall have a minimum thermal efficiency of 78 percent.

412.1.ABCD.4 Hot Water Piping Insulation.

412.1.ABCD.4.1 Circulating Systems. Piping insulation shall conform to the requirements of Table 4-11 in section 411.1.ABCD.2.

412.1.ABCD.4.2 Non-circulating Systems. The first 8 feet of outlet piping from a storage system that is maintained at a constant temperature and the inlet pipe between the storage tank and a heat trap shall be insulated as provided in Table 4-11, section 411.1.ABCD.2. Systems without a heat trap to prevent circulation due to natural convection shall be considered circulating systems and shall be insulated accordingly.

413 ELECTRIC POWER DISTRIBUTION

413.0 Applicability. This section applies to all building electrical systems except required emergency systems. The provisions for electrical distribution for all sections of this Code are subject to the applicable Florida Public Service Commission rules regarding electric utilities set forth in Chapter 25-6, Florida Administrative Code, and the design conditions in ASHRAE Standard 90.1-1989.

413.1.ABCD Basic Prescriptive Requirements for Methods A, B , C and D.

413.1.ABCD.1 Metering. Single-tenant buildings with a service over 250 kva and tenant spaces with a connected load over 100 kva in multiple tenant buildings shall have provisions for check metering of electrical consumption.

413.1.ABCD.1.1 The electrical power feeders for which provision for check-metering is required shall be divided as follows:

1. Lighting and receptacle outlets;
2. HVAC systems and equipment;
3. Service water heating, elevators, and special-occupant equipment or systems of more than 20 KW.

EXCEPTION:

10% or less of the loads on a feeder may be from another usage category.

413.1.ABCD.1.2 Tenant-shared HVAC and service hot water systems in multiple tenant buildings shall have provision to be separately check metered.

413.1.ABCD.1.3 Subdivided feeders shall contain provisions for portable or permanent check metering.

413.1.ABCD.1.4 The minimum acceptable arrangement for compliance with section 413.1.ABCD.1 shall provide a safe method for access by qualified persons to the enclosures through which feeder conductors pass and provide sufficient space to attach clamp-on or split-core current transformers. These enclosures may be separate compartments or combined spaces with electrical cabinets serving another function. Dedicated enclosures so furnished shall be identified as to measuring function available.

NOTE: A preferred arrangement would include kWh meters and demand registers or a means to transmit such information to a building energy management control system.

414 MOTORS

414.0 Applicability. All permanently wired polyphase motors of 1 hp or more serving the building shall meet the requirements of this section.

414.1.ABCD Basic Prescriptive Requirements for Methods A, B, C, and D.

414.1.ABCD.1 Motor Sizing. Motor horsepower rating shall not exceed 125% of the calculated maximum load being served. If a standard rated motor is not available within the range, the next larger standard motor size may be used.

414.1.ABCD.2 Motor Nameplates. Motor nameplates shall list the minimum nominal full-load motor efficiency. Full-load power factor for three-phase motors can be approximated from nameplate data by the equation:

EQUATION 4-3

$$\%PF = (hp \times 746 \times 10^4)/(\text{nominal efficiency} \times \text{Amps} \times \text{Voltage} \times 3^{0.5})$$

Where:

PF	=	Power factor (whole number)
Amps	=	Full load amps
hp	=	Horse power (whole number)
Voltage	=	Rated voltage

414.1.ABCD.3 Full Load Motor Efficiencies. Design A and B squirrel-cage, foot mounted, T-frame induction motors having synchronous speeds of 3600, 1800, 1200 and 900 rpm that are expected to operate more than 1000 hours per year shall have a nominal full-load motor efficiency no less than that shown in Table 4-13 or shall be classified under the National Electric Manufacturers Association's Standard as "energy efficient".

EXCEPTIONS:

1. Motors used in systems designed to use more than one speed of a multi-speed motor.
2. Motors used as a component of the equipment meeting the minimum equipment efficiency requirements of sections 407 and 408 provided that the motor input is included when determining the equipment efficiency.

414.1.ABCD.4 Electrical Schematic. The person responsible for installing the electrical distribution system shall provide the building owner a single-line diagram of the record drawing for the electrical distribution system, which includes the location of check-metering access, schematic diagrams of non-HVAC electrical control systems, and electrical equipment manufacturers' operating and maintenance literature as part of the operating and maintenance manual required by section 102.1.

Table 4-13a
Minimum Acceptable Nominal Full-Load Motor Efficiency For Single-Speed Polyphase Squirrel-Cage Induction Motors Having Synchronous Speeds of 3600, 1800, 1200 and 900 rpm Open Motors

HP	2 Pole		4 Pole		6 Pole		8 Pole	
	Nom. Eff.	Min. Eff.	Nom. Eff.	Min. Eff.	Nom. Eff.	Min. Eff.	Nom. Eff.	Min. Eff.
1.0	—	—	82.5	81.5	80.0	78.5	74.0	72.0
1.5	82.5	81.5	84.0	82.5	84.0	82.5	75.5	74.0
2.0	84.0	82.5	84.0	82.5	85.5	84.0	85.5	84.0
3.0	84.0	82.5	86.5	85.5	86.5	85.5	86.5	85.5
5.0	85.5	84.0	87.5	86.5	87.5	86.5	87.5	86.0
7.5	87.5	86.5	88.5	87.5	88.5	87.5	88.5	87.5
10.0	88.5	87.5	89.5	88.5	90.2	89.5	89.5	88.5
15.0	89.5	88.5	91.0	90.2	90.2	89.5	89.5	88.5
20.0	90.2	89.5	91.0	90.2	91.0	90.2	90.2	89.5
25.0	91.0	90.2	91.7	91.0	91.7	91.0	90.2	89.5
30.0	91.0	90.2	92.4	91.7	92.4	91.7	91.0	90.2
40.0	91.7	91.0	93.0	92.4	93.0	92.4	91.0	90.2
50.0	92.4	91.7	93.0	92.4	93.0	92.4	91.7	91.0
60.0	93.0	92.4	93.6	93.0	93.6	93.0	92.4	91.7
75.0	93.0	92.4	94.1	93.6	93.6	93.0	93.6	93.0
100.0	93.0	92.4	94.1	93.6	94.1	93.6	93.6	93.0
125.0	93.6	93.0	94.5	94.1	94.1	93.6	93.6	93.0
150.0	93.6	93.0	95.0	94.5	94.5	94.1	93.6	93.0
200.0	94.5	94.1	95.0	94.5	94.5	94.1	93.6	93.0

Table 4-13b
Minimum Acceptable Nominal Full-Load Motor Efficiency For Single-Speed Polyphase Squirrel-Cage Induction Motors Having Synchronous Speeds of 3600, 1800, 1200 and 900 rpm Enclosed Motors

HP	2 Pole		4 Pole		6 Pole		8 Pole	
	Nom. Eff.	Min. Eff.	Nom. Eff.	Min. Eff.	Nom. Eff.	Min. Eff.	Nom. Eff.	Min. Eff.
1.0	75.5	74.0	82.5	81.5	80.0	78.5	74.0	72.0
1.5	82.5	81.5	84.0	82.5	85.5	84.0	77.0	75.5
2.0	84.0	82.5	84.0	82.5	86.5	85.5	82.5	81.5
3.0	85.5	84.0	87.5	86.5	87.5	86.5	84.0	82.5
5.0	87.5	86.5	87.5	86.5	87.5	86.5	85.5	84.0
7.5	88.5	87.5	89.5	88.5	89.5	88.5	85.5	84.0
10.0	89.5	88.5	89.5	88.5	89.5	88.5	88.5	87.5
15.0	90.2	89.5	91.0	90.2	90.2	89.5	88.5	87.5
20.0	90.2	89.5	91.0	90.2	90.2	89.5	89.5	88.5
25.0	91.0	90.2	92.4	91.7	91.7	91.0	89.5	88.5
30.0	91.0	90.2	92.4	91.7	91.7	91.0	91.0	90.2
40.0	91.7	91.0	93.0	92.4	93.0	92.4	91.0	90.2
50.0	92.4	91.7	93.0	92.4	93.0	92.4	91.7	91.0
60.0	93.0	92.4	93.6	93.0	93.6	93.0	91.7	91.0
75.0	93.0	92.4	94.1	93.6	93.6	93.0	93.0	92.4
100.0	93.6	93.0	94.5	94.1	94.1	93.6	93.0	92.4
125.0	94.5	94.1	94.5	94.1	94.1	93.6	93.6	93.0
150.0	94.5	94.1	95.0	94.5	95.0	94.5	93.6	93.0
200.0	95.0	94.5	95.0	94.5	95.0	94.5	94.1	93.6

415 LIGHTING

415.0 Applicability. The rooms, spaces and areas covered by the criteria in this section include 1) interior spaces of buildings, 2) building exteriors and exterior areas such as entrances, exits, loading docks, etc., and 3) roads, grounds, parking, automobile display lots and other exterior areas where lighting is required and is constructed in conjunction with any building which is required to comply with this Code.

EXCEPTIONS:

1. Outdoor activities such as manufacturing, commercial greenhouses, and processing facilities.
2. Lighting power for theatrical productions, television broadcasting, audio-visual presentations, and those portions of entertainment facilities such as stage areas in hotel ballrooms, night clubs, discos and casinos where lighting is an essential technical element for the function performed.
3. Specialized luminaires for medical and dental purposes;
4. Outdoor athletic facilities.
5. Display lighting required for art exhibits or displays in galleries, museums and monuments.
6. Exterior lighting for public monuments.
7. Special lighting needs for research.
8. Lighting to be used solely for indoor plant growth during the hours of 10:00 PM to 6:00 AM.
9. Emergency lighting that is automatically OFF during normal building operation.
10. High risk security areas or any area identified by local ordinances or regulations or by security or safety officials as requiring additional lighting.
11. Spaces specifically designed for primary use by the visually impaired or hard-of-hearing (lipreading) and by senior citizens;
12. Lighting for signs.
13. Store-front, exterior-enclosed display windows in retail facilities.
14. Lighting for dwelling units.

Criteria in this section establish a maximum total lighting power allowance. When over 20% of the building's tasks or interior areas are undefined, the most appropriate value for that building from Table 4-16 (pages 261-265) shall be used for the undefined spaces. The performance compliance procedures of the Code shall not constitute an illumination design procedure.

415.1.ABCD Basic Prescriptive Requirements for Methods A, B, C and D

415.1.ABCD.1 Lighting Controls. All covered lighting systems, except those required for emergency or exit lighting, shall be provided with manual, automatic or programmable controls that, together or singly, are capable of turning off all the lights within that space.

415.1.ABCD.1.1 Minimum Number of Lighting Control Points. Spaces enclosed by walls or ceiling-high partitions shall have a minimum of one control point for the space and in addition one control point for each task location.

The minimum number of control points required shall be determined from FLA/COM based on the type of lighting controls and the number of control points calculated (see Table 4-14). The number of control points required shall be at least one for every 1500 W of *Connected Lighting Power* (CLP).

Table 4-14
Control Types and Equivalent Control Points

Types of Control	Equivalent Number of Control Points
Manually operated On-Off switch	1
Occupancy sensor	2
Timer, programmable from the space controller	2
Three level, including Off, step control, or pre-set dimming	2
Four level, including Off, step control, or pre-set dimming	3
Automatic or continuous dimming	3

EXCEPTIONS:

1. Continuous lighting for security purposes.
2. Spaces with only one lighting fixture or a single ballast.
3. Spaces which must be used as a whole.
4. Lighting for dwelling units.

415.1.ABCD.1.1.1 Task Areas. Controls provided for task areas, if readily accessible, may be mounted as part of the task lighting luminaire.

415.1.ABCD.1.1.2 Multiple Controls on the Same Load. Controls for controlling the same load from more than one location shall not be credited as increasing the number of controls to meet the requirements of section 415.1.ABCD.1.1.

415.1.ABCD.1.1.3 Control Accessibility. All lighting controls shall be located so as to be readily accessible from within the space controlled.

EXCEPTIONS:

The following lighting controls may be centralized in remote locations.

1. Lighting controls for spaces which must be used as a whole.
2. Automatic control.
3. Programmable controls.
4. Controls requiring trained operators.
5. Controls for safety hazards and security.

415.1.ABCD.1.1.4 Hotel and Motel Guest Room Controls. Hotel and motel guest rooms and suites shall have at least one master switch at the main entry door that controls all permanently wired lighting fixtures and switched receptacles, excluding bathrooms.

EXCEPTION:

When switches are provided at the entry to each room of a multiple-room suite.

415.1.ABCD.1.1.5 Switching of Exterior Lighting. Exterior lighting not intended for 24 hour use shall be automatically switched by either timer or photocell, or a combination of timer and photocell. When used, timers shall be capable of 7 day and seasonal daylight adjustment and have power backup for at least four hours.

415.1.ABCD.2 Ballasts

415.1.ABCD.2.1.4 Power Factor. All ballasts shall have a power factor of at least 90%.

EXCEPTIONS:

1. Ballasts for circline and compact fluorescent lamps and low wattage high intensity discharge lamps of not over 100 W.

2. Dimming ballasts.

415.1.ABCD.2.2 Tandem Wiring. One-lamp or three-lamp fluorescent luminaires that are recess-mounted within 10 ft center-to-center of each other or pendant mounted or surface mounted within 1 ft of each other, and within the same room, shall be tandem wired unless three-lamp ballasts are used.

415.1.ABCD.3 Exterior Lighting Power Allowance (ELPA). The exterior lighting power to be installed with a building shall not exceed the total ELPA for the building as determined by FLA/COM based on budgets provided in Table 4-15. Tradeoffs of exterior lighting budgets among exterior areas are permitted as long as the total Connected Lighting Power (CLP) of exterior lighting does not exceed the ELPA. Tradeoffs between interior lighting power allowances and exterior lighting power allowances shall not be made.

EXCEPTION:

Lighting for outdoor manufacturing or process facilities, commercial greenhouses, outdoor athletic facilities, public monuments, designated high-risk security areas, signs, retail storefronts, exterior enclosed display windows, and lighting specifically required by local ordinances and regulations.

415.1.ABCD.4 Exit Signs. Exit signs shall not use more than 7 watts of total input power per face in normal operation.

Table 4-15
Exterior Lighting Unit Power Allowance

Area Description	Allowances
Exit (with or without canopy)	24 W/lin. ft door opening
Entrance (without canopy)	30 W/lin. ft door opening
Entrance (without canopy) High traffic (retail, hotel, airport, theater, etc.) Light traffic (hospital, office, school, etc.)	 10 W/lin. ft of canopied area 4 W/sq ft of canopied area
Loading area	0.4 W/sq ft
Loading door	20 W/lin. ft door opening
Building exterior surfaces/facades	0.25 W/sq ft of surface area to be illuminated
Storage and non-manufacturing work areas	0.20 W/sq ft
Other activity areas for casual use such as picnic grounds, gardens, parks, and other landscaped areas	0.10 W/sq ft
Private driveways/walkways	0.10 W/sq ft
Public driveways/walkways	0.15 W/sq ft
Private parking lots	0.12 W/sq ft
Public parking lots	0.18 W/sq ft

Table 4-16
Interior Lighting Unit Power Density

Code #	Space Type	Unit Power Density (UPD) (W / ft²)
	Auditorium	
1	Auditorium	1.6
	Corridor	
2	Corridor	0.8
	Classroom/Lecture Hall	
3	Classroom/Lecture Hall	2.0
	Electrical/Mechanical Equipment Room	
4	General	0.7
5	Control Room	1.5
	Food Service	
6	Fast Food/Cafeteria	1.3
7	Leisure Dining[a]	2.5
8	Bar/Lounge[a]	2.5
9	Kitchen	1.4
	Recreation/Lounge	
10	Recreation/Lounge	0.7
	Stair	
11	Active Traffic	0.6
12	Emergency Exit	0.4
	Toilet and Washroom	
13	Toilet and Washroom	0.8
	Garage	
14	Auto and Pedestrian Circulation	0.3
15	Parking Area	0.2
	Laboratory	
16	Laboratory	2.3
	Library	
17	Audio Visual	1.1
18	Stack Area	1.5
19	Card Filing and Cataloging	1.6
20	Reading Area	1.9
	Lobby (General)	
21	Reception and Waiting	1.0
22	Elevator Lobbies	0.8
	Atrium (Multi-Story)	
23	First three floors	0.7
24	Each additional floor	0.2

Table 4-16
Interior Lighting Unit Power Density (cont'd)

Code #	Space Type	Unit Power Density (UPD) (W / ft^2)
	Locker Room and Shower	
25	Locker Room and Shower	0.8
	Office **(Partition >4.5 ft. below ceiling)**	
	Enclosed Offices	
26	Reading, Typing, Filing	1.8
27	Drafting	2.6
28	Accounting	2.1
	Office (Partition[b] 3.5–4.5 ft. below ceiling)	
	Open Plan Office >900 ft^2	
29	Reading, Typing, Filing	1.9
30	Drafting	2.9
31	Accounting	2.4
	Office (Partition[b] <3.5 ft. below ceiling)	
	Open Plan Office ≥900 ft^2	
32	Reading, Typing, Filing	2.2
33	Drafting	3.4
34	Accounting	2.7
	Common Activity Areas	
35	Conference/Meeting Room	1.8
35 Alternate	Conference Meeting[c] (Multiple Functions)	2.7
36	Computer/Office Equipment	2.1
37	Inactive Filing	1.0
38	Mail Room	1.8
	Shop (Non-Industrial)	
39	Machinery	2.5
40	Electrical/Electronics	2.5
41	Painting	1.6
42	Carpentry	2.3
43	Welding	1.2
	Storage/Warehouse	
44	Inactive Storage	0.3
45	Bulky Active Storage	0.3
46	Fine Active Storage	1.0
47	Material Handling	1.0
	Unlisted Space	
48	Unlisted Space	0.2
	Airport, Bus, and Rail Station	
49	Baggage Area	1.0
50	Concourse/Main Thruway	0.9
51	Ticket Counter	2.5
52	Waiting and Lounge Area	1.2

Table 4-16
Interior Lighting Unit Power Density (cont'd)

Code #	Space Type	Unit Power Density (UPD) (W / ft²)
	Bank	
53	Customer Area	1.1
54	Banking Activity Area	2.8
	Barber and Beauty Parlor	
55	Barber and Beauty Parlor	2.0
	Church, Synagogue, Chapel	
56	Worship/Congregational	2.5
57	Preaching and Sermon/Choir	2.7
	Dormitory	
58	Bedroom	1.1
59	Bedroom and Study	1.4
60	Study Hall	1.8
	Fire and Police Department	
61	Fire Engine Room	0.7
62	Jail Cell	0.8
	Hospital/Nursing Home	
63	Corridor	1.3
64	Dental Suite/Exam/Treatment	1.6
65	Emergency	2.3
66	Laboratory	1.9
67	Lounge/Waiting Room	0.9
68	Medical Supplies	2.4
69	Nursery	2.0
70	Nurse Station	2.1
71	Occupational/Physical Therapy	1.6
72	Patient Room	1.4
73	Pharmacy	1.7
74	Radiology	2.1
	Surgery and O.B. Suites	
75	General Area	2.1
	Hotel/Conference Center	
78	Banquet/Multipurpose Room	2.4
78 Alternate	Banquet/Multipurpose[c] (multiple functions)	3.6
79	Bathroom/Powder Room	1.2
80	Guest Room	1.4
81	Public Area	1.2
82	Exhibition Hall	2.6
83	Conference/Meeting	1.8
83 Alternate	Conference/Meeting[c] (multiple functions)	2.7
84	Lobby	1.9
85	Reception Desk	2.4

Table 4-16
Interior Lighting Unit Power Density (cont'd)

Code #	Space Type	Unit Power Density (UPD) (W / ft²)
	Laundry	
86	Washing	0.9
87	Ironing/Sorting	1.3
	Museum/Gallery	
88	General Exhibition	1.9
89	Inspection/Storage	3.9
90	Inactive Artifacts Storage	0.6
91	Active Artifacts Storage	0.7
	Post Office	
92	Lobby	1.1
93	Sorting and Mailing	2.1
	Service Station/Auto Repair	
94	Service Station	1.0
	Theater	
95	Performance Arts	1.5
96	Motion Picture	1.0
97	Lobby	1.5
	Retail Establishments (as per Code, p.8-7)	
98	Type A (Jewelry Merchandising)	5.6
99	Type B (Fine Merchandising)	3.2
100	Type C (Mass Merchandising)	3.3
101	Type D (General Merchandising)	3.1
102	Type E (Food and Miscellaneous)	2.8
103	Type F (Service Establishment)	2.7
104	Mall Concourse	1.4
	Retail Support	
105	Tailoring	2.1
106	Dressing/Fitting Rooms	1.4
107	Seating Area	0.4
	Badminton	
108	Club	0.5
109	Tournament	0.8
	Basketball/Volleyball	
110	Intramural	0.8
111	College	1.3
112	Professional	1.9
	Bowling	
113	Approach Area	0.5
114	Lanes	1.1

Table 4-16
Interior Lighting Unit Power Density (cont'd)

Code #	Space Type	Unit Power Density (UPD) (W / ft²)
	Boxing/Wrestling (Platform)	
115	Amateur	2.4
116	Professional	4.8
	Gymnasium	
	Handball/Racquetball/Squash	
118	Club	1.3
119	Tournament	2.6
	Ice Hockey	
120	Amateur	1.3
121	College/Professional	2.6
	Skating Park	
122	Recreational	0.6
123	Exhibitional/Professional	2.6
	Swimming	
124	Recreational	0.9
125	Exhibition	1.5
126	Underwater	1.0
	Tennis	
127	Recreational (Class III)	1.3
128	Club/College (Class II)	1.9
129	Professional (Class I)	2.6
	Table Tennis	
130	Club	1.0
131	Tournament	1.6.04

[a] *UPD includes lighting power for cleanup purposes.*

[b] *Not less than 90% of all work stations shall be individually enclosed with partitions of at least the height described.*

[c] *Where a conference or meeting room serves multiple functions and a supplementary system compliant with section 415.2.B.1.1.4.1 has been installed, the ALT UPD space type may be used.*

RESIDENTIAL BUILDING COMPLIANCE METHODS

600 ADMINISTRATION

600.0 Methods of Compliance. This Chapter provides three Methods by which residential buildings may be brought into compliance with this Code.

Method A, the Whole Building Performance Method. This is a performance based Code compliance method which considers energy use for the whole building, both for the envelope and its major energy-consuming systems. Under this method, points are calculated for the energy-consuming elements of an *As-Built* house and simultaneously for a *Baseline* house of the same configuration and orientation. The As-Built points shall be less than the Baseline points to comply with this Code. Applicable prescriptive requirements described in sections 601 through 612 shall also be met.

Method A may be applied to demonstrate Code compliance for new residential construction, both single-family detached and multifamily attached structures, and to additions to existing residential buildings. Existing buildings not exempt from this Code may be brought into compliance by this Method in accordance with the provisions of section 101.4.2.

Method B, the Component Prescriptive Method. This is a prescriptive Code compliance method for residences of three stories or less and additions. Using this method, a residence would meet or exceed all requirements for one of several prepackaged lists of minimum construction requirements.

EXCEPTIONS: Method B shall not be applied in the following cases:

1. New construction, excluding additions, which is only heated or cooled but not both.
2. New construction, including additions, which incorporates steel stud walls, single assembly roof/ceiling construction or skylights.
3. Residences with raised floors other than continuous stem wall structures except for Package C in north Florida, Package D in central Florida, and Package B in south Florida.

Method C, Limited Applications Prescriptive Method. This is a prescriptive Code compliance method for residential additions of 600 square feet or less, renovations to existing residential buildings; heating, cooling, and water heating systems of existing buildings; and site-added components of manufactured homes and manufactured buildings. To comply by this method, all energy-related components or systems being installed or changed in the addition or renovation shall meet the minimum prescriptive levels listed for that component.

600.0.ABC Compliance Criteria. Residential buildings demonstrating compliance with this Code by Method A shall meet all of the criteria given in the text as specific to Method A for 1, 2, 3 and 4 below. Residential buildings utilizing Methods B or C for Code compliance shall meet all criteria specific to that Method for 1, 3 and 4 below.

1. Prescriptive Requirements

2. Performance Calculation Procedures

3. Certification of Compliance.

4. Reporting.

600.1.ABC Prescriptive Requirements. Basic Prescriptive Requirements shall be met for all buildings. The section number followed by the combined number and letters ".1.ABC" indicates these Basic Prescriptive Requirements (i.e., prescriptive requirements that shall be met by buildings complying by either Method A, B or C) in sections 601 through 612. Prescriptive Requirements specific to Method A, B or C (i.e., ".1.B" is specific to Method B) shall be met when complying with the Code by that method. Prescriptive Requirements for Methods B or C may be more stringent than the Basic Prescriptive Requirements and shall supersede them.

600.1.A Prescriptive Requirements Specific to Method A. Prescriptive Requirements specific to Method A are included in the text under the applicable building component section. Primary compliance is by Form 600A which is a performance-based method.

600.1.B Prescriptive Requirements Specific to Method B. All of the Prescriptive Requirements listed for one of the five or six alternate Compliance Packages of building components listed on Table 6B-1 Form 600B shall be met or exceeded. No substitutions or variations less energy efficient than the established levels and standards listed for each component type shall be permitted for the Compliance Package chosen.

Any practice, system, or rating for which the multiplier in Method A is lower than the multiplier of the prescribed practice or system in the same climate zone may be used to comply with the Compliance Package prescriptives. No components or systems shall be installed with efficiencies less than the Basic Prescriptive Requirements for that component or system.

600.1.C Prescriptive Requirements Specific to Method C. Method C is a prescriptive Code compliance method. It requires meeting or exceeding the Prescriptive Requirements specific to this method described in sections 601 through 612 and listed on Tables 6C-1, 6C-2 and 6C-3 of Form 600C, where applicable.

600.1.C.1 Additions. Prescriptive Requirements shall apply only to building components and equipment being added to an addition or replaced in an existing building to service an addition. Existing components or systems in a residence need not meet the Prescriptive Requirements. Substitutions or variations that are less energy efficient than the prescribed efficiency levels and standards listed shall not be permitted.

600.1.C.2 Renovations. Prescriptive Requirements shall apply only to those components or systems being repaired or replaced.

600.1.C.3 Manufactured Homes and Manufactured Buildings. Prescriptive requirements specified for manufactured homes and manufactured buildings shall be met for all site-installed components and features of such buildings at the time of first set-up. Complete Code compliance shall be demonstrated for manufactured buildings.

600.2 Performance Calculation Procedures

600.2.A Performance Calculation Procedures for Method A. The calculation procedures contained in Form 600A shall be used to demonstrate Code compliance of the building design for residential buildings complying by Method A of this Chapter. The building components' efficiency levels specified in this performance compliance calculation are the minimum efficiencies allowed to be installed in the building unless a recalculation is submitted to the building department.

The Method A calculation shall result in either a PASS or FAIL status for a building. To PASS, the total points calculated for the *As-Built* house shall be less than or equal to the total points calculated for the *Baseline* house.

Energy points shall be calculated for an *As-Built* house and a *Baseline* house using actual house configuration and component net areas. *Cooling Points*, *Heating Points* and *Water Heating Points* shall be calculated separately and then summed. For a complete description of how to complete Form 600A, see the *Residential Instruction Manual*.

600.2.A.1 General

600.2.A.1.1 Multipliers. Multipliers are provided on Form 600A for commonly installed technologies for each building component. Multipliers for some less commonly installed technologies are provided in Appendix C to this document and are referenced by the appropriate Code section.

Interpolations of multipliers are allowed by the procedure described in section 1.3 of Appendix C where rated efficiencies of installed components fall within a range. Extrapolations of multipliers above the highest value given or below the lowest values given shall not be permitted. Multipliers are interpolated automatically in the FLA/RES computer program.

600.2.A.1.2 Insulation R-Values. R-values used to determine the appropriate multiplier for the insulation level installed shall be the R-value of the added insulation only. Appendix C, section 1.2 contains general rules for insulation which shall be followed.

600.2.A.1.3 Areas. Areas used in the calculation shall be the actual *net* areas for each component determined from the plans and specifications of the building to be constructed.

600.2.A.2 Residences Not Heated or Not Cooled. Residences which are heated or cooled, but not both, shall complete both summer and winter calculations. The *Baseline* system multiplier divided by the multiplier for an R-6 duct from Form 600A shall be used for the heating or cooling system not installed. The duct multiplier for the duct system to be installed shall be used for both calculations.

If an addition or part of an addition is claimed to be exempt from the Code because it will be neither heated nor cooled, the exempt area shall be fully separated from the conditioned area by walls or doors.

600.2.A.3 ADDITIONS

600.2.A.3.1 Additions Complying Alone. Additions to existing buildings shall follow the same Method A calculation procedure as new construction with the following qualifications:

1. Calculations shall be conducted using only the components of the addition itself, including those pre-existing components which separate the addition from unconditioned spaces.
2. Heating and Cooling System Multipliers shall be equal to the Baseline System Multiplier unless new equipment is installed to replace existing equipment or to service the addition specifically. Addition of new equipment may qualify for multizone credit (see section 607.2.A.3.2) if all other criteria are met. The multiplier for the new ductwork to supply the addition shall be used in the calculation.
3. Water heating is not included in the calculation unless a supplemental water heater is installed, an existing water heater is replaced, or an alternative water heater (gas, solar, HRU, dedicated heat pump) is installed to gain credit.

600.2.A.3.2 Additions Unable To Comply Alone. Section 101.2.2 allows additions to either comply with the Code requirements for the addition alone or by demonstrating that the entire building including the addition complies with the Code requirements for new buildings. Section 101.4.2.1 contains restrictions which shall apply if the entire building is used to demonstrate compliance.

600.2.A.4 Multifamily Occupancies.

600.2.A.4.1 Common Conditioned Spaces. Common conditioned spaces occurring in multifamily buildings that are not part of specific tenancy units, such as corridors, lobbies, recreation rooms, offices, etc., shall be calculated using one of the following procedures.

1. No energy use calculation is required for common areas if less than five percent (5%) of the building area is used for such common areas.
2. Corridors, lobbies and similar areas shall be calculated using Chapter 4.
3. Non-residential occupancies within a multifamily structure such as cafeterias, offices, and gyms shall be calculated in accordance with Chapter 4.

600.2.A.5 Worst Case Calculations. Residential occupancies which are identical in configuration, square footage, and building materials may comply with the Code by performing a *worst case* calculation. When submitting *worst case* calculations, copies of the Form 600A shall be submitted or referenced with each set of plans, dependent on the requirements of the building department.

600.3 Certification of Compliance

600.3.ABC.1 Code Compliance Preparation.

600.3.ABC.1.1 Single-Family Residential, Duplexes, Townhouses. No license or registration is required to prepare the Code compliance form for single-family residential, duplexes and townhouses. The person preparing the compliance form shall certify that the plans and pecifications covered by the form, or amendments thereto, are in compliance with the Florida Energy Efficiency Code for Building Construction.

600.3.ABC.1.2 Multifamily Residential. Form preparation for multifamily dwellings, with the exception of duplexes and townhouses as exempted by Section 481.229, Florida Statutes, shall be made a part of the plans and specifications for the building and require signing and sealing by an architect or engineer registered in the State of Florida with the exception of buildings excluded by Section 481.229, Florida Statutes, or Section 471.003, Florida Statutes. Calculations for buildings falling within the exception of Section 471.003, Florida Statutes, may be performed by air conditioning or mechanical contractors licensed in accordance with Chapter 489, Florida Statutes, or under any special act or ordinance.

600.3.ABC.2 Code Compliance Certification. The building's owner, the owner's architect, or other authorized agent legally designated by the owner shall certify to the building official that the building is in compliance with the Energy Efficiency Code For Building Construction prior to receiving the permit to begin construction or renovation.

All Chapter 6 compliance calculations and certifications shall be made using the 600 series forms or the FLA/RES computer program printout for the climate zone in which the building will be constructed.

If, during the building construction or renovation, alterations are made in the design, materials, or equipment which would diminish the energy performance of the building, an amended copy of the compliance certification shall be submitted to the building department agency by the building owner or his legally authorized agent on or before the date of final inspection.

The certified compliance form shall be made a part of the plans and specifications submitted for permitting the building.

600.3.ABC.3 Forms. Code compliance by this chapter shall be demonstrated by completing and submitting to the building official the appropriate forms described below and referenced in Table 6-1. An original form or FLA/RES-97 computerized printout, accompanied by a copy of the front page of the form as provided in section 600.4, shall be submitted to the building department to demonstrate compliance with this Code before a building permit is issued.

The Code compliance form used shall be specific to the climate zone in which the building will be located. See Appendix A for climate zone locations.

Forms are available from the local jurisdiction permitting offices or may be obtained from the Department of Community Affairs, Codes and Standards Section, 2555 Shumard Oak Blvd., Tallahassee, Florida 32399-2100. *Copies of Chapter 6 forms may be found in Appendix D.*

600.3.ABC.3.1 EPL Display Card. The building official shall require that an *Energy Performance Level (EPL) Display Card* be completed and certified by the builder to be accurate and correct before final approval of a residential building for occupancy. The *EPL Display Card* contains information indicating the energy performance level and efficiencies of components installed in a dwelling unit. The EPL Display Card shall be included as an addendum to the sales contract for both presold and non-presold residential buildings in accordance with Section 553.9085, Florida Statutes.

600.3.ABC.3.2 Form 600D-97 (Desuperheater, Heat Recovery Unit Water Heater Efficiency Certification). This form shall be submitted when credit is being taken for water heating with a *Heat Recovery Unit*. The form is used to demonstrate that the *Net Superheat Recovery* is equal to or greater than the 50 percent minimum required to obtain credit. The form shall be affixed to the Heat Recovery Unit by the manufacturer.

EXCEPTION:

If the Heat Recovery Unit is listed in the current *ARDM Directory of Certified Refrigerant Desuperheater Heat Recovery Unit Water Heaters* as meeting the net heat recovery minimum and the unit bears the ARDM label signifying compliance with this Code, the label shall serve as a certification in place of Form 600D-97.

600.3.A Forms Used for Method A Compliance. *Form 600A-97* or a printout of the FLA/RES-97 computer program shall be used to demonstrate Code compliance by Method A, the Whole Building Performance Method. Form 600A-97 is color coded by climate zone (see Table 6-1). The correct form for the location where the residence will be built or a printout of the FLA/RES-97 computer program for the appropriate climate zone shall be submitted to the building department to demonstrate compliance by Chapter 6 before a building permit is issued. Signatures on this form by persons authorized under the provisions of section 600.3.ABC.2 shall constitute certification of Code compliance by Method A of this Chapter.

Form 600A-97 shall remain on file at the building department.

600.3.B Forms Used for Method B Compliance. *Form 600B-97* shall be completed and submitted to the building department to demonstrate that all Prescriptive Requirements have been met. *Form 600B-97* contains the compliance packages used to demonstrate Code compliance by Method B of Chapter 6, the Component Prescriptive Method. This form is color coded by climate zone (see Table 6-1). a completed and signed form specific to the location where the residence will be built shall be submitted to the building department to obtain a building permit. Signatures on this form by persons authorized under the provisions of section 600.3.ABC.2 shall constitute certification of Code compliance by Method B of this Chapter.

Form 600B-97 shall remain on file at the building department.

Table 6-1
Index to Residential Forms by Climate Zone

Region	Climate Zones	Form 600A-97* Compliance Method A Color	Form 600B-97 Compliance Method B Color	Form 600C-97 Compliance Method C Color
North	1,2,3	Green	Beige	Blue
Central	4,5,6	Yellow	Peach	Tan
South	7,8,9	White	Gray	Pink

**The FLA/RES-97 computer program printout is equivalent to, and may be submitted in lieu of, Form 600A-97.*

600.3.C Forms Used for Method C Compliance. *Form 600C-97* shall be completed and submitted to the building department to demonstrate that all Prescriptive Requirements have been met for buildings complying with the Code by Method C, the Limited Applications Prescriptive Method. *Form 600C-97* contains the requirements for Code compliance for additions of 600 sq.ft. or less, for renovations, for building systems, and for site-added components of manufactured buildings and manufactured homes. This form is color coded by climate zone (see Table 6-1). a completed and signed form specific to the location where the residence will be built shall be submitted to the building department to obtain a building permit. Signatures on this form by persons authorized under the provisions of section 600.3.ABC.2 shall constitute certification of Code compliance by Method C of this Chapter.

Form 600C-97 shall remain on file at the building department.

600.4 Reporting. a copy of the front page of the 600 series form submitted to demonstrate Code compliance shall be sent by the building department to the Department of Community Affairs on a quarterly basis for reporting purposes.

601 FENESTRATIONS (GLAZING)

601.1.ABC Basic Prescriptive Requirements for Methods A, B and C

601.1.ABC.1 Glazing Types. Windows shall contain at least the minimum efficiency glazing type certified to be in compliance with the Code. Glazing in doors shall be considered fenestrations.

601.1.ABC.2 Window Infiltration. Windows shall meet the minimum air infiltration requirements of section 606.1.

601.1.ABC.3 Overhangs. Non-permanent shading devices such as canvas awnings shall not be considered overhangs. Permanently attached wood and metal awnings may be considered overhangs.

601.2.A Performance Calculation Procedures for Method A.

601.2.A.3.3 All glazing areas of a residence, including windows, sliding glass doors, glass in doors, skylights, etc. shall include the manufacturer's frame area in the total window area. Window measurements shall be as specified on the plans and specifications for the residence.

When a window in existing exterior walls is enclosed by an addition, an amount equal to the area of this window may be subtracted from the glazing area for the addition for that overhang and orientation.

602 WALLS

602.1.ABC Basic Prescriptive Requirements for Methods A, B and C

602.1.ABC.1 Wall Insulation. Walls shall be insulated to at least the level certified to be in compliance with this Code.

Insulation R-values claimed shall be in accordance with the criteria described in section C-1.2 of Appendix C.

602.1.ABC.1.1 Common Walls. Walls common to two separate conditioned tenancies shall be insulated to a minimum of R-11 for frame walls, and to R-3 on both sides of common masonry walls.

602.1.ABC.1.2 Walls Considered Ceiling Area. Wall areas that separate conditioned living space from unconditioned attic space (such as attic knee walls, walls on cathedral ceilings, skylight chimney shafts, gambrel roofs, etc.) shall be considered ceiling area and have a minimum insulation value of R-19.

602.1.C Prescriptive Requirements Specific to Method C.

602.1.C.3 Manufactured Homes and Manufactured Buildings. Marriage walls between sections of double wide or multiple units shall be sealed with long-life caulk or gasketing and shall be mechanically fastened in accordance with the manufacturer's instructions. See also the section 610.1.C.3 requirements for ducts located in marriage walls of multiple unit manufactured homes and buildings.

602.2.A Performance Calculation Procedures for Method A

602.2.A.2 Wall Area Determination. Net wall area (gross wall area of the building less all doors and windows) taken from the plans and specifications shall be used in the compliance calculation.

603 DOORS

603.1.ABC Basic Prescriptive Requirements For Methods A, B and C

603.1.ABC.1 Door Types Allowed. All *exterior* and *adjacent* doors other than glass doors shall be solid core wood, wood panel, or insulated doors. Hollow core doors shall not be used in either *exterior* or *adjacent* walls. Doors may have glass sections.

603.2.A.2 Door Area Determination. Door areas shall be determined from the measurements specified on the plans for each exterior and adjacent door.

All sliding glass doors and glass areas in doors shall be included in the glazing calculation and meet the requirements of section 601 unless the glass is less than one-third of the area of the door.

604 CEILINGS

604.1.ABC Basic Prescriptive Requirements for Methods A, B and C

604.1.ABC.1 Ceiling Insulation. Ceilings shall have an insulation level of at least R-19, *space permitting*. For the purposes of this Code, types of ceiling construction that are considered to have inadequate space to install R-19 include single assembly ceilings of the exposed deck and beam type and concrete deck roofs. Such ceiling assemblies shall be insulated to at least a level of R-10.

Ceiling insulation R-values claimed shall be in accordance with the criteria described in section 1.2 of Appendix C.

604.1.ABC.1.1 Ceilings With Blown-In Insulation. Ceilings with a rise greater than 5 and a run of 12 (5 over 12 pitch) shall not be insulated with blown-in insulation. Blown-in (loose fill) insulation shall not be used in sections of attics where the distance from the top of the bottom chord of the trusses, ceiling joists or obstructions (such as air conditioning ducts) to the underside of the top chord of the trusses at the ridge is less than 30" or where the distance from any point of 30" minimum clearance out to the ceiling surface in the roof eave area that is to be insulated is greater than 10 feet.

In every installation of blown-in (loose fill) insulation, insulation dams (for installations up to R-19 only); or insulation chutes, insulation baffles, or similar devices (for installations over R-19) shall be installed in such a manner so as to restrict insulation from blocking natural ventilation at the roof eave area to the attic space. Such devices shall be installed in spaces between all rafters of the roof structure and shall extend from the eave plate line to the attic area. In all cases, including the use of batt insulation, the insulation shall not be installed so as to block natural ventilation flow.

In that portion of the attic floor to receive blown insulation, reference marks or rules shall be placed within every 6' to 10' throughout the attic space. The reference marks shall show the height to which the insulation must be placed in order to meet the planned insulation level. Such marks shall be used by the Code Official to verify the claimed insulation level. The reference marks or rules may be placed on truss webs or other appropriate roof framing members. Each reference mark or rule shall be visible from at least one attic access point.

604.1.ABC.1.2 Common Ceilings/Floors. Wood, steel and concrete ceilings/floors common to separate conditioned tenancies shall be insulated to a minimum R-11, space permitting.

604.1.ABC.1.3 Roof Decks Over Dropped Ceiling Plenum. Roof decks shall be insulated to R-19 if the space beneath it will be used as a plenum of the air distribution system. Plenums shall meet all criteria of section 610.1.ABC.3.6.

604.1.A Prescriptive Requirements Specific to Method A.

604.1.A.1 Walls Considered Ceiling Area. Wall areas that separate conditioned living space from unconditioned attic space (such as attic knee walls, walls on cathedral ceilings, skylight chimney shafts, gambrel roofs, etc.) shall be considered ceiling area. Such areas shall be included in calculations of ceiling area and shall have a minimum insulation value of R-19.

604.2.A.2 Ceiling Area Determination. *As-Built* ceiling area shall be the actual ceiling area exposed to attic or single assembly roof conditions, including walls that separate conditioned living space from unconditioned attic space. *Baseline* ceiling area shall be the total floor area within the conditioned space located directly below the roof.

605 FLOORS

605.1.ABC Basic Prescriptive Requirements For Methods A, B and C

605.1.ABC.1 Floor Insulation. Insulation R-values claimed shall be in accordance with the criteria described in section 1.2 of Appendix C.

605.1.ABC.1.1 Wood, steel and concrete floors/ceilings common to two separate conditioned tenancies in multifamily applications shall be insulated to a minimum of R-11, space permitting.

605.1.ABC.1.2 For insulated slab-on-grade floors, the exposed vertical edge of the slab shall be covered with exterior slab insulation extending from the top of the slab down to at least the finished grade level. Extending the insulation to the bottom of the footing or foundation wall is recommended.

605.2.A.2 Floor Perimeter/Area Determination. *Slab-on-grade* floor points shall be determined based on the perimeter of the slab which encloses the conditioned space, including both *exterior* and *adjacent* wall linear footage for single-family residential applications. In multifamily applications, the slab perimeter between two conditioned tenancies shall be ignored. Raised floor points shall be determined based on the conditioned floor area of floors above unconditioned space.

606 AIR INFILTRATION

606.1.ABC Basic Prescriptive Requirements for Methods A, B and C. Buildings shall be constructed and sealed in such a way as to prevent excess air infiltration.

CAUTION: Caution should be taken to limit the use of materials and systems which produce unusual or excessive levels of indoor air contaminants.

606.1.ABC.1 INFILTRATION LEVELS ALLOWED.

606.1.ABC.1.1 Exterior Doors and Windows. Exterior doors and windows shall be designed to limit air leakage into or from the building envelope. Manufactured doors and windows shall have air infiltration rates not exceeding those shown in Table 6-2. These rates shall be determined from tests conducted at a pressure differential of 1.567 lb/ft^2, which is equivalent to the impact pressure of a 25 mph wind. Compliance with the criteria of air leakage shall be determined by testing to AAMA/NWWDA 101/I.S. 2-97 or ASTM E283-91, as appropriate. Site-constructed doors and windows shall be sealed in accordance with section 606.1.ABC.1.2.

606.1.ABC.1.2 Exterior Joints or Openings in the Envelope. Exterior joints, cracks, or openings in the building envelope that are sources of air leakage shall be caulked gasketed, weatherstripped or otherwise sealed in accordance with the criteria in sections 606.1.ABC.1.2.1 through 606.1.ABC.1.2.5.

Table 6-2
Allowable Air Infiltration Rates

Frame Type	Windows (cfm per sq ft of window area)	Doors (cfm per sq ft of door area)	
		Sliding	Swinging
Wood	0.3	0.3	0.5
Aluminum	0.3	0.3	0.5
PVC	0.3	0.3	0.5

606.1.ABC.1.2.1 Exterior and Adjacent Walls. Exterior and adjacent walls shall be sealed at the following locations:

1. Between windows and doors and their frames;
2. Between windows and door frames and the surrounding wall;
3. Between the foundation and wall assembly sill-plates;
4. Joints between exterior wall panels at changes in plane, such as with exterior sheathing at corners and changes in orientation;
5. Openings and cracks around all penetrations through the wall envelope such as utility services and plumbing;
6. Between the wall panels and top and bottom plates in exterior and adjacent walls. In frame construction, the crack between exterior and adjacent wall bottom plates and floors shall be sealed with caulking or gasket material. Gypsum board or other wall paneling on the interior surface of exterior and adjacent walls shall be sealed to the floor; and
7. Between walls and floor where the floor penetrates the wall.
8. Log walls shall meet the criteria contained in section 4.2 of Appendix C.

EXCEPTION:

As an alternative to 1 through 7 above for frame buildings, an infiltration barrier may be installed in the exterior and adjacent walls. The infiltration barrier shall provide a continuous air barrier from the foundation to the top plate of the ceiling of the house, and shall be sealed at the foundation, the top plate, at openings in the wall plane (windows, doors, etc.), and at the seams between sections of infiltration barrier material. When installed on the interior side of the walls, such as with insulated face panels with an infiltration barrier, the infiltration barrier shall be sealed at the foundation or subfloor.

606.1.ABC.1.2.2 Floors. Penetrations and openings in raised floors, greater than or equal to 1/8 inch in the narrowest dimension, shall be sealed unless backed by truss or joist members against which there is a tight fit or a continuous air barrier.

EXCEPTION:

Where an infiltration barrier is installed in the floor plane of a house with raised floors. The infiltration barrier shall create a continuous air barrier across the entire floor area, and shall be sealed at the perimeter, at openings in the floor plane (grills, registers, crawl space accesses, plumbing penetrations, etc.), and at seams between sections of infiltration barrier material.

606.1.ABC.1.2.3 CEILINGS. **CEILINGS SHALL BE SEALED AT THE FOLLOWING LOCATIONS:**

1. Between walls and ceilings.

2. At penetrations of the ceiling plane of the top floor of the building (such as chimneys, vent pipes, ceiling fixtures, registers, open shafts, or chases) so that air flow between the attic or unconditioned space and conditioned space is stopped.

3. Large openings, such as shafts, chases soffits, opening around chimneys, and dropped ceiling spaces (such as above kitchen cabinets, bathroom vanities, shower stalls, and closets), shall be sealed with an airtight panel or sheeting material and sealed to adjacent top plates (or other framing members) so that a continuous air barrier separates the spaces below and above the ceiling plane.

4. Gaps between ceiling gypsum board and the top plate shall be sealed with a sealant to stop air flow between the attic and the interior of wall cavities.

5. The attic access hatch, if located in the conditioned space shall have an airtight seal.

EXCEPTION:

Where an infiltration barrier is installed in the ceiling plane of the top floor of the house. The infiltration barrier shall: create a continuous air barrier across the entire ceiling plane, be continuous across the tops of interior and exterior walls, and be sealed at the perimeter, at openings in the ceiling plane (grills, registers, attic accesses, plumbing penetrations, vent pipes, chimneys, etc.), and at seams between sections of infiltration barrier material.

606.1.ABC.1.2.4 Recessed Lighting Fixtures. Recessed lighting fixtures installed in ceilings that abut an attic space shall meet one of the following requirements:

1. Type IC rated, manufactured with no penetrations between the inside of the recessed fixture and ceiling cavity and sealed or gasketed to prevent air leakage into the unconditioned space.

2. Type IC or non-IC rated, installed inside a sealed box (minimum of ½" thick gypsum wall board, preformed polymeric vapor barrier, or other air tight assembly manufactured for this purpose) and maintaining required clearances of not less than ½" from combustible material and not less than 3" from insulation material.

3. Type IC rated, with no more than 2.0 cfm air movement from the conditioned space to the ceiling cavity when measured in accordance with ASTM E283-91. The fixture shall be tested at 75 Pa and shall be labeled.

606.1.ABC.1.2.5 Multi-story Houses. In multi-story houses, the perimeter of the floor cavity (created by joists or trusses between floors) shall have an air barrier to prevent air flow between this floor cavity and outdoors or buffer zones of the house (such as a space over the garage).

1. Airtight panels, sheathing, or sheeting shall be installed at the perimeter of the floor cavity. The panels, sheathing, or sheeting material shall be sealed to the top plate of the lower wall and the bottom plate of the upper wall by mastic or other adhesive caulk, or otherwise bridge from the air barrier of the upper floor to the air barrier of the lower floor.

2. Joints between sections of panels, sheathing, or sheeting shall be sealed.

606.1.ABC.1.3 Additional Infiltration Requirements. The following additional requirements shall be met:

1. All exhaust fans vented to the outdoors shall have dampers. This does not apply to combustion devices with integral exhaust ductwork, which shall comply with NFPA 54 or the locally adopted code.

2. All combustion space heaters, furnaces, and water heaters shall be provided with adequate combustion air. Such devices shall comply with NFPA or the locally adopted code.

CAUTION: Caution should be taken to limit the use of materials and systems which produce unusual or excessive levels of indoor air contaminants.

606.1.ABC.1.4 Apertures or Openings. Any apertures or openings in walls, ceilings or floors between conditioned and unconditioned space (such as exits in the case of hydrostatic openings in stairwells for coastal buildings) shall have dampers which limit air flow between the spaces.

607 SPACE COOLING SYSTEMS

607.1.ABC Basic Prescriptive Requirements For Methods A, B and C

607.1.ABC.1 Equipment Sizing. An HVAC sizing calculation shall be performed on the building and shall be attached to the Form 600 submitted when application is made for a building permit, or in the event the mechanical permit is obtained at a later time, the sizing calculation shall be submitted with the application for the mechanical permit. Cooling and heating design loads, for the purpose of sizing HVAC systems, shall be determined for each zone within a dwelling in accordance with ACCA Manual J, ACCA Manual N, or the ASHRAE Cooling and Heating Load Calculation Manual, Second Edition. This Code does not allow designer safety factors, provisions for future expansion or other factors which affect equipment sizing in excess of the capacity limitations in section 607.1.ABC.1.1.

EXCEPTIONS:

1. Where mechanical systems are designed by an engineer registered in the State of Florida, a signed and sealed summary sheet may be submitted in lieu of the complete sizing calculation(s). Such summary sheet shall include the following (by zone):

   - Project name/owner
   - Project address
   - Sizing method used
   - Area in sq.ft.
   - Total heating required with outside air
   - Total sensible gain
   - Total latent gain
   - Total cooling required with outside air
   - Grains water (difference)
   - Outdoor dry bulb used
   - Outdoor wet bulb used
   - Relative humidity
   - Indoor dry bulb

2. Systems installed in existing buildings not meeting the definition of renovation in section 202.

607.1.ABC.1.1 Cooling Equipment Capacity. Cooling only equipment shall be selected so that its sensible capacity is not less than the calculated total sensible load but not more than 120% of the design sensible load calculated according to the procedure selected in section 607.1.ABC.1., or the closest available size provided by the manufacturer's product lines. The corresponding latent capacity of the equipment shall not be less than the calculated latent load.

607.1.ABC.1.2 Extra Capacity Required For Special Occasions. Residences requiring excess cooling or heating equipment capacity on an intermittent basis, such as anticipated additional loads caused by major entertainment events, shall have equipment sized or controlled to prevent continuous space cooling or heating within that space by one or more of the following options:

1. a separate cooling or heating system is utilized to provide cooling or heating to the major entertainment areas.

2. a variable capacity system sized for optimum performance during base load periods is utilized.

607.1.ABC.2 Controls. Each mechanical supply and exhaust ventilation system shall be equipped with a readily accessible switch or other means for shut-off or volume reduction and shut-off when ventilation is not required. Automatic or manual dampers installed for the purpose of shutting off ventilation systems shall be designed with tight shut-off characteristics to minimize air leakage.

EXCEPTION:

Manual dampers for outdoor air intakes may be used for single-family and multifamily residential buildings or for fan system capacities of less than 5000 cfm.

607.1.ABC.2.1 Zoning for Temperature Control. In one- and two-family dwellings, at least one thermostat for regulation of space temperature shall be provided for each separate HVAC system or zone.

607.1.ABC.2.2 Control Setback and Shut-off. The thermostat required in section 607.1.ABC.2.1, or an alternate means including, but not limited to, a switch or clock, shall provide a readily accessible manual or automatic means for reducing the energy required for heating and cooling during periods of non-use or reduced need including, but not limited to, unoccupied periods or sleeping hours.

607.1.ABC.2.3 Humidity Control. Where a humidistat is used for comfort dehumidification, it shall be capable of being set to prevent the use of fossil fuel or electricity to reduce humidities below 60 per cent.

607.1.ABC.3 Equipment Performance Standards

607.1.ABC.3.1 Equipment Ratings. Equipment efficiency ratings shall be obtained from a nationally recognized certification program directory, or from a manufacturer's rating certified to be in compliance with an approved Department of Energy (DOE) or Air-conditioning and Refrigeration Institute (ARI) rating procedure. Equipment efficiencies shall be based on the Standard Rating Conditions contained in the test standard referenced in Chapter 3 that is appropriate for that equipment. The procedure for determining the Integrated Part-Load Value (IPLV) for a piece of equipment shall be the one provided in the appropriate ARI test standard for the type of equipment referenced. Minimum ratings for products covered under the National Appliance Energy Conservation Act of 1987 shall be those determined for Region IV and used for the Federal Trade Commission's required appliance labeling.

Cooling system efficiencies shall be rated as follows:

1. Central air conditioning equipment under 65,000 Btu/h capacity, both split-system and single-package equipment, single- or three-phase, shall be rated with a *Seasonal Energy Efficiency Ratio* (SEER).

2. Packaged terminal air conditioners and heat pumps shall be rated with an *Energy Efficiency Ratio* (EER).

3. Room air conditioners shall be rated by an *Energy Efficiency Ratio* (EER).

4. Central air conditioning equipment over 65,000 Btu/h shall be rated with an *Energy Efficiency Ratio* (EER).

5. Water-cooled and evaporatively cooled central systems under 135,000 Btu/h shall be rated with an *Energy Efficiency Ratio* (EER).

6. Large capacity air-cooled, evaporatively-cooled and water source unitary air conditioning systems may also be rated with an *Integrated Part-Load Value* (IPLV).

7. Heat-operated cooling equipment and gas-driven heat pumps shall be rated with a *Coefficient of Performance* (COP)-cooling.

607.1.ABC.3.1.1 Mix-Matched Equipment. Ratings for unitary central air conditioning and heat pump systems less than 65,000 Btu/h, using evaporator/(condenser) coils manufactured by independent companies, shall meet all requirements of either section 607.1.ABC.3.1.1.1 or 607.1.ABC.3.1.1.2. Where such equipment is sold as a system, the separate assemblies shall be designed to be used together. Equipment components manufactured by the same company that are not designed and tested for operation together shall also meet these requirements.

607.1.ABC.3.1.1.1 Companies whose equipment is certified under a nationally recognized certification program or rating procedure where sample units are tested on a regular basis and efficiencies are published in a directory may rate their equipment in accord with the requirements of that program.

607.1.ABC.3.1.1.2 Companies whose equipment is not certified under a nationally recognized testing and certification program shall publish equipment efficiencies not greater than the efficiency rating of the condensing unit (cooling mode) or outdoor unit (heating mode) manufacturer's most commonly sold condensing unit-evaporator coil or outdoor unit-indoor coil combination.

The evaporator/(condenser) coil manufacturer shall submit computer simulated equipment efficiency ratings to demonstrate predicted equipment efficiencies. Where simulated efficiencies are less than the condensing unit or outdoor unit manufacturer's most commonly sold combination efficiency, a rating not to exceed the simulated rating shall be used. Published simulated equipment efficiency rating submittals shall identify any enhancement features included to attain claimed ratings.

Computer simulated equipment efficiency ratings submitted shall be based on the condensing unit manufacturer's tested combination (as listed in the current ARI Directory and identified by the model numbers of both the condensing unit and coil or outdoor unit and indoor coil as listed by ARI) and the independent coil manufacturer's evaporator/(condenser) coil performance data. Such simulated ratings shall be certified, signed and dated by a Florida registered professional engineer, or, for the cases of a secondary original equipment manufacturer (OEM) and a company manufacturing component parts specifically for mix-matched cooling or heating equipment, the president or chairman of the board of the manufacturing company and a professional engineer registered in the state of manufacture, and shall show that the unit, identified by model number, meets the minimum Code requirements. The certification shall attest to the accuracy of the input data, the validity of the calculation procedure utilized and that the results of the simulation are in accordance with the DOE approved methodology. Simulated equipment efficiency rating certifications shall identify any enhancement features included to attain claimed ratings. a full set of input data utilized to arrive at the rating shall be available as documentation on request.

When challenged, computer simulated ratings shall not exceed 105 percent of the SEER, EER, HSPF or COP rating, as appropriate, of the actual tested performance for that condensing unit evaporator coil configuration. Unsubstantiated claims for such equipment shall be dropped from publication.

607.1.ABC.3.1.2 Field-Assembled Equipment and Components. Air conditioning and heat pump systems with capacities of 65,000 Btu/h or greater where components such as indoor or outdoor coils are used from more than one manufacturer, shall be rated by a calculated total system Energy Efficiency Ratio (EER). Component efficiencies shall be specified based on data provided by the component manufacturers. Calculations documenting how the efficiency rating was derived shall be submitted with the appropriate Code compliance form and shall be signed and sealed by a registered professional engineer.

Total on-site energy input to the equipment shall be determined by combining inputs to all components, elements and accessories, such as compressor(s) internal circulating pump(s), condenser-air fan(s), evaporative-internal circulating pump(s), purge devices, viscosity control heaters, and controls.

607.1.ABC.3.2 Minimum Efficiencies for Cooling Equipment

607.1.ABC.3.2.1 Electrically Operated, Cooling Mode. These requirements apply to unitary (central) cooling equipment (air-cooled, water-cooled and evaporatively cooled); the cooling mode of unitary (central) and packaged terminal heat pumps (air source and water source); packaged terminal air conditioners; roof air conditioners; and room air conditioners.

607.1.ABC.3.2.1.1 HVAC system equipment of less than 65,000 Btu/h, whose energy input in the cooling mode is entirely electric, shall have a Seasonal Energy Efficiency Ratio (SEER) or Energy Efficiency Ratio (EER), as specified for that piece of equipment in section 607.1.ABC.3.1, of not less than the values shown in Table 6-3.

Table 6-3
Electrically Driven Cooling Equipment
Capacities: <65,000 BTU/H
Minimum Performance Efficiencies[1,2]

Type of Equipment, Capacities, Standard Rating Conditions (°F)	EER	SEER	IPLV[2]
Central Units			
Air-Cooled—Seasonal Rating[3]			
Split-system		10.0	
Single-package		9.7	
Evaporatively Cooled			
Standard Rating (80db/67wb indoor 95db/75wb outdoors)	9.3		
Int. Part Load Value (80db/67wb out)			8.5
Water-Cooled			
Water-Source Heat Pump (80db/67wb indoor)			
Standard Rating (85 entering water)	9.3		
Low Temp. Rating (75 entering)	10.2		
Ground-Water Heat Pump			
Standard Rating (70 entering)	11.0		
Low Temp. Rating (50 entering)	11.5		
Ground Source Heat Pump			
77° Entering brine	10.0		
70° Entering brine	10.4		
Unitary Air Conditioners (80db/67wb indoor)			
Standard Rating (85 entering)	9.3		
Int. Part Load Value (75 entering)			8.3
Packaged Terminal Units (PTAC & PTHP)			
Standard Rating (95db outdoor)			
≤ 7,000	8.9		
7,001-8,000 Btu/h	8.8		
8,001-9,000 Btu/h	8.6		
9,001-10,000 Btu/h	8.5		
10,001-11,000 Btu/h	8.3		
11,001-12,000 Btu/h	8.2		
12,001-13,000 Btu/h	8.0		
13,001-14,000 Btu/h	7.8		
14,001-15,000 Btu/h	7.7		
>15,000 Btu/h	7.6		
Room Units[3]			
Without reverse cycle			
<6,000 Btu/h	8.0		
6,000-7,999 Btu/h	8.5		
8,000-13,999 Btu/h (with louvers)	9.0		
14,000-20,000 Btu/h (with louvers)	8.8		
20,000 Btu/h (with louvers)	8.2		
8,000-20,000 BTU/H (without louvers)	8.5		
>20,000 Btu/h (without louvers)	8.2		
With reverse cycle (with louvers)	8.5		
With reverse cycle (without louvers)	8.0		

[1] *Test procedures for equipment referenced shall be in accordance with the applicable standard listed in Chapter 3.*

[2] *Products covered by the 1992 Energy Policy act have no efficiency requirements at other than standard rating conditions for products manufactured after 1/1/94.*

[3] *To be consistent with National Appliance Energy Conservation Act of 1987, P.L. 100-12.*

607.1.ABC.3.2.1.2 HVAC system equipment with capacities between 65,000 Btu/h and 135,000 Btu/h whose energy input in the cooling mode is entirely electric, shall show an Energy Efficiency Ratio (EER) and/or Integrated Part-Load Value (IPLV), as specified for that piece of equipment in section 607.1.ABC.3.1, of not less than values shown in Table 6-4.

Table 6-4
Electrically Driven Cooling Equipment
Capacities: ≥ 65,000 BTU/H <135,000 BTU/H
Minimum Performance Efficiencies

Type of Equipment, Capacities, Standard Rating Conditions (°F)	EER	IPLV[2]
Central Units		
Air-Cooled		
Standard Rating (95db outdoor)	8.9	
Int. Part Load Value (80db outdoor)		8.3
Evaporatively Cooled		
Standard Rating (80db/67wb indoor, 95 db/75 wb outdoor)	10.5	
Int. Part Load Value (80db/67wb outdoor)		9.7
Water-Cooled		
Water-Source Heat Pump (85° entering water)		
Standard Rating (80db/67wb indoor)	10.5	
Groundwater-Cooled Heat Pump[3]		
Standard Rating (70° entering)	11.0	
Low Temperature Rating (50° entering)	11.5	
Ground Source Heat Pumps[3]		
77° Entering brine	10.0	
70° Entering brine	10.4	
Unitary Air-Conditioners (80db/78wb)		
Standard Rating (85° entering)	10.5	

[1] *Reference standards for equipment testing are specified in Chapter 3.*

[2] *Products covered by the 1992 Energy Policy Act have no efficiency requirements at other than standard rating conditions for products manufactured after 1/1/94.*

[3] *Rating for groundwater-cooled, ground source heat pumps applies to all units under 135,000 Btu/h.*

607.1.ABC.3.2.1.3 HVAC system equipment with capacities equal to or greater than 135,000 Btu/h whose energy input in the cooling mode is entirely electric, shall meet the efficiency requirements of section 407.1.ABCD.3.2.1.3 and Table 4-5 in Chapter 4.

607.1.ABC.3.2.2 Heat Operated, Cooling Mode. These requirements apply to, but are not limited to, absorption equipment, engine-driven equipment and turbine-drive equipment.

Heat-operated cooling equipment shall show a COP-cooling not less than the values shown in Table 6-5. Electrical auxiliary inputs shall be excluded from the COP-cooling calculation.

607.1.C Prescriptive Requirements Specific to Method C.

607.1.C.1 Additions. All new air conditioners installed in additions complying by Method C shall meet the minimum efficiencies in section 607.1.ABC.3.2.

Minimum equipment efficiencies shall be met only when equipment is installed to specifically serve the addition or is being installed in conjunction with the construction of the addition.

607.1.C.2 Renovations. Minimum efficiencies for cooling equipment to be added or replaced in renovations shall not be less than those specified in section 607.1.ABC.3.2.

607.1.C.3 Manufactured Homes and Manufactured Buildings. Minimum efficiencies for site-installed cooling equipment in manufactured homes shall not be less than those specified in section 607.1.ABC.3.2.

607.1.C.4 Building Systems. Newly manufactured cooling systems installed in existing buildings shall meet minimum requirements for that system in section 607.1.ABC. See also section 101.6.

Table 6-5
Heat-Operated[1] Cooling Equipment
Minimum Performance Efficiencies

Heat Source Minimum	COP[2]
Direct-fired (gas, oil)	0.48
Indirect-fired (steam, hot water)	0.68

[1] *Standard rating conditions at sea level.*

[2] *Minimum COP =* $\frac{\text{Net Cooling Output}}{\text{Total Heat Input (electrical auxiliary excluded)}}$

608 SPACE HEATING SYSTEMS

608.1.ABC Basic Prescriptive Requirements for Methods A, B, and C

608.1.ABC.1 Equipment Sizing. An HVAC equipment sizing calculation shall be performed on the building in accordance with the criteria in section 607.1.ABC.1 and shall be attached to the Form 600 submitted when application is made for a building permit. This Code does not allow designer safety factors, provisions for future expansion or other factors which affect equipment sizing in excess of the capacity limitations in sections 608.1.ABC.1.1 through 608.1.ABC.1.4.

608.1.ABC.1.1 Heat Pumps. Heat pump sizing shall be based on the cooling requirements as calculated according to section 607.1.ABC.1 unless the refrigeration cycle heating capacity is less than the heating requirements of the conditioned space at design conditions. In that case, the refrigeration cycle heating capacity shall be sized to provide the lowest possible balance point on heating without exceeding 12.5% of the cooling load at design conditions. Capacity at the design heating temperature may be determined by interpolation or extrapolation of manufacturers' performance data if these data are not available for design temperatures. The auxiliary capacity plus refrigeration cycle heating capacity shall not exceed 120% of the calculated heating requirements at the 99 percent design dry bulb temperature.

608.1.ABC.1.2 Electric Resistance Furnaces. Electric resistance furnaces shall be sized within 4 kW of the design requirements calculated according to the procedure selected in section 607.1.ABC.1.

608.1.ABC.1.3 Fossil Fuel Heating Equipment. The capacity of fossil fuel heating equipment with natural draft atmospheric burners shall not be more than 120% of the design load calculated at the 99 percent design dry bulb temperature.

608.1.ABC.1.4 Extra Capacity Required For Special Occasions. Residences requiring excess heating capacity on an intermittent basis shall comply with section 607.1.ABC.1.2.

608.1.ABC.2 Controls. Requirements specified for controls in section 607.1.ABC.2 shall apply for space heating systems.

Lowering thermostat set points to reduce energy consumption of heating systems shall not cause energy to be expended to reach the reduced setting.

608.1.ABC.3 Equipment Performance Standards

608.1.ABC.3.1 Equipment Ratings. Equipment efficiency ratings shall be obtained from a nationally recognized certification program directory, from a manufacturer's rating certified to be in compliance with an approved Department of Energy (DOE) or Air-conditioning and Refrigeration Institute (ARI) rating procedure. Equipment efficiencies shall be based on the Standard Rating Conditions contained in the test standard referenced in Chapter 3 that is appropriate for that equipment. Minimum ratings for products covered under the National Appliance Energy Conservation Act of 1987 shall be those determined for Region IV and used for the Federal Trade Commission's required appliance labeling.

Heating system efficiencies shall be rated as follows:

1. Central electric heat pumps under 65,000 Btu/h capacity, both split-system and single-package equipment, single- or three-phase, shall be rated with a *Heating Seasonal Performance Factor* (HSPF).

2. Packaged terminal heat pumps shall be rated with a *Coefficient of Performance* (COP).

3. Air source heat pumps of 65,000 Btu/h or larger and water-source heat pumps shall be rated with a *Coefficient of Performance* (COP).

4. Gas- and oil-fired warm air furnaces under 225,000 Btu/h and boilers under 300,000 Btu/h shall be rated with an *Annual Fuel Utilization Efficiency* (AFUE).

5. Gas- and oil-fired warm air furnaces and unit heaters of 225,000 Btu/h and over and boilers of 300,000 Btu/h or greater shall be rated with a steady-state combustion efficiency, E_t/E_c.

6. Gas- and oil-fired direct heating equipment shall be rated with an *Annual Fuel Utilization Efficiency* (AFUE).

7. Central gas-driven heat pumps shall be rated with a Coefficient of Performance (COP).

608.1.ABC.3.1.1 Mix-Matched Equipment. Ratings for unitary central heat pump systems less than 65,000 Btu/h, using evaporator/(condenser) coils manufactured by independent companies, shall meet all requirements of section 607.1.ABC.3.1.1.

608.1.ABC.3.1.2 Field-Assembled Equipment and Components. Heat pump systems with capacities of 65,000 Btu/h or greater where components such as indoor or outdoor coils are used from more than one manufacturer, shall be rated by a calculated total system Coefficient of Performance (COP). The rate of net heat output used in the COP calculation is the change in the total heat content of the air entering and leaving the equipment, not including supplementary heat. Component efficiencies shall be specified based on data provided by the component manufacturers. Calculations documenting how the overall system efficiency rating was derived shall be submitted with the appropriate Code compliance form and shall be signed and sealed by a registered professional engineer.

Total on-site energy input to the heat pump shall be determined by combining the energy input to all elements, except supplementary heaters, of the heat pump, including, but not limited to, compressor(s), compressor pump heater(s), pump(s), supply-air fan(s), return-air fan(s), outdoor air fan(s), cooling-tower fan(s), and the HVAC system equipment control circuit.

608.1.ABC.3.2 Minimum Efficiencies for Heating Equipment

608.1.ABC.3.2.1 Heat Pump - Heating Mode. These requirements apply, but are not limited to: unitary central electric heat pumps, either air or water source in the heating mode; water source (hydronic) heat pumps as used in multiple unit hydronic HVAC systems; and packaged terminal heat pumps and room air-conditioner heat pumps in the heating mode.

608.1.ABC.3.2.1.1 Minimum Efficiencies. Heat pumps shall have a Heating Seasonal Performance Factor (HSPF) or Coefficient of Performance (COP), as described in section 608.1.ABC.3.1, in the heating mode of not less than the values shown in Table 6-6.

608.1.ABC.3.2.1.2 Supplementary Heat

608.1.ABC.3.2.1.2.1 Heat pumps having supplementary heaters shall have controls that prevent heater operation when the heating load can be met by the heat pump.

Supplemental heater operation is permitted during outdoor coil defrost cycles not exceeding 15 minutes.

EXCEPTION:

> Heat pumps that incorporate a control system that allows auxiliary electric resistance heat to operate above the balance point are permitted, providing the use of all resistance heat is included in the determination of the HSPF for that heat pump and the HSPF meets the minimum efficiency requirements as shown in Table 6-7.

Table 6-7
Electric Driven Heating Equipment
Heat Pumps
Minimum Performance Efficiencies

Category and Rating Conditions Outdoor Temperatures (° F)		Minimum COP	Minimum HSPF
Electric Heat Pumps			
Packaged Terminal (PTHP)			
Standard Rating (47db/43wb)			
<10,000 Btu/h		2.7	
10,000-13,000 Btu/h		2.6	
>13,000 Btu/h		2.5	
Central Systems			
Air Source			
<65,000 Btu/h- Season Rating[2]			
Split-system			6.8
Single-package			6.6
>65,000 Btu/h			
High Temp. Rating (47db/43wb)		3.0	
Low Temp Rating (17db/15wb)		2.0	
>135,000 Btu/h			
High Temp. Rating (47db/43wb)		2.9	
Low Temp. Rating (17db/15wb)		2.0	
Water Source[3]			
Standard Rating	75°F Entering water	3.9	
	70°F Entering water	3.8	
Ground Source[3]			
	32°F Entering water	2.5	
	41°F Entering water	2.7	
Groundwater Source[3]			
High Temp. Rating	70 °F Entering water	3.4	
Low Temp. Rating	50°F Entering water	3.0	

[1] *Equipment testing reference standards are specified in Chapter 3.*

[2] *To be consistent with the National Appliance Energy Conservation Act of 1987.*

[3] *Ratings for water source, ground source, and ground water source heat pumps apply to all units under 135,000 Btu/h.*

[4] *Products covered by the 1992 Energy Policy Act have no efficiency requirements at other than standard rating conditions for products manufactured after 1/1/94.*

608.1.ABC.3.2.1.2.2 Tempering of indoor air during defrost cycles shall be controlled so as to minimize use of supplemental heat.

608.1.ABC.3.2.1.2.4 Supplementary heat on heat pumps with capacities of less than 65,000 Btu/h that is provided by electric resistance heaters shall meet the following conditions:

1. Supplementary electric resistance heat greater than 10kW shall be divided into at least two stages and controlled by outdoor thermostats, multi-stage indoor thermostats, or combinations thereof, to operate only when the system's refrigerating capacity plus previous strip heat stages cannot meet the heating load of the building.

2. Supplementary electric resistance heat plus refrigeration cycle heating capacity shall not exceed 120 percent of the design load at the 99 percent design dry bulb temperature.

608.1.ABC.3.2.2 Central Electric Furnaces. Central electric furnaces greater than 10 kW shall be divided into at least two stages and controlled by an outdoor thermostat, multi-stage indoor thermostat, or combinations thereof.

608.1.ABC.3.2.3 COMBUSTION HEATING EQUIPMENT, MINIMUM EFFICIENCIES AND REQUIREMENTS.

608.1.ABC.3.2.3.1 All gas- and oil-fired furnaces and boilers (as defined in 10 CFR Part 430) shall have an Annual Fuel Utilization Efficiency (AFUE) or steady-state combustion efficiency (E_t), as described in section 608.1.ABC.3.1, of not less than the values shown in Table 6-8.

Table 6-8
Gas- and Oil-Fired Heating Equipment
Rating Conditions and Minimum Performance Efficiencies[1]

Types of Equipment, Rating Conditions	E_t/E_c (%)[2]	AFUE(%)
Warm Air Furnaces		
<225,000 Btu/h[3] (Seasonal Rating)		
Gas-fired		78
Oil-fired		78
≥225,000 Btu/h (Steady-State)		
Gas-fired		
Max. Rating Capacity	80	
Min. Rated Capacity	78	
Oil-fired		
Max. Rated Capacity	81	
Min. Rated Capacity	81	
Warm Air Duct Furnaces		
Gas-fired		
Max. Rated Capacity	78	
Min. Rated Capacity	75	
Unit Heaters		
Gas-fired		
Max. Rated Capacity	78	
Min. Rated Capacity	74	
Oil-fired		
Max. Rated Capacity	81	
Min. Rated Capacity	81	
Boilers		
<300,000 Btu/h (Seasonal Rating)		
Gas-fired except steam boilers		80
Gas-fired steam boilers		75
Oil-fired		80
≥300,000 Btu/h (Steady-State)		
Gas-fired		
Max. Rated Capacity	80	
Min. Rated Capacity	80	
Oil-fired		
Max. Rated Capacity	83	
Min. Rated Capacity	83	
Oil-fired (Residual)		
Max. Rated Capacity	83	
Min. Rated Capacity	83	

1 *Reference standards for equipment testing are specified in Chapter 3.*

2 *Combustion efficiency E_c and thermal efficiency E_t constitute 100 percent minus flue losses in percent of heat input. See the reference standard in Chapter 3 for more information.*

3 *To be consistent with the National Appliance Energy Conservation Act of 1987, Appendix M to Subpart B, 10 CPR Part 430.*

608.1.ABC.3.2.3.2 All gas-fired direct heating equipment shall have an Annual Fuel Utilization Efficiency (AFUE) of not less than the values shown in Table 6-9.

Table 6-9
Gas-Fired Direct Heating Equipment
Minimum Performance Efficiencies

Types of Equipment, BTU/H Heating Capacity	AFUE (%)
Wall	
Fan Type	
Up to 42,000	73
Over 42,000	74
Gravity Type	
Up to 10,000	59
Over 10,000 up to 12,000	60
Over 12,000 up to 15,000	61
Over 15,000 up to 19,000	62
Over 19,000 up to 27,000	63
Over 27,000 up to 46,000	64
Over 46,000	65
Floor	
Up to 37,000	56
Over 37,000	57
Room	
Up to 18,000	57
Over 18,000 up to 20,000	58
Over 20,000 up to 27,000	63
Over 27,000 up to 46,000	64
Over 46,000	65

608.1.ABC.3.2.4 Heating Systems Having Other Functions. Space heating equipment used to provide additional functions (e.g. service water heating) as part of a combination (integrated) system shall comply with minimum performance requirements for the appropriate space heating equipment category. Service water heating equipment used to provide additional functions (e.g. space heating) as part of a combination (integrated) system shall, as a minimum, meet the minimum performance requirements for water heating equipment in section 612.1.ABC.3.5.

608.1.C PRESCRIPTIVE REQUIREMENTS SPECIFIC TO METHOD C

608.1.C.1 Additions. New heating equipment to be added or replaced in small additions complying by Method C shall meet the minimum efficiencies in section 608.1.ABC.3.2. Minimum equipment efficiencies shall be met only when equipment is installed to specifically serve the addition or is being installed in conjunction with the construction of the addition.

608.1.C.2 Renovations. Minimum efficiencies for heating equipment to be added or replaced in renovations shall not be less than those specified in section 608.1.ABC.3.2.

608.1.C.3 Manufactured Homes and Manufactured Buildings. Minimum efficiencies for site-installed heating equipment in manufactured homes shall not be less than those specified in section 608.1.ABC.3.2.

608.1.C.4 Building Systems. Newly manufactured heating systems installed in existing buildings shall meet the minimum requirements for that system in section 608.1.ABC. See section 101.6 for exceptions.

609 VENTILATION SYSTEMS

609.1.ABC Basic Prescriptive Requirements for Methods A, B and C

609.1.ABC.1 Buildings Operated at Positive Indoor Pressure. Residential buildings designed to be operated at a positive indoor pressure or for mechanical ventilation shall meet the following criteria:

1. The design air change per hour minimums for residential buildings in ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, shall be the maximum rates allowed for residential applications where pressurization is provided.

2. No ventilation or air conditioning system make up air shall be provided to conditioned space from attics, roof tops, crawlspaces, attached enclosed garages or outdoor spaces adjacent to swimming pools or spas.

   EXCEPTION: Makeup air may be taken from rooftops for multistory multifamily buildings.

3. If ventilation air is drawn from enclosed space(s), then the walls of the space(s) from which air is drawn shall be insulated to a minimum of R-11 and the ceiling shall be insulated to a minimum of R-19, space permitting, or R-10 otherwise.

610 AIR DISTRIBUTION SYSTEMS

610.1.ABC Basic Prescriptive Requirements for Methods A, B and C

610.1.ABC.1. Air Distribution System Sizing and Design. All air distribution systems shall be sized and designed in accordance with recognized engineering standards such as ACCA Manual D or other standards based on the following:

1. Calculation of the supply air for each room shall be based on the greater of the heating load or sensible cooling load for that room.
2. Duct size shall be determined by the supply air requirements of each room, the available static pressure and the total equivalent length of the various duct runs.
3. Friction loss data shall correspond to the type of material used in duct construction.

610.1.ABC.2 Air Distribution System Insulation Requirements. All air distribution system components which move or contain conditioned air, including but not limited to, air filter enclosures, air ducts and plenums located in or on buildings shall be thermally insulated in accordance with the requirements of sections 610.1.ABC.2.1 through 610.1.ABC.2.3.

610.1.ABC.2.1 Insulation Required. The minimum installed thermal resistance (R-value) for air distribution system components shall be as specified in Table 6-10.

Table 6-10
Minimum Insulation Levels
Air Distribution System Components[1]

Location	R-Value
On roof	R-6
Exterior of building	R-6
Attic with ceiling insulation	R-6
Between conditioned floors[2]	R-4.2
Enclosed attached garages	R-4.2
Unconditioned basement	R-4.2
Vented crawlspace	R-4.2

[1] *See section 610.1.ABC.3.5, Air Handling Units.*
[2] *Except where perimeter walls to the between floor space are insulated.*

EXCEPTION:

Air distribution system component insulation (except where required to prevent condensation) is not required in the following cases:

1. Within conditioned space.

2. Exhaust air ducts.

3. Factory-installed plenums, casings, or ductwork furnished as a part of HVAC equipment tested and rated in accordance with section 607.1.ABC.3 or 608.1.ABC.3.

610.1.ABC.2.2 R-Value Determination. All duct insulation and factory-made ducts shall be labeled with R-values based on flat sections of insulation only at installed thickness and excluding any air film resistance. The thermal resistance (R) shall be determined using the relationship R = t/k where t (inches) is the installed thickness and k (Btu-in/hr·ft^2°F) is the measured apparent thermal conductivity at 75°F mean temperature and at installed thickness tested in accordance with ASTM C 518 or ASTM C 177.

The installed thickness of duct insulation used to calculate R-values shall be determined as follows:

1. Duct board, duct liner and factory-made rigid ducts not normally subjected to compression shall use the nominal insulation thickness.

2. Duct wrap shall have an assumed installed thickness of 75% of nominal thickness (25% compression).

3. Factory-made flexible air ducts shall have the installed thickness and calculated R-values determined in accordance with Paragraph 3.4 of the 1996 Edition of the ADC Standard, Flexible Duct Performance & Installation Standards, Third Edition.

610.1.ABC.2.3 Condensation Control. Additional insulation with vapor barrier shall be provided where the minimum duct insulation requirements of 610.1.ABC.2 are determined to be insufficient to prevent condensation.

610.1.ABC.2.4 Fibrous Glass Duct Liner. Fibrous glass duct liner shall be fabricated and installed in accordance with the provisions of the NAIMA Fibrous Glass Duct Liner Standard, 1994.

610.1.ABC.3 Air Distribution System Construction and Installation. Ducts shall be constructed, braced, reinforced and installed to provide structural strength and durability. All transverse joints, longitudinal seams and fitting connections shall be securely fastened and sealed in accordance with the applicable standards of this section.

As an alternative to compliance with specific criteria of sections 610.1.ABC.3.0.4 through 610.1.ABC.3.2.1, 610.1.ABC.3.3.1 through 610.1.ABC.3.3.2, and 610.1.ABC.3.3.6, air ducts and duct systems complying with the applicable requirements of the following standards shall be deemed as meeting the intent of this Code. Where these standards do not address the specific closure details of the Code, in the manner required by the subsequent sections of this Code, the requirements of the Code shall govern.

1. SMACNA HVAC Duct Construction Standards, Metal and Flexible.
2. NAIMA Fibrous Glass Duct Construction Standards.
3. ADC Flexible Duct Performance and Installation Standards.
4. ASHRAE Handbook - HVAC Systems and Equipment.
5. UL 181.
6. UL181A: Part I; Part II; Part III.
7. UL 181B: Part I; Part II.

610.1.ABC.3.0 General. All enclosures which form the primary air containment passageways for air distribution systems shall be considered ducts or plenum chambers and shall be constructed and sealed in accordance with the applicable criteria of this section.

610.1.ABC.3.0.1 Mechanical Fastening. All joints between sections of air ducts and plenums, between intermediate and terminal fittings and other components of air distribution systems, and between subsections of these components shall be mechanically fastened to secure the sections independently of the closure system(s).

610.1.ABC.3.0.2 Sealing. Air distribution system components shall be sealed to 100 percent closure with approved closure systems.

610.1.ABC.3.0.3 Space Provided. Sufficient space shall be provided adjacent to all mechanical components located in or forming a part of the air distribution system to assure adequate access for 1) construction and sealing in accordance with the requirements of section 610.1.ABC.3 of this Code 2) inspection and 3) cleaning and maintenance. A minimum of 4" is considered sufficient space around air handling units.

610.1.ABC.3.0.4. Product Application. Closure products shall be applied to the air barriers of air distribution system components being joined in order to form a continuous barrier or they may be applied in accordance with the manufacturer's instructions or appropriate industry installation standard where more restrictive.

610.1.ABC.3.0.5 Surface Preparation. The surfaces upon which closure products are to be applied shall be clean and dry in accordance with the manufacturer's installation instructions.

610.1.ABC.3.0.6 Approved Mechanical Attachments. Approved mechanical attachments for air distribution system components include screws, rivets, welds, inter-locking joints crimped and rolled, staples, twist in (screw attachment), and compression systems created by bend tabs or screw tabs and flanges or by clinching straps. Mechanical attachments shall be selected to be appropriate to the duct system type.

610.1.ABC.3.0.7 Approved Closure Systems. The following closure systems and materials are approved for air distribution construction and sealing for the applications and pressure classes prescribed in sections 610.1.ABC.3.1 through 610.1.ABC.3.8:

1. Metal Closures.
   a. Welds applied continuously along metal seams or joints through which air could leak.
   b. Longitudinal grooved metal seams and snaplock seams that are rolled and crimped by the manufacturer.
2. Gasketing material placed between mated surfaces which are mechanically fastened with sufficient force to compress the gasket and to fill all voids and cracks through which air leakage would otherwise occur.
3. Mastic Closures. Mastics shall be placed over the entire joint between mated surfaces. Mastics shall not be diluted. Approved mastics include the following:
   a. Mastic or mastic plus embedded fabric systems applied to fibrous glass ductboard that are listed and labeled in accordance with the Standard UL 181A, Part III.
   b. Mastic or mastic plus embedded fabric systems applied to non-metal flexible duct that are listed and labeled in accordance with the Standard UL 181B, Part II.

4. Tapes. Tapes shall be applied such that they extend not less than 1 inch onto each of the mated surfaces and shall totally cover the joint. When used on rectangular ducts, tapes shall be used only on joints between parallel rigid surfaces and on right angle joints. Approved tapes include the following:

   a. Pressure-sensitive tapes.

      1) Pressure-sensitive tapes applied to fibrous glass ductboard that are listed and labeled in accordance with the Standard UL181A, Part I.

      2) Pressure-sensitive tapes applied to non-metal flexible duct that are listed and labeled in accordance with the Standard UL 181B, Part I.

   b. Heat-activated tapes applied to fibrous glass ductboard that are listed and labeled in accordance with the Standard UL 181A, Part II.

610.1.ABC.3.1 Metal Duct, Rigid and Flexible. All transverse joints, longitudinal seams and duct wall penetration of ducts and joints with other air distribution system components shall be mechanically attached and sealed to 100 percent closure using approved closure systems for that pressure class specified in section 610.1.ABC.3.1.1 or section 610.1.ABC.3.1.2.

610.1.ABC.3.1.1 Pressures Less Than 1 Inch Water Gauge, Approved Closure Systems. The following closure systems are approved for rigid metal duct designed to be operated at pressures less than 1" w.g. when they conform to the approved closure and mechanical attachment requirements of section 610.1.ABC.3.0:

1. Continuous welds.
2. Longitudinal grooved seams, Pittsburgh lock and snaplock seams.
3. Mastic or mastic-plus-embedded fabric.
4. Gaskets.
5. Pressure-sensitive tape.

610.1.ABC.3.1.2 Pressures 1 Inch Water Gauge or Greater, Approved Closure Systems. The following closure systems are approved for rigid metal duct designed to be operated at pressures 1" w.g. or greater and flexible duct when they conform to the approved closure and mechanical attachment requirements of section 610.1.ABC.3.0:

1. Continuous welds.

2. Mastic or mastic-plus-embedded fabric systems.

3. Gaskets.

610.1.ABC.3.1.3 High Pressure Duct Systems. High pressure duct systems designed to operate at pressures greater than 3 inches water gauge (4 inches water gauge pressure class), shall be tested in accordance with the SMACNA HVAC Air Duct Leakage Test Manual. The tested duct leakage class, at a test pressure equal to the design duct pressure class rating, shall be equal to or less than Leakage Class 6. Leakage testing may be limited to representative sections of the duct system but in no case shall such tested sections include less than 25 percent of the total installed duct area for the designated pressure class.

610.1.ABC.3.2 Fibrous Glass Duct, Rigid. All rigid fibrous glass ducts and plenums shall be constructed and erected in accordance with the provisions of the NAIMA Fibrous Glass Duct Construction Standards, 1993.

All joints, seams and duct wall penetrations including, but not limited to, the joints between sections of duct and the joints between duct and other distribution system components shall be mechanically attached and sealed to 100 percent closure using approved closure systems as specified in section 610.1.ABC.3.2.1.

610.1.ABC.3.2.1 Approved Closure Systems. The following closure systems are approved for rigid fibrous glass ducts when they conform to the approved closure and mechanical attachment requirements of section 610.1.ABC.3.0:

1. Heat-activated tapes.

2. Pressure-sensitive tapes.

3. Mastics or mastic-plus-embedded fabric systems.

610.1.ABC.3.3 Flexible Duct Systems, Non-Metal. Flexible non-metal ducts shall be joined to all other air distribution system components by either terminal or intermediate fittings. All duct collar fittings shall have a minimum 5/8 inch integral flange for sealing to other components and a minimum 3 inch shaft for insertion into the inner duct core.

Flexible ducts having porous inner cores shall not be used.

EXCEPTION:

> Ducts having a non-porous liner between the porous inner core and the outer jacket. Fastening and sealing requirements shall be applied to such intermediate liners.

All joints of flexible ducts to fittings and fittings to other air distribution system components shall be mechanically attached and sealed as specified in sections 610.1.ABC.3.3.1 through 610.1.ABC.3.3.6.

610.1.ABC.3.3.1 Duct Core to Duct Fitting, Mechanical Attachment. The reinforced core shall be mechanically attached to the duct fitting by a drawband installed directly over the wire-reinforced core and the duct fitting. The duct fitting shall extend a minimum of 2 inches into each section of duct core. When the flexible duct is larger than 12 inches in diameter or the design pressure exceeds 1 inch water gauge, the drawband shall be secured by a raised bead or indented groove on the fitting.

610.1.ABC.3.3.2 Duct Core to Duct Fitting, Approved Closure Systems. The reinforced lining shall be sealed to the duct fitting using one of the following sealing materials which conforms to the approved closure and mechanical attachment requirements of section 610.1.ABC.3.0:

1. Gasketing.
2. Mastic or mastic-plus-embedded fabric.
3. Pressure-sensitive tape.

610.1.ABC.3.3.3 Duct Outer Jacket to Duct Collar Fitting. The outer jacket of a flexible duct section shall be secured at the juncture of the air distribution system component and intermediate or terminal fitting in such a way as to prevent excess condensation. The outer jacket of a flexible duct section shall not be interposed between the flange of the duct fitting and the flexible duct, rigid fibrous glass duct board, or sheet metal to which it is mated.

610.1.ABC.3.3.4 Duct Collar Fitting to Rigid Duct, Mechanical Attachment. The duct collar fitting shall be mechanically attached to the rigid duct board or sheet metal by appropriate mechanical fasteners, either screws, spin-in flanges, or dovetail flanges.

610.1.ABC.3.3.5 Duct Collar Fitting to Rigid Duct, Approved Closure Systems. The duct collar fitting's integral flange shall be sealed to the rigid duct board or sheet metal using one of the following closure systems/materials which conforms to the approved closure and mechanical attachment standards of section 610.1.ABC.3.0:

1. Gasketing.
2. Mastic or mastic-plus-embedded fabric systems.
3. Pressure-sensitive tape.

610.1.ABC.3.3.6 Flexible Duct Installation and Support. Flexible ducts shall be configured and supported so as to prevent the use of excess duct material, prevent duct dislocation or damage, and prevent constriction of the duct below the rated duct diameter in accordance with the following requirements:

1. Ducts shall be installed fully extended. The total extended length of duct material shall not exceed 5 percent of the minimum required length for that run.
2. Bends shall maintain a center line radius of not less than one duct diameter.
3. Terminal devices shall be supported independently of the flexible duct.
4. Horizontal duct shall be supported at intervals not greater than 5 feet. Duct sag between supports shall not exceed 1/2 inch per foot of length. Supports shall be provided within 1.5 feet of intermediate fittings and between intermediate fittings and bends. Ceiling joists and rigid duct or equipment may be considered to be supports.
5. Vertical duct shall be stabilized with support straps at intervals not greater than 6 feet.
6. Hangers, saddles and other supports shall meet the duct manufacturer's recommendations and shall be of sufficient width to prevent restriction of the internal duct diameter. In no case shall the material supporting flexible duct that is in direct contact with it be less than 1½ inches wide.

610.1.ABC.3.4 Terminal and Intermediate Fittings. All seams and joints in terminal and intermediate fittings, between fitting subsections and between fittings and other air distribution system components or building components shall be mechanically attached and sealed to 100 percent closure as specified in section 610.1.ABC.3.4.1 or 610.1.ABC.3.4.2.

610.1.ABC.3.4.1 Fittings and Joints Between Dissimilar Duct Types, Approved Closure Systems. Approved closure systems shall be as designated by air distribution system component material type in section 610.1.ABC.3.

EXCEPTION:

When the components of a joint are fibrous glass duct board and metal duct, including collar fittings and metal equipment housings, the closure systems approved for fibrous glass duct shall be used.

610.1.ABC.3.4.2 Terminal Fittings and Air Ducts to Building Envelope Components, Approved Closure Systems. Terminal fittings and air ducts which penetrate the building envelope shall be mechanically attached to the structure and sealed to the envelope component penetrated and shall use one of the following closure systems/materials which conform to the approved closure and mechanical application requirements of section 610.1.ABC.3.0:

1. Mastics or mastic-plus-embedded fabrics.
2. Gaskets used in terminal fitting/grille assemblies which compress the gasket material between the fitting and the wall, ceiling or floor sheathing.

610.1.ABC.3.5 Air Handling Units. All air handling units shall be mechanically attached to other air distribution system components. Air handling units located outside the conditioned space shall be sealed to 100 percent closure using approved closure systems conforming to the approved closure and mechanical application requirements of section 610.1.ABC.3.1.

610.1.ABC.3.5.1 Approved Closure Systems. Systems conforming to the product and application standards of section 610.1.ABC.3.0 may be used when sealing air handling units.

610.1.ABC.3.6 Cavities of the Building Structure. Cavities in framed spaces, such as dropped soffits and walls, shall not be used to deliver air from or return air to the conditioning system unless they contain an air duct insert which is insulated in accordance with section 610.1.ABC.2 and constructed and sealed in accordance with the requirements of section 610.1.ABC.3 appropriate for the duct materials used.

EXCEPTION:

Return air plenums.

Cavities designed for air transport such as mechanical closets, chases, air shafts, etc. shall be lined with an air barrier and sealed in accordance with section 610.1.ABC.3.7 and shall be insulated in accordance with section 610.1.ABC.2.

Building cavities which will be used as return air plenums shall be lined with a continuous air barrier made of durable non-porous materials. All penetrations to the air barrier shall be sealed with a suitable long-life mastic material.

EXCEPTION:

> Surfaces between the plenum and conditioned spaces from which the return/mixed air is drawn.

Building cavities beneath a roof deck that will be used as return air plenums shall have an insulated roof with the insulation having an R-value of at least R-19.

610.1.ABC.3.7 Mechanical Closets. The interior surfaces of mechanical closets shall be sheathed with a continuous air barrier as specified in section 610.1.ABC.3.7.1 and shall be sealed to 100 percent closure with approved closure systems as specified in section 610.1.ABC.3.7.2. All joints shall be sealed between air barrier segments and between the air barriers of walls and those of the ceiling, floor and door framing. All penetrations of the air barrier including, but not limited to, those by air ducts, plenums, pipes, service lines, refrigerant lines, electrical wiring, and condensate drain lines shall be sealed to the air barrier with approved closure systems.

EXCEPTION:

> Air passageways into the closet from conditioned space that are specifically designed for return air flow.

Through-wall, through-floor and through-ceiling air passageways into the closet shall be framed and sealed to form an airtight passageway using approved air duct materials and approved closure systems.

Duct penetrations through any part of the ceiling, walls or floor of a mechanical closet shall have sufficient space between surrounding ceiling, walls or floor and any duct or plenum penetration to allow for sealing of the penetration and inspection of the seal.

Clothes washers, clothes dryers, combustion water heaters and atmospheric combustion furnaces shall not be located in mechanical closets used as return air plenums.

610.1.ABC.3.7.1 Approved Air Barriers. The following air barriers are approved for use in mechanical closets:

1. One-half inch thick or greater gypsum wallboard, taped and sealed.
2. Other panelized materials having inward facing surfaces with an air porosity no greater than that of a duct product meeting section 22 of UL 181 which are sealed on all interior surfaces to create a continuous air barrier.

610.1.ABC.3.7.2 Approved Closure Systems. The following closure systems are approved for use in mechanical closets:

1. Gypsum wallboard joint compound over taped joints between gypsum wallboard panels.
2. Sealants complying with the product and application standards of section 610.1.ABC.3.2.1 for fibrous glass ductboard;
3. A suitable long-life caulk or mastic compliant with the locally adopted mechanical code for all applications.

610.1.ABC.3.8 Enclosed Support Platforms. Enclosed support platforms located between the return air inlet(s) from conditioned space and the inlet of the air handling unit or furnace, shall contain a duct section constructed entirely of rigid metal, rigid fibrous glass duct board, or flexible duct which is constructed and sealed according to the respective requirements of section 610.1.ABC.3. and insulated according to the requirements of section 610.1.ABC.2.

The duct section shall be designed and constructed so that no portion of the building structure, including adjoining walls, floors and ceilings, shall be in contact with the return air stream or function as a component of this duct section.

The duct section shall not be penetrated by a refrigerant line chase, refrigerant line, wiring, pipe or any object other than a component of the air distribution system.

Through-wall, through-floor and through-ceiling penetrations into the duct section shall contain a branch duct which is fabricated of rigid fibrous glass duct board or rigid metal and which extends to and is sealed to both the duct section and the grille side wall surface. The branch duct shall be fabricated and attached to the duct insert in accordance with section 610.1.ABC.3.2 or section 610.1.ABC.3.1, respective to the duct type used.

610.1.C Prescriptive Requirements Specific to Method C.

610.1.C.1 Additions. New ducts that are installed to serve an addition shall either be insulated to R-6 or be installed in conditioned space as designated on Table 6C-1 of Form 600C.

EXCEPTION:

> Only new or replacement ducts installed as part of the addition shall meet this requirement.

610.1.C.2 Renovations. Replacement duct systems that are not in conditioned space shall be insulated to levels specified in section 610.1.C.1.

EXCEPTION:

Only new or replacement ducts installed as part of the renovation shall meet this requirement.

610.1.C.3 Manufactured Homes and Manufactured Buildings. Site-installed components and features of the air distribution system(s) of manufactured homes shall be insulated, constructed, sealed and supported in accordance with the requirements of sections 610.1.ABC.2 and 610.1.ABC.3. The duct connection between the air distribution systems of separate units of multiple unit manufactured homes and buildings shall be installed, sealed and inspected according to the provisions of this Code.

Manufactured homes and buildings having interior furnaces and site-installed single package air conditioners which share the same supply registers shall have an automatic backflow damper installed between the air conditioning unit and the factory-installed duct to prevent the functioning of return grilles as supply registers and to prevent the forced passage of conditioned air through inactive air handlers when another system is in operation.

610.1.C.4 Building Systems. Newly manufactured air distribution system components installed in existing buildings shall meet the minimum requirements for air distribution systems contained in sections 610.1.ABC.2 through 610.1.ABC.8, as appropriate. See section 101.6 for exceptions.

611 PIPING

611.1.ABC Basic Prescriptive Requirements for Methods A, B and C

611.1.ABC.1 Piping Insulation. All piping installed to service buildings and within buildings, including the vapor line of HVAC refrigerant piping, shall be thermally insulated in accordance with Table 6-11, except as stated herein (for service water heating systems, see section 612.1.ABC.5).

Table 6-11
Minimum Pipe Insulation

Piping System Types	Fluid Temperature Range (°F)	Runouts [2] (inches)	Insulation for Pipe ≤1"	Thickness Sizes[1] 1.25"-2"
Heating Systems				
Steam and hot water				
Low pressure/temp.	201-250	1.0	1.5	1.5
Low temp.	120-200	0.5	1.0	1.0
Steam condensate (for feed water)	Any	1.0	1.0	1.5
Cooling Systems				
Chilled water, refrigerant or brine	40-55	0.5	0.5	0.75
	Below 40	1.0	1.0	1.50

[1] *For piping larger than 1 inch diameter and exposed to outdoor ambient temperatures, increase thickness by 0.5 inch.*

[2] *Runouts to individual thermal units (not exceeding 12 feet in length).*

[3] *The required minimum thicknesses do not consider water vapor transmission and condensation. Additional insulation, vapor retarders, or both, may be required to limit water vapor transmission and condensation.*

EXCEPTIONS:

Piping insulation is not required in the following cases:

1. Piping installed within HVAC equipment.
2. Piping containing fluid at temperatures between 55°F and 120°F.
3. Piping within the conditioned space.
4. Piping within basements or unvented crawl spaces (plenums) having insulated walls.

611.1.ABC.1.1 Other Insulation Thicknesses. Insulation thickness in Table 6-10 are based on insulation having thermal resistance in the range of 4.0 to 4.6 °F·ft²·h/Btu· per inch of thickness on a flat surface at a mean temperature of 75°F.

Minimum insulation thickness shall be increased for materials having R-values less than 4.0 °F·ft²·h/Btu·in. or may be reduced for materials having R-values greater than 4.6 °F·ft²·h/Btu·in. as follows:

1. For materials with thermal resistivity greater than R-4.6, the minimum insulation thickness may be reduced as follows:

$$\text{New Minimum Thickness} = \frac{4.6 \times \text{Table 6-10 Thickness}}{\text{Actual Resistivity}}$$

2. For material with thermal resistivity less than R-4.0, the minimum insulation thickness shall be increased as follows:

$$\text{New Minimum Thickness} = \frac{4.0 \times \text{Table 6-10 Thickness}}{\text{Actual Resistivity}}$$

612 WATER HEATING SYSTEMS

612.1.ABC Basic Prescriptive Requirements for Methods A, B and C

612.1.ABC.2 Controls.

612.1.ABC.2.1 Storage Water Heater Temperature Controls.

612.1.ABC.2.1.1 Automatic Controls. Service water heating systems shall be equipped with automatic temperature controls capable of adjustment from the lowest to the highest acceptable temperature settings for the intended use. The minimum temperature setting range shall be from 100°F to 140°F.

612.1.ABC.2.1.2 Shut Down. a separate switch or a clearly marked circuit breaker shall be provided to permit the power supplied to electric service systems to be turned off. a separate valve shall be provided to permit the energy supplied to the main burner(s) of combustion types of service water heating systems to be turned off.

612.1.ABC.2.2 Heat Traps. Residential water heaters with storage tanks shall have heat traps on both the inlets and outlets. Those not having built-in heat traps shall be installed with an external heat trap. Such devices shall consist of either a commercially available heat trap or a downward and upward bend of at least 3½ inches in the hot water distribution line and cold water line located as close as practical to the storage tank.

612.1.ABC.2.3 Swimming Pool and Spa Temperature Controls

612.1.ABC.2.3.1 On-Off Switch Required. All pool and spa heaters shall be equipped with an ON-OFF switch mounted for easy access to allow the heater to be shut off without adjusting the thermostat setting and to allow restarting without relighting the pilot light.

All gas- and oil-fired pool heaters when tested in accordance with ANSI Z21.56-94 shall have a minimum thermal efficiency of 78 percent.

612.1.ABC.2.3.2 Covers Required. Spas and heated swimming pools shall be equipped with a cover designed to minimize heat loss.

EXCEPTION:

> Outdoor pools deriving over 70 percent of the energy for heating from non-depletable on site-recovered sources computed over an operating season are exempt from this requirement.

612.1.ABC.2.3.3 Time Clocks on Private Pools. Time clocks shall be installed on private pools so that the pump can be set to run during off-peak electric demand periods and can be set for the minimum time necessary to maintain the water in a clear and sanitary condition in keeping with applicable health standards.

EXCEPTIONS:

Pumps connected to swimming pool solar water heating systems or any pool legally considered a public pool.

612.1.ABC.2.4 Showers. Showers used for other than safety reasons shall be equipped with flow control devices to limit the water discharge to a maximum of two and one-half (2.50) gpm per shower head at a distribution pressure of 80 psig when tested in accordance with the procedures of ANSI A112.18.1M-1989. Flow restricting inserts used as a component part of a showerhead shall be mechanically retained at the point of manufacture.

612.1.ABC.3.1 ELECTRIC WATER HEATER EFFICIENCIES.

612.1.ABC.3.1.1 Storage Capacities Of 120 Gallons Or Less. All automatic electric storage water heaters having a storage capacity of 120 gallons or less and an input rating of 12 kw or less shall, when tested in accordance with the DOE Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Appendix E to Subpart B, 10 CFR Part 430, meet the performance minimums listed in Table 6-11.

612.1.ABC.3.1.2 Storage Capacities Greater Than 120 Gallons. Performance minimums for electric storage water heaters with capacities greater than 120 gallons or an input rate greater than 12 KW shall have a standby loss of $.30+27/V_T$ percent/hour or less, where V_T is the tested storage volume in gallons and tested in accordance with ANSI test method Z21.10.3-1990.

612.1.ABC.3.2 GAS- AND OIL-FIRED WATER HEATER EFFICIENCIES.

612.1.ABC.3.2.1 Tanks With Input Ratings Of 75,000 Btu/h or Less (Gas) or 105,000 Btu/h or Less (Oil). All gas- and oil-fired automatic storage water heaters with capacities of 100 gallons or less and an input rating of 75,000 Btu/h or less (gas) or 105,000 Btu/h or less (oil) shall, when tested in accordance with the DOE Uniform Test Method for Measuring the Energy Consumption of Water Heaters, Appendix E to Subpart B, 10 CFR Part 430, meet the performance minimums listed in Table 6-12.

Table 6-12 Minimum Performance Standards Water Heating Equipment: Fired Storage Water Heater Minimum Energy Factors (EF)

Type/ Volume	Tank Volume (Gallons)								
	20	30	40	50	65	75	80	100	120
Electric: Up to 120 gal or 12kW input	.90	.89	.88	.86	.84	—	.82	.80	.77
Gas: Up to 100 gal or 75,000 Btu/h input	.58	.56	.54	.52	.50	.48	—	.43	—
Oil: Up to 50 gal or 75,000 Btu/h input	—	.53	.51	.50	—	—	—	—	—

612.1.ABC.3.2.2 Tanks With Input Ratings Greater Than 75,000 Btu/h (Gas) or Greater Than 105,000 Btu/h (Oil). All gas-fired storage water heaters with input ratings greater than 75,000 Btu/h but less than or equal to 155,000 Btu/h, and all oil-fired storage water heaters with input ratings greater than 105,000 Btu/h but less than or equal to 155,000 Btu/h, shall have a steady-state combustion efficiency E_t of .78 or less and a standby loss of $1.30+114/V_T$ (in percent/hour) or less, where V_T is the tested storage volume in gallons. All gas- and oil-fired storage water heaters with input ratings greater than 155,000 Btu/h shall have a steady-state combustion efficiency E_t of .78 or more and a standby loss of $1.30+95/V_T$, where V_T is the tested storage volume in gallons.

612.1.ABC.3.3 Unfired Storage Tanks. All unfired storage tanks shall have a standby loss of 6.5 Btu/h/ft^2 or less, based on an 80°F water-air temperature difference.

612.1.ABC.3.4 Solar Water Heating Systems. Solar systems for domestic hot water production are rated by the *Energy Factor* of the system. The Energy Factor of a system shall be determined from a Florida Solar Energy Center Directory of Certified Solar Systems. Solar collectors shall be tested and rated in accordance with ASHRAE Standard 93-1986 (RA91), Method of Testing to Determine the Thermal Performance of Solar Collectors and should meet the following criteria:

1. Be installed with a tilt angle between 15° and 40° of horizontal; and
2. Be installed at an orientation within 45° of South.

612.1.ABC.3.5 Combination Service Water Heating and Space Heating Equipment. Service water heating equipment used to provide additional functions (e.g. space heating) as part of a combination (integrated) system shall comply with minimum performance requirements for water heating equipment.

Combination water and space heating systems with input ratings of 105,000 Btu/h or less shall utilize a water heater listed by the Gas Appliance Manufacturer's Association (GAMA). Changeouts of burners to increase capacity shall not be made unless the unit has been listed at that capacity by GAMA.

Combination systems with input ratings greater than 105,000 Btu/h shall comply with the criteria of section 412.1.ABCD.3.4, Chapter 4.

612.1.ABC.4 Pumps. Circulating hot water systems shall be arranged so that the circulating pump(s) can be conveniently turned off (automatically or manually) when the hot water system is not in operation.

612.1.ABC.5 Piping Insulation. Circulating hot water systems (including piping for waste heat recovery systems (HRUs)) shall be insulated with insulation of at least ½" minimum thickness with a thermal conductivity no greater than 0.28 $Btu/in./h \cdot ft^{2} \cdot {}^{\circ}F$.

Pipe insulation buried underground shall be as specified by the manufacturer for underground use.

612.1.C Prescriptive Requirements Specific to Method C. New water heating equipment installed in small additions and renovations shall meet the minimum efficiencies given on Table 6C-1 of Form 600C.

612.1.C.1 Additions. All new water heaters installed in an addition shall meet the minimum efficiencies listed in section 612.1.ABC.3, Table 6-11.

EXCEPTION:

> Only water heating systems which are being replaced or installed as part of the addition shall meet this requirement.

612.1.C.2 Renovations. Minimum efficiencies for water heating equipment installed in renovations shall be not less than those listed in Table 6-11, section 612.1.ABC.3.

EXCEPTION:

> Only water heating systems which are being replaced or installed as part of the renovation shall meet this requirement.

612.1.C.3 Building Systems. New water heating systems installed in existing buildings shall meet the minimum requirements for that system in section 612.1.ABC.

SUPPLEMENTAL INFORMATION FOR CHAPTER 4

1.1 GENERAL

Information on thermal properties, performance of building envelope sections, and components and heat transfer shall be obtained from the 1997 ASHRAE Handbook of Fundamentals. When the information is not available from this source, the data may be obtained from manufacturer's information based on laboratory or field test measurements.

If laboratory or field test measurements are used for envelope heat transmission, they shall be obtained using one of the following test methods:

1. Guarded Hot Plate: ASTM C-177-97
2. Heat Flow Meter: ASTM C-518-91
3. Guarded Hot Box: ASTM C-236-89
4. Calibrated Hot Box: ASTM C-976-90

1.1.1 Climate data for determining criteria or compliance values for various cities shall be as provided in the FLA/COM computer program.

1.1.2 The requirements of this Chapter are to be used for determining compliance with this Code. They are not intended to replace the building loads calculation procedures in the 1997 ASHRAE Handbook of Fundamentals. Relative to mean radiant temperature, the requirements are based on the assumption that mean radiant temperature is equal to dry-bulb air temperature. For consideration of mean radiant temperature effects under other conditions, reference should be made to ASHRAE Standard 55-92.

2.1 THERMAL TRANSMITTANCE

2.1.1 Overall Thermal Transmittance (U_o). The overall thermal transmittance of the building envelope assembly shall be calculated in accordance with Equation 4-5:

EQUATION 4-5

$$U_o = U_i A_i / A_o$$
$$= (U_1 A_1 + U_2 A_2 + \cdots + U_n A_n)/A_o$$

Where:

U_o	=	The area-weighted average thermal transmittance of the gross area of an envelope assembly; i.e., the exterior wall assembly including fenestration & doors, the roof and ceiling assembly, and the floor assembly, Btu/(h·ft²·°F).
A_o	=	The gross area of the envelope assembly, ft².
U_i	=	The thermal transmittance of each individual path of the envelope assembly, i.e., the opaque portion of the fenestration, Btu/(h·ft²·°F).
U_i	=	$1/R_i$ (where R_i is the total resistance to heat flow of an individual path through an envelope assembly).
A_i	=	The area of each individual element of the envelope

2.1.2 Fenestration Assemblies. U-values (thermal transmittances) of fenestration products (windows, doors and skylights) shall be determined in accordance with the National Fenestration Rating Council 100, *Procedure for Determining Fenestration Product Thermal Properties* by an accredited, independent laboratory and labeled and certified by the manufacturer. Such certified and labeled U-values shall be accepted for the purposes of determining compliance with the building envelope requirements of this code.

When a manufacturer has not determined product U-value in accordance with NFRC 100 for a particular product line, compliance with the building envelope requirements of this code shall be determined by assigning such products a default U-value in accordance with Tables 4B-1 and 4B-2. Product features must be verifiable for the product to qualify for the default value associated with those features. Where the existence of a particular feature cannot be determined with reasonable certainty, the product shall not receive credit for that feature. Where a composite of materials from two different product types are used, the product shall be assigned the higher U-value.

2.1.3 Walls. The thermal transmittance of each envelope assembly shall be determined with due consideration of all major series and parallel heat flow paths through the elements of the assembly and film coefficients. Compression of insulation shall be considered in determining the thermal resistance.

Table 4B-1
U-Value Default Table for Windows, Glazed Doors and Skylights

Product Description	Single Glazed	Double Glazed
Metal without Thermal Break		
Operable	1.30	0.87
Fixed	1.17	0.69
Door	1.26	0.80
Skylight	1.92	1.30
Metal with Thermal Break		
Operable	1.07	0.67
Fixed	1.11	0.63
Door	1.10	0.66
Skylight	1.93	1.13
Metal-Clad Wood		
Operable	0.98	0.60
Fixed	1.05	0.58
Door	0.99	0.57
Skylight	1.50	0.88
Wood or Vinyl		
Operable	0.94	0.56
Fixed	1.04	0.57
Door	0.98	0.56
Skylight	1.47	0.85

Glass block assemblies shall have a U-value of 0.60.
(Source: 1995 Model Energy Code, Table 102.3a)

Table 4B-2
U-Value Default Table for Non-glazed Doors

Product Description	With Foam Core	Without Foam Core
Steel Doors (1 3/4" thick)	0.35	0.60
Wood Doors (1 3/4" thick)	Without Storm Door	With Storm Door
Panel with 7/16" panels	0.54	0.36
Hollow core flush	0.46	0.32
Panel with 1 1/8" panels	0.39	0.28
Solid core flush	0.40	0.26

(Source: 1995 Model Energy Code, Table 102.3b)

2.1.4 Parallel Path Procedure. The thermal transmittance of opaque elements of assemblies shall be determined using a series path procedure with correction for the presence of parallel paths within an element of the envelope assembly (such as wall cavities with parallel paths through insulation and studs).

2.1.5 Metal Framing. For envelope assemblies containing metal framing, the thermal transmittance of the series elements (U_i) shall be determined by using one of the following methods:

1. Results from laboratory or field test measurements. One of the procedures specified in section 1.1 of Appendix B shall be used.

2. The zone method described in Chapter 24 of the 1997 ASHRAE Handbook of Fundamentals and the formulas on pages 24.10 through 24.11 shall be used for calculation.

3. The total thermal resistance of the series path shall be calculated in accordance with the following equations:

EQUATION 4-6

$$U_i = 1/R_t$$

EQUATION 4-7

$$R_t = R_i + R_e$$

Where:

R_t = The total resistance of the envelope assembly.

R_i = The resistance of the series elements (for I = 1 to n) excluding the parallel path element(s).

R_e = The equivalent resistance of the element containing the parallel path.

= (R-value of insulation × F_c). Values for F_c and equivalent resistances shall be taken from Tables 4B-3 or 4B-4 below.)

2.1.6 Non-Metal Framing. For envelope assemblies containing non-metal framing, the U_i shall be determined from one of the laboratory or field test measurements specified in section 1.1 of Appendix B or from the ASHRAE series-parallel method. Formulas in Chapter 22, page 22.8 of the 1997 ASHRAE Handbook of Fundamentals shall be used for these calculations.

2.1.7 Below-Grade Components. In all below-grade applications, the thermal performance of the adjacent ground shall be excluded in determining the thermal resistance of the below-grade components. The R-value required for below-grade walls refers to the overall R-value of the wall assembly excluding air film coefficients and the adjacent ground.

2.1.8 (A) Roofs/Ceiling. Method B of FLA/COM uses the following equation and exceptions to determine overall thermal transmittance.

EQUATION 4-8

Overall Thermal Transmittance-Roofs

$$U_{or} = \frac{1}{(5.3 + 1.8 \times 10^{-3} \times HDD65 + 1.3 \times 10^{-3} \times CDD65 + 2.6 \times 10^{-4} \times CDH80)}$$

EXCEPTIONS:

1. Any building that is heated only shall have an overall thermal transmittance value (U_{or}) for the gross area of the roof assembly less than or equal to the value determined by Equation 4-8 with CDD65 and CDH80 set equal to zero.

2. Any building that is mechanically cooled only shall have an overall thermal transmittance value (U_{or}) for the gross area of the roof assembly less than or equal to the value determined by Equation 4-8 with HDD65 set equal to zero.

3. Spaces that are neither heated nor cooled shall have an overall thermal transmittance value (U_{or}) for the gross area of roof assembly less than or equal to 0.19 Btu/(h·ft^2·°F).

2.1.8 (B) Roofs/Ceilings. For thermal transmittance purposes, when return air ceiling plenums are employed, the roof or ceiling assembly shall not include the resistance of the ceiling or the plenum space as part of the total resistance of the assembly.

2.1.9 Floors. The thermal resistance of floors shall be in accordance with the criteria of section 2.1.1 of Appendix B.

2.1.10 Slabs. The R-value and dimensions required for slabs refers only to the insulation materials. Insulative continuity shall be maintained in the design of slab edge insulation systems. Continuity shall be maintained from the wall insulation through the slab/wall/footing intersection to the body of the slab edge insulation.

3.1 SHADING COEFFICIENTS AND SOLAR HEAT GAIN COEFFICIENTS

The Shading Coefficient (SC) for fenestrations shall be determined by converting the product's Solar Heat Gain Coefficient to a Shading Coefficient (dividing the SHGC by 0.87). The Solar Heat Gain Coefficient (SHGC) for glazed fenestration products (windows, glazed doors and skylights) shall be determined in accordance with National Fenestration Rating Council 200: *Procedure for Determining Fenestration Product Solar Heat Gain Coefficients at Normal Incidence* by an accredited, independent laboratory and labeled and certified by the manufacturer.

When a manufacturer has not determined SHGC in accordance with NFRC 200 for a particular product line, compliance with the building envelope requirements of this code shall be determined by assigning such products a default SHGC in accordance with Table 4B-5 Product features must be verifiable for the product to qualify for the default value associated with those features. Where the existence of a particular feature cannot be determined with reasonable certainty, the product shall not receive credit for that feature. Where a composite of materials from two different product types are used, the product shall be assigned the higher SHGC.

Table 4B-5
SHGC Default Table For Fenestration

Product Description	Single Glazed				Double Glazed			
	Clear	Bronze	Green	Gray	Clear + Clear	Bronze + Clear	Green + Clear	Gray + Clear
Metal Frames								
Operable	0.75	0.64	0.62	0.61	0.66	0.55	0.53	0.52
Fixed	0.78	0.67	0.65	0.64	0.68	0.57	0.55	0.54
Nonmetal Frames								
Operable	0.63	0.54	0.53	0.52	0.55	0.46	0.45	0.44
Fixed	0.75	0.64	0.62	0.61	0.66	0.54	0.53	0.52

5.1 CALCULATION PROCEDURES

5.1.1 Cooling System Design Loads. Cooling system design loads, for the purpose of sizing HVAC systems and equipment, shall be determined in accordance with one of the procedures described in Chapter 26 of the 1997 ASHRAE Handbook of Fundamentals or ACCA Manual N, Commercial Load Calculation, 4th Edition, 1988.

5.1.2 Interior Design Conditions. Indoor design temperature and humidity conditions for general comfort applications shall be in accordance with the comfort criteria established in ANSI/ASHRAE Standard 55-92, Thermal Environmental Conditions for Human Occupancy, or Chapter 8 of the 1997 ASHRAE Handbook of Fundamentals, except that winter humidification and summer dehumidification are not required.

5.1.3 Exterior Design Conditions. Outdoor design conditions shall be selected from the 1997 ASHRAE Handbook of Fundamentals, or from data obtained from the National Climatic Center or a similar recognized weather data source. Cooling design temperatures shall be no greater than the temperature listed in the 2.5% column or statistically similar 0.5% annualized value. Heating design temperatures shall be no lower than the temperature listed in the 99% column or statistically similar 0.2% annualized value. EXCEPTION: Where necessary to assure the prevention of damage to the building or to material and equipment within the building, the 1% column for cooling may be used.

5.1.4 Ventilation. Outdoor air ventilation loads shall be based on ventilation rates specified in ASHRAE Standard 62-1989.

5.1.5 Envelope. Envelope cool loads shall be based on envelope characteristics such as thermal conductance, shading coefficient, and air leakage consistent with the values used to demonstrate compliance with FLA/COM of this Code.

5.1.6 Lighting. Lighting loads shall be based on actual design lighting levels or power budgets consistent with the prescriptive requirements of section 415.1. Lighting loads may be ignored for the purpose of calculating design heating loads.

5.1.7 Other Loads. Other HVAC system loads such as those due to people and equipment shall be based on design data compiled from one or more of the following sources:

1. Actual information based on the intended use of the building.
2. Published data from manufacturers' technical publications.
3. Technical society publications such as the 1995 ASHRAE Handbook of HVAC Applications.

4. Allereza, "Estimates of recommended heat gains due to commercial appliances and equipment."

5. Other data based on designer's experience of loads and occupancy patterns.

Internal heat gains may be ignored for the purpose of calculating design heating loads.

5.1.8 Safety Factor. Design loads may at the designer's option be increased by as much as 10% to account for unexpected loads or changes in space usage.

5.1.9 Pick-up Load. Transient loads such as warm-up or cool-down loads which occur after off-hour setback or shutoff may be calculated from principles based on the heat capacity of the building and its contents, the degree of setback, and desired recovery time; or may be assumed to be up to 10% for cooling and 30% for heating of the steady-state design loads. The steady-state load may include a safety factor in accordance with section 5.1.8 of Appendix B.

Study Guide for APPENDIX C 331

SUPPLEMENTAL INFORMATION FOR CHAPTER 6

1.2 BUILDING ENVELOPE, INSULATION

All R-values referenced in this chapter refer to the R-values of the added insulation only. The R-values of structural building materials such as framing members, concrete blocks or gypsum board shall not be included. Insulation levels shall be achieved with insulation products tested and rated according to the procedures recognized by the Federal Trade Commission (FTC) in 16 CFR Part 460.

See section 104.4.3 for compliance requirements pertaining to insulation installed in locations where the R-value is not readily apparent or the FTC label is not affixed to the installed product.

1.2.1 When installing two layers of bulk or board insulation, the R-values of each material may be added together for a total R-value. When installing two separate reflective insulation products in layers, the total R-value of the system shall have been achieved by testing under Federal Trade Commission regulations, 16 CFR Part 460.

1.2.2 Insulation that has been compressed to 85% or less of the manufacturer's rated thickness for the product shall use the R-values given in Table 6C-1 for selecting a multiplier.

Table 6C-1
R-Values of Compressed Insulation

% of Original Thickness	R-5	R-7	R-11	R-14	R-19	R-30	R-38
90%	5	6	10	13	18	28	36
80%	4	6	10	12	17	26	33
70%	4	5	9	11	15	24	30
60%	3	5	8	10	14	22	27
50%	3	4	7	9	12	18	24
40%	2	4	6	8	10	15	20
30%	2	3	4	6	8	12	16
20%	2	2	3	4	7	10	10

These values are to be used except where data developed by an independent testing laboratory is provided and approved by the Department of Community Affairs.

Section 1.2.3 The thermal insulation materials listed below shall comply with the requirements of their respective ASTM standard specification and shall be installed in accordance with their respective ASTM installation practice.

Table 6C-2
Insulation Installation Standards

Insulation Material	Standard Specification	Installation Practice
Mineral Fiber Batt/Blanket	C 665-95	C 1320-95
Mineral Fiber Loose Fill	C 764-94	C 1015-84 (1995)
Cellulose Loose Fil	C 739-91	C 1015-84 (1995)
Polystyrene Foam	C 578-95	—
Polyisocyanurate Foam	C 1289-95	—
Reflective	C 1224-93	C 727-90
Radiant Barrier	C 1313-95	C 1158-90
Vermiculite	C 516-80 (1990)	C 1049-85 (1995)
Perlite	C 549-81	C 1049-85 (1995)

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American Council for an Energy Efficient Economy (ACEEE)
[Online] Available http://www.aceee.org/consumerguide/mostenef.htm
Publishes an annual list of most energy-efficient residential appliances for which there are standardized efficiency ratings

Appliance Standards Awareness Project (ASAP)
[Online] Available http://www.standardsasap.org/cw/cwfacts.htm
This organization seeks to develop awareness of appliance standards and their benefits.

Association of Home Appliance Manufacturers
[Online] Available http://www.aham.org/indexconsumer.htm
Find advice on the use, maintenance, and repair of major appliances.

California Energy Commission
[Online] Available http://www.energy.ca.gov/efficiency/appliances
Directory of appliances by brand and model number that exceed California and NAECA standards by at least 10 percent.

Energy Efficiency and Renewable Energy Network (EREN) - Department of Energy (DOE) - Office of Building Technology, State, and Community Programs [Online] Available http://www/eren.doe.gov/buildings/homeowners.html
No brand names but information about the department's Appliance Standards Program as well as the economic and environmental benefits of choosing and using efficient appliances

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[Online] Available http://www.energystar.gov/products/appliances.html
Detailed energy consumption information for the brands of clothes washers, refrigerators, dishwashers, and room air conditioners that exceed the minimum federal National Appliance Energy Conservation Act (NAECA) standards.

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An excellent description of the basics about lighting. Includes good descriptions of CRI and CCT and provides excellent technical information about different kinds of lights. Updated regularly.

Kathryn M. Conway. 1994. "Lighting Makeovers: The Best Is Not Always the Brightest."
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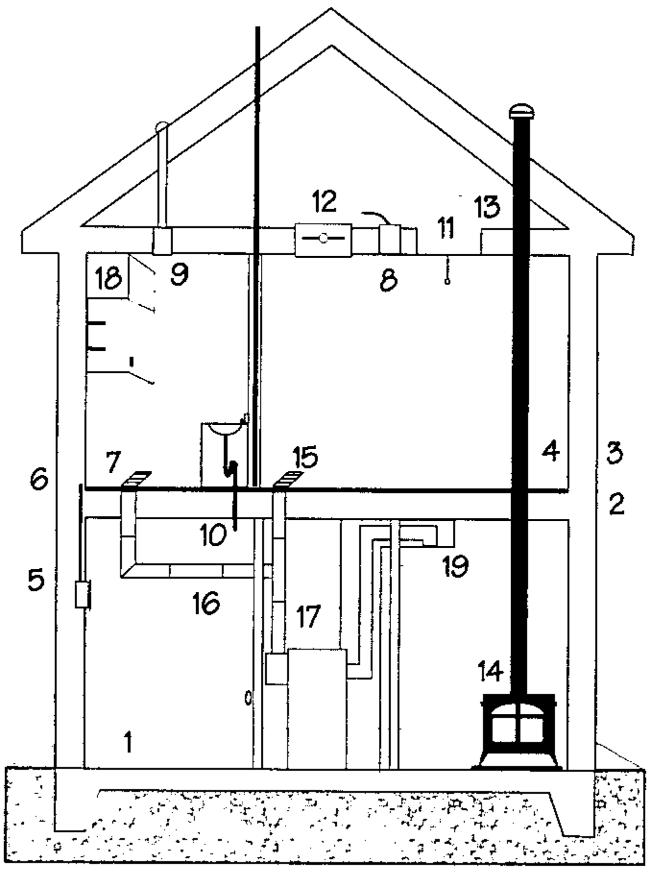

1. Slab Floors
2. Sill Plate and Rim Joist
3. Bottom Plate
4. Subfloor
5. Electrical Wiring
6. Electrical Boxes
7. Electrical Box Gaskets
8. Recessed Light Fixtures
9. Exhaust Fans
10. Plumbing
11. Attic Access
12. Whole House Fan
13. Flue Stacks
14. Combustion Appliances
15. Return and Supply Registers
16. Ductwork
17. Air Handling Unit
18. Dropped Ceiling Soffit
19. Chases

See chapter 4 for details.