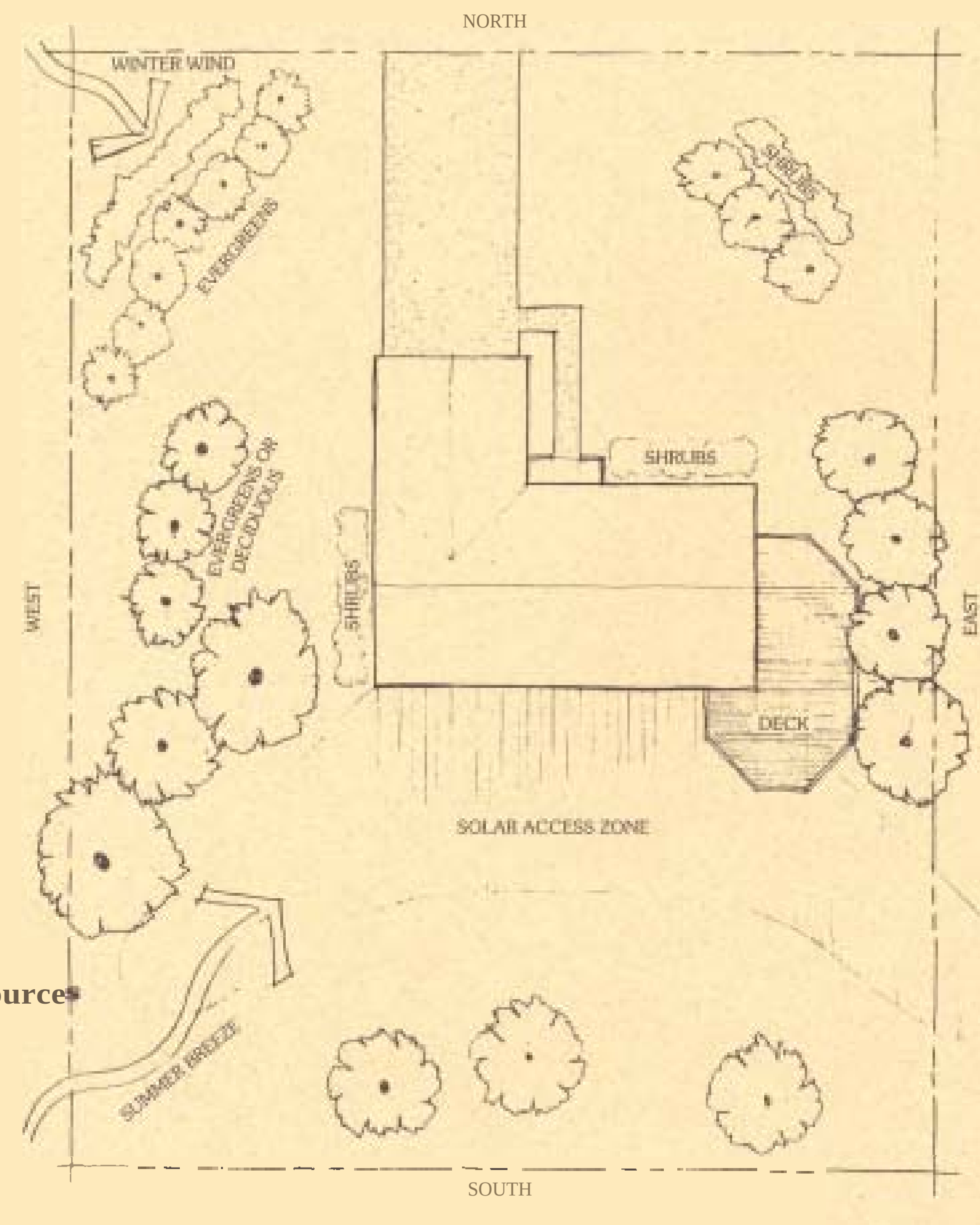
A Builder's Guide to IOWA'S IDEAL HOMES



Energy Bureau
Iowa Department of Natural Resources
Wallace State Office Building
Des Moines, Iowa 50319-0034

A Builder's Guide
to
Iowa's IDEAL Homes
1987

The details presented in this book are schematic design ideas and are not meant to be construction drawings. Consult an architect, engineer, designer or builder for complete construction details. The Iowa Department of Natural Resources makes no statement, representation, claim, or warranty with respect to the methods described. For questions on this book, or other energy related information, write Energy Information, Iowa Department of Natural Resources, Wallace State Office Building, Des Moines, Iowa 50319-0034.

A Builders Guide to Iowa's IDEAL *Homes*

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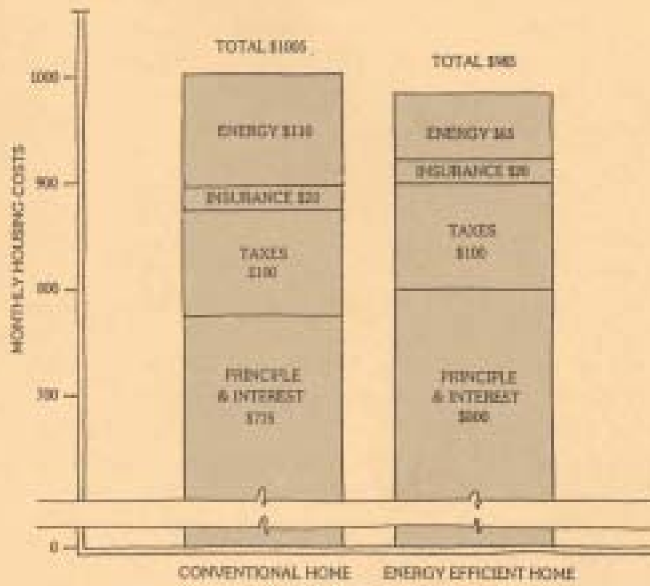
INTRODUCTION

A Builder's Guide to Iowa's IDEAL Homes was developed to inform builders of current methods of building energy efficient homes. The IDEAL home concept was first presented by the Iowa Energy Policy Council in the Iowa's IDEAL Homes book published in 1982. The book included a set of energy efficient home designs. Thus the word IDEAL serves as an acronym for Innovative Designs for Energy Affordable Living.

The new book presents three approaches to building energy efficient homes. It provides updated information from state and international home building experts. It modifies the Double 2x4 Approach, adds strapping to the 2x6 Approach, and introduces the Airtight Drywall Approach. These are not the only methods of building energy efficient homes. (Other methods include passive solar, earthsheltered, and envelope.) There are many variations to the methods described. However, the design concepts presented in this book are appropriate for the climate of Iowa, easy to understand and to construct, and appeal to the tastes of Iowa homebuyers.

Constructing an energy efficient home benefits everyone involved. First of all, Iowa benefits. Iowa imports 98% of its energy. The more dollars Iowans spend on energy conservation, the more dollars they have left after paying their utility bill to spend in the local economy. So, choosing energy conservation is choosing economic development for Iowa.

Here's how various parts of the local economy benefit from energy efficient construction. The utility company benefits by not having to build a new power plant or install a new pipeline as soon. The building supplier sells more materials. The builder sells a more expensive house. The real estate agent gets a larger commission. The lender lends more money and receives more interest, without putting an additional burden on the borrower. The borrower's annual payments for princple, interest, taxes, insurance, and energy (PITIE) can actually decrease with an energy efficient home. Figure 1 shows that a homeowner can invest $2500 in an energy efficient home and have smaller annual payment than they would with a conventional home. And, as energy prices increase, the owners of the energy efficient home will be even farther ahead of their neighbors with conventional homes. Building an energy efficient home is planning for the future.



*PITIE - Principle/Interest/Taxes/Insurance/Energy
2400 SF home, $75,000 30 yr. mortgage @ 12%, $2500 additional cost for IDEAL
Conventional: $543 heating, $180 water heating, $600 electrical
IDEAL: $200 heating, $100 water heating, $480 electrical

Figure 1 Monthly Housing Cost Comparison (PITIE)*.

Most homes built using the design concepts presented in this book can be heated for $100-$300 per year, but economics is not the only reason to build an energy efficient home. The homeowner also gets a home that's comfortable; there are no drafts, and temperatures are even throughout. A tight, well-insulated home is also very quiet. The design concepts presented in this book provide for plenty of natural light and better air quality than you can get in a conventional home. These homes have comfortably high, but controllable, humidity in the winter. They use standard construction practices and materials, can be adapted to almost any architectural style, and are suitable for any lot.

The bottom line is that energy efficient features give builders a better sale price and homeowners a better quality home. In this book, you'll find the essential concepts needed for energy efficiency: construction techniques with over 95 schematic drawings and information on airtight construction, controlled ventilation, insulation, heating and cooling, windows, doors, lights, appliances, and landscaping. Let's get started. □

ENERGY EFFICIENT CONSTRUCTION IS QUALITY CONSTRUCTION

Energy efficient construction requires attention to detail. This attention to detail leads to a well-built home. Following the details in this book will result in a home that is affordable not only because it's energy efficient, but also because it will survive the test of time.

There are three key design elements that ensure quality and energy savings. They are airtight construction, controlled ventilation, and high levels of insulation. A home that combines all of these features is often called a superinsulated home. We will call it an IDEAL home.

Airtight Construction

Why airtight construction? Energy savings is an obvious reason. The air within the average new home is replaced by outside air approximately once every one to two hours, accounting for 30-40% of the home's heating requirement. You can't expect to eliminate all of it, but using the techniques illustrated in this book, you can greatly reduce it. Figure 2 shows the common air leakage locations that must be sealed. Another reason to build the home airtight is not as obvious, but is much more important. Air leakage in a new home can result in a house rotting before its time. Here's how it happens. Leaking air carries moisture with it. Moisture condenses when it hits a cold surface. This condensation wets the insulation, lowering its insulating ability. It can also cause wood structural members to rot if they are not given the opportunity to dry out.

Measuring natural air leakage can be done using a tracer gas test, but this is not practical on an individual builder's scale. A relative measurement can be obtained using a blower door. The blower door uses a large fan to pressurize or depressurize a home. By measuring the difference in pressure between the inside and outside of the home, the air flowing through the fan yields an induced air change per hour (acph) rate. The common pressure to measure this induced air change rate is 50 pascals or *2* inches of water which is roughly equivalent to a 20 mph wind acting on all sides of the house at once. A properly built IDEAL home will yield an air change rate between 1 and 3 air changes per hour.

The blower door can also measure the equivalent leakage area (ELA). **ELA** is the summation of all the holes in the building envelope added together. Thii area is usually calculated at 10 pascals pressure difference. To be able to compare the **ELA** of one building with another, you can convert it to the specific leakage area (SLA). The **SLA** is the **ELA** divided by the total building envelope area and is usually expressed in square inches per hundred square feet of surface area.

Blower doors can also be used to locate leaks so they can be sealed. When the house is being pressurized, a technician can use a smoke stick to locate the leaks and seal them appropriately. It may be a long time before every builder owns a blower door, but there are companies today that specialize in this type of service.

Controlled Ventilation

Controlled ventilation is essential to an IDEAL home.

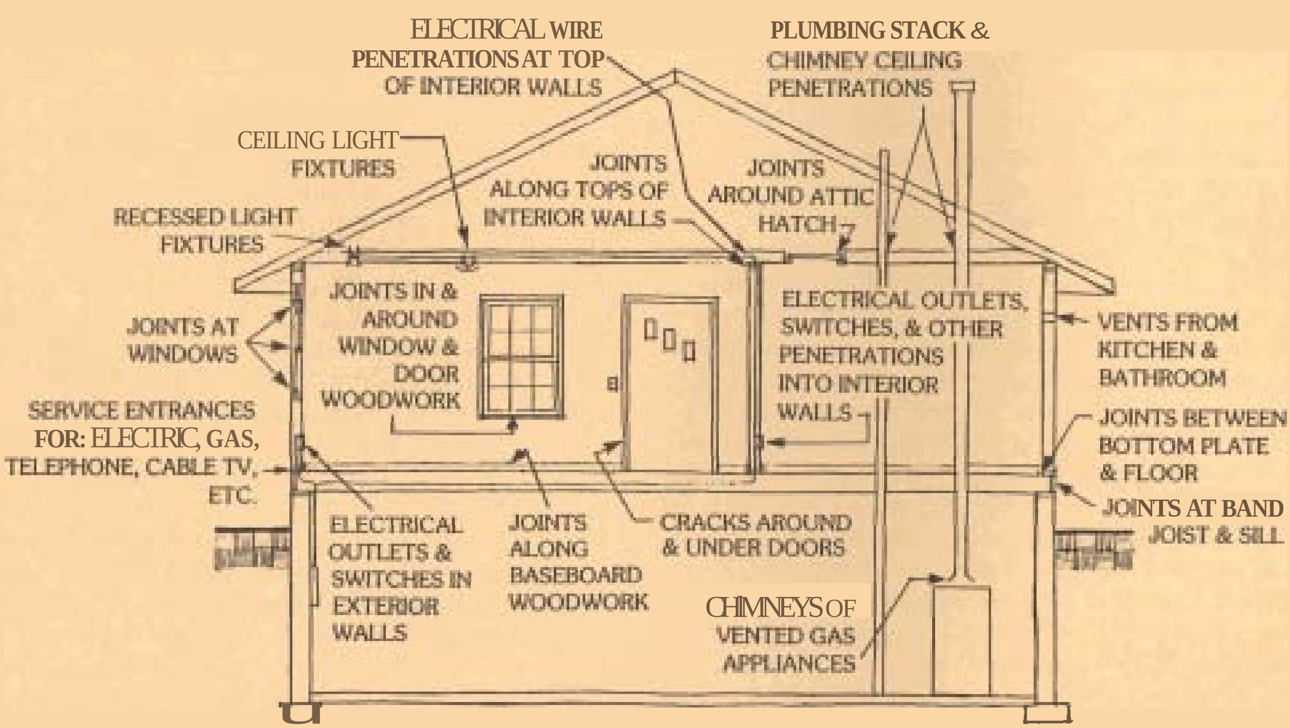


Figure 2 Common Air Leakage Locations in Conventional Housing.

It may seem illogical to bring in outside air after going to great lengths to build an airtight house, but a controlled ventilation system has significant advantages over natural air leakage. These advantages include energy savings, a healthier environment, and a home free of moisture problems. In a conventional home, air leakage may average one air change per hour, but there are times when no air is w i n g through the home. A controlled ventilation system, however, provides a constant flow of fresh air and increases ventilation when it is needed most. This ensures the common contaminants (Figure 3) found in many new homes are kept at a harmless level. An IDEAL home should be built as tight as possible with ventilation provided by the controlled ventilation system.

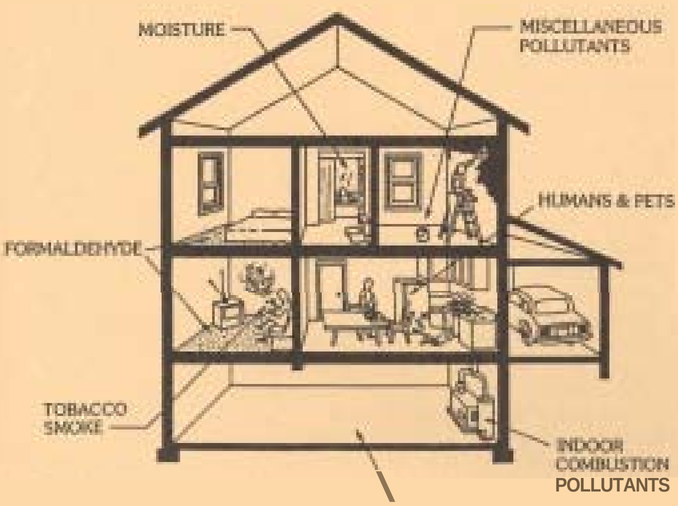


Figure 3 Sources of Indoor Pollution

Since the controlled ventilation system can be integrated with the heating, cooling and water heating systems, we've included a more detailed discussion of controlled ventilation options in a section called Mechanical Systems.

Insulation

The IDEAL home concept demands the entire envelope of the home — ceiling, walls, windows, doors, and foundation — receive appropriate insulation to minimize heat loss. The recommended R-values for various building components are shown in Table 1. R-value refers to the material's ability to stop heat from passing through it; the higher the R-value the greater the resistance to heat loss.

These recommended R-values can be achieved by using either one type of insulation or several types in combination with other building components. When different materials make up a section of the building envelope, the total R-value for that section is simply

Table 1 Minimum R-Values for an IDEAL Home

Ceiling	R-40
Walls	R-25
Band Joist	R-25
Foundation Walls	R-12
Floors wer Unheated Spaces	R-30
Windows	R-3
Doors	R-10

the sum of the individual components. Table 2 shows the R-values of common insulating and building materials. Table 3 lists the common types of insulation with their advantages and limitations.

Reduce thermal defects as much as possible. These defects include insulation voids, thermal bridging through the materials, air intrusion into the insulation (common in attics), convective loops caused by the insulation not filling the full width of the wall cavity, and moisture condensing in the wall cavity getting the insulation wet. These thermal defects can make a home which appears to be well insulated, a poor conservation investment. Figure 4 shows thermal defects which are quite common in conventional construction.

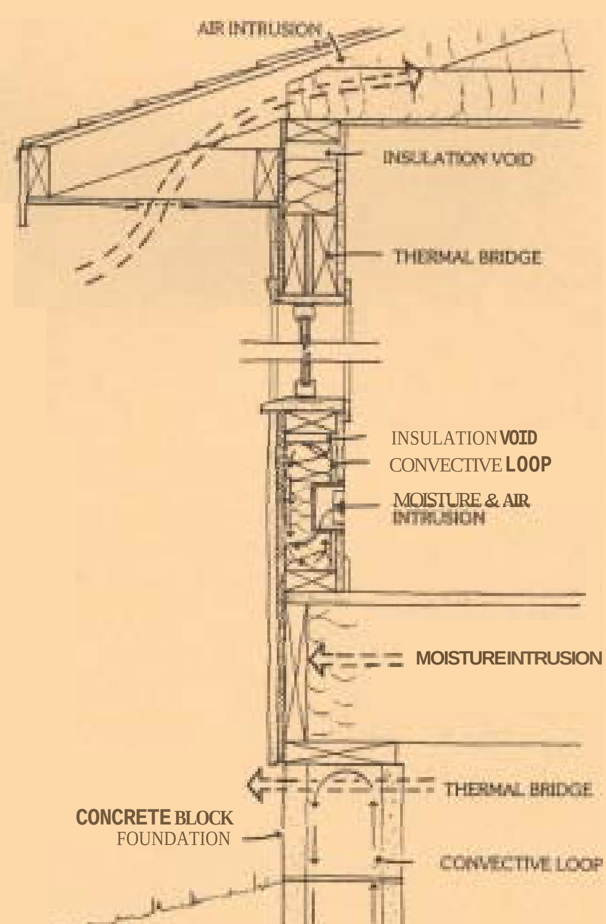


Figure 4 Thermal Defects Common in Conventional Housing.

Table 2 R-Values of Common Building Materials

	R/Inch	R/Thickness
bmdauon1(.tari.L		
Fiberglass Batt	3.14	
blown (attic)	2.20	
blown (wall)	3.20	
Rock Wool Batt	3.14	
blown (attic)	3.10	
blown (wall)	3.03	
Cellulose blown (attic)	3.13	
blown (wall)	3.70	
Vermiculite	2.13	
Air-entrained Concrete	3.90	
Urea terpolymer foam	4.48	
Rigid Fiberglass (>4 lb/ft3)	4.00	
Expanded Polystyrene (beadboard)	4.00	
Extruded Polystyrene	5.00	
Polyurethane (foamed-in-place)	6.25	
Polysocyanurate (foil-dated)	7.20	
Construction Materials		
Concrete Block 4"		0.80
8"		1.11
12"		1.28
Brick 4" common		0.80
4" face		0.44
Poured Concrete	0.08	
Soft wood lumber	1.25	
2" nominal (1 1/2")		1.88
2X4 (3 1/2")		4.38
2x6 (5 1/2")		6.88
Cedar Logs and lumber	1.33	
Sheathing Materials		
plywood	1.25	
1/4"		0.31
3/8"		0.47
1/2"		0.63
5/8"		0.77
3/4"		0.94
Fiberboard	2.64	
1/2"		1.32
25/32"		2.06
[illegible] (3/4")		3.00
(1")		4.00
(1 1/2")		6.00
Extruded Polystyrene (3/4")		3.75
(1")		5.00
(1 1/2")		7.50
Foil-faced Polyisocyanurate (3/4")		5.40
(1")		7.20
(1 1/2")		10.80
Siding Materials		
Hardboard (1/2")		0.34
Plywood (5/8")		0.77
(3/4")		0.93
Wood Bevel Lapped		0.80
Aluminum, Steel, Vinyl (hollow backed)		0.61
(1/2" Insulating board backed)		1.80
Brick 4"		0.44

Material	*R/Inch*	*R/Thickness*
Interior Finish Materials		
Gypsum Board (drywall 1/2")		0.45
(5/8")		0.56
Paneling (3/8")		0.47
Flooring Materials		
Plywood	1.25	
(3/4")		0.93
Particle Board		
(underlayment)	1.31	
(5/8")		0.82
Hardwood Flooring	0.91	
(3/4")		0.68
T i, Linoleum		0.05
Carpet (fibrous pad)		2.08
(rubber pad)		1.23
Roofing Materials		
Asphalt Shingles		0.44
Wood shingles		0.97
Windows		
Single glass		0.91
w/ storm		2.00
Double insulating glass		
(3/16" air space)		1.61
(1/4" air space)		1.69
(1/2" air space)		2.04
(3/4" air space)		2.38
(1/2" w/ Low-E 0.20)		3.13
(w/ suspended film)		2.77
(w/ 2 suspended films)		3.85
(w/ suspended film and low-E)		4.05
Triple insulating glass		
(1/4" air spaces)		2.56
(1/2" air spaces)		3.23
Addition for tight fitting drapes or shades, or closed blinds		0.29
Doors		
Wood Hollow Core Flush (1 3/8")		2.17
Solid Core Flush (1%")		3.03
Solid Core Flush (2%")		3.70
Panel Door w/ 7/16" Panels (1%")		1.85
Storm Door (wood 50% glass)		1.25
(metal)		1.00
Metal Insulating (2" w/ urethane)		15.00
Air Films		
Interior Ceiling		0.61
Interior Wall		0.68
Exterior		0.17
Air Spaces		
1/2" to 4" approx.		1.00
1/2" to 4" w/ one surface fairly reflective		2.36
1/2" to 4" w/ one surface highly reflective		3.48
Misc.		
6mil Polyethylene Vapor Barrier		0.00

Table 3 Insulation Advantages and Disadvantages

Insulation Type	Advantages	Disadvantages
Fiberglass Batt	Easy to install in open cavities Light Weight Non-settling Good fire resistance Fairly inexpensive per R-value Widely available	Little resistance to air infiltration Can't be installed in already enclosed cavities Compressing lowers effective R-value Fibers can irritate lungs during installation Condensation & infiltration lower R-value
Fiberglass Loose Fi	Easily fills irregular horizontal spaces Lightweight Good fire resistance Does not absorb water Widely available Can be blown or poured	Lowest R-value of loose fill material Little resistance to air infiltration Can hang upon wires & naiis in walls May settle if installed at too low density Fibers can irritate lungs during installation
Rock Wool Loose Fill	Easily fills irregular horizontal spaces Non-combustible Does not absorb water Widely available	Little resistance to air infiltration May settle if installed at too low density Fibers can irritate lungs during installation
Cellulose Loose Fi	Easily fills irregular horizontal spaces Good resistance to air infiltration Highest R/inch of ail loose fill Can be blown through smaller holes Very low cost per R-value Can be blown or poured Widely available	May settle if blown at to low density Potentially combustible Absorbs water, dries very slowly Can deteriorate if not able to dry out May corrode steel, aluminum, & copper
Vermiculite/ Perlite	Noncombustible Pours easily into irregular cavities	Low Rlinch Heavy weight Not as readily available Cannot be blown
Rigid Fiberglass	Highest R/inch of all types of fiberglass Good fire resistance Vapor permeable Available in many thicknesses and densities	More compressible than other rigid boards
Expanded Polystyrene	Lowest cost/R of all rigid boards Light weight Available in a variety of thicknesses Available in a variety of densities Vapor permeable Widely available	Breaks easily Must be protected from exposure to sunlight Very combustible
Extruded Polystyrene	will not absorb water Excellent for exterior of foundations Available in a variety of thicknesses Can perform as vapor barrier on inside Air infiltration doesn't degrade R-value	Combustible, drywall must cover on interior Must be protected from exposure to sunlight Relatively expensive per R-value
Urethane/ Isocyanurate	Highest Rlinch of all insulation materials Vapor barrier with foil facing Negligible water absorption Can also be foamed in place	Combustible, drywall must cover on interior Fairly expensive per R-value Must be protected from exposure to sunlight
Phenolic	Very good fire resistance Vapor permeable Doesn't need drywall covering on interior Suitable for window insulation panels	Highest cost/R of all rigid board insulation Brittle, easily crumbles May warp due to moisture absorption Not readily available

Other thermal bridges often overlooked are where the garage, outside patio, porch and/or stoop slabs meet the foundation of the house or where a concrete retaining wall connects to the foundation. A thermal break must be installed any place where cold can be transferred through the building materials into the house. Therefore, install two inches of extruded polystyrene against the foundation before the slabs or retaining wall are poured.

A Measure of Energy Efficient Construetion - Home Heating Index (HHI)

To get a measure of the energy efficiency of the house as a whole, extension specialists at Iowa State University developed the Home Heating Index (HHI). It is a number, usually between 1 and 15, that describes the energy efficiency of your home. The lower the number the more efficient your home. It is measured in British thermal units per square foot of heated floor space per heating degree day (a measure of the severity of the winter). The HHI can be calculated before the house is built using the R-values of the components; it can be obtained after the house is built by using the heating and electric bills.

An older home without efficiency improvements may have an HHI as high as 15. The average older home in Iowa has an HHI of around 8. The average new home built in Iowa in 1984 had an HHI of around 5. A home built to the specifications presented in this book should have an HHI of between 1 and 3. The construction method you choose will determine how low your HHI will be. □

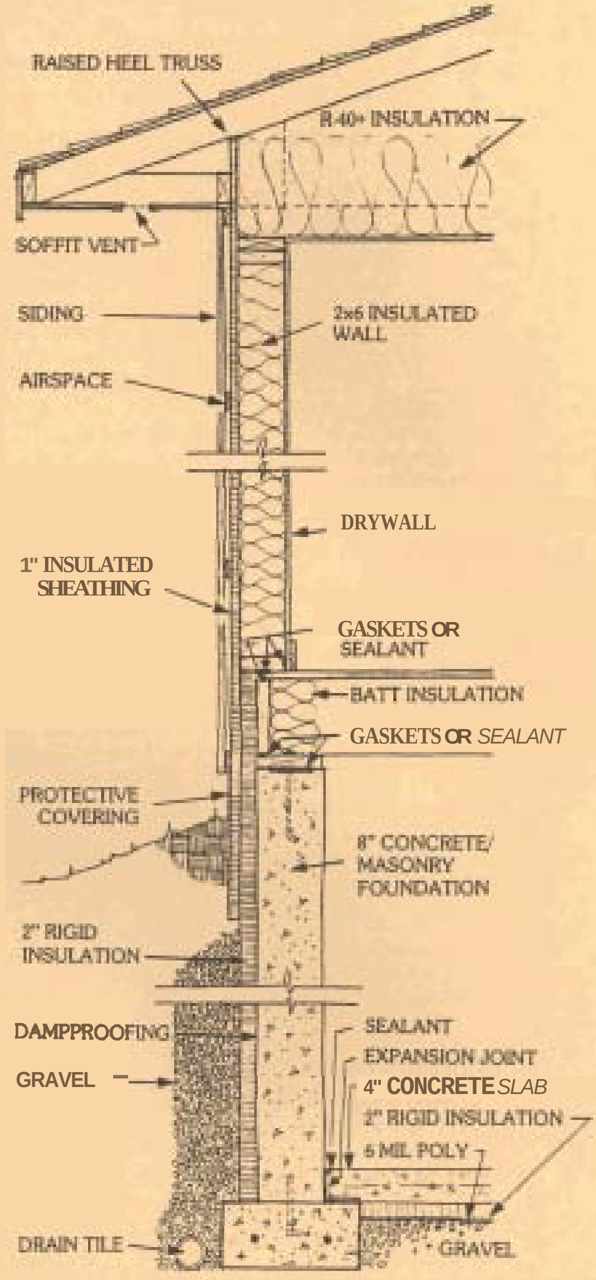
CONSTRUCTION DETAILS

This book will present three approaches to building an airtight, well-insulated house with controlled ventilation. The approaches include the Airtight Drywall Approach (ADA), the Strapped 2x6 Approach, and the Double 2x4 Approach. These approaches are explained in the order they would normally be constructed: Foundations, Walls and Roof Systems. However, the kind of wall you choose will determine the construction approach you use, so be sure to read each section's Construction Details before making a decision.

The Airtight Drywall Approach: Two Canadian researchers at the University of Toronto, James Lischkoff and Joseph Lstibwek, noticed that large builders were reluctant to build energy efficient homes. The polyethylene (plastic bag) approach was the major hurdle for these builders because it was labor intensive. With simplicity of construction and cost-effectiveness in mind, the two researchers perfected a construction technique that reduces energy consumption, makes energy efficiency affordable, and prevents moisture problems without using polyethylene. They call it the Airtight Drywall Approach (ADA).

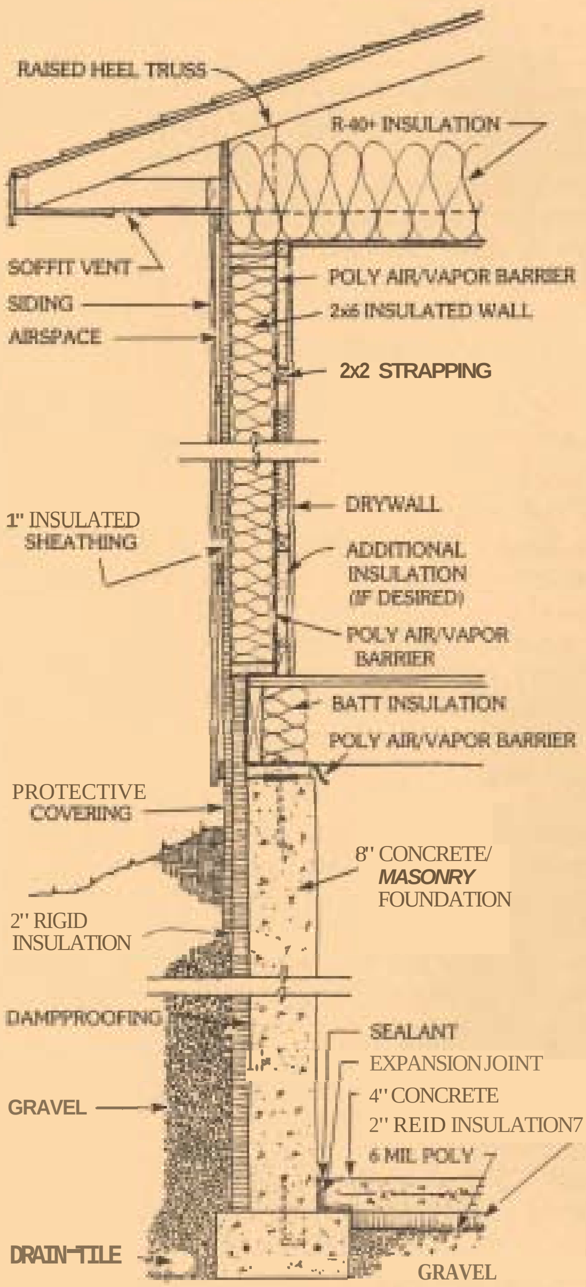
In the past, it was believed that a plastic vapor barrier was needed to prevent moisture from diffusing through the drywall and ,condensing in the walls and attic. Research has shown that moisture problems are most frequently caused by air leakage and not vapor diffusion through the materials. The term "vapor barrier" has commonly been used to describe a construction material that slows vapor diffusion. A more accurate term for this material would be "vapor diffusion retarder." Most building codes require a vapor diffusion retarder with a permeance of less than one. This perm rating can be obtained by using polyethylene, aluminum backed drywall, kraft faced batts, or by painting normal drywall with a coat of "vapor barrier" paint. One coat of some oil-based paints and some semi-gloss latex paints will also work. Permeance varies by manufacturer and you will have to check with the manufacturer to find the rating. Two to three coats of some oil or latex paints may be necessary to obtain a perm rating of less than one. When painted in one of the above ways, drywall is an good vapor diffusion retarder and an excellent air barrier if properly installed. It inhibits moisture penetration and conserves energy.

The Airtight Drywall Approach relies on the building materials and gaskets placed at particular joints between these materials to create an airtight envelope. See Detail 1. These gaskets need to be **made** of a material that is soft, easily compressed, and thick enough to fill the joint. The gasket must also be able to stop air infiltration. Saturated polyurethane gaskets appear to be the best option. Closed cell foam gaskets used in log homes and neoprene rubber gaskets are also options.

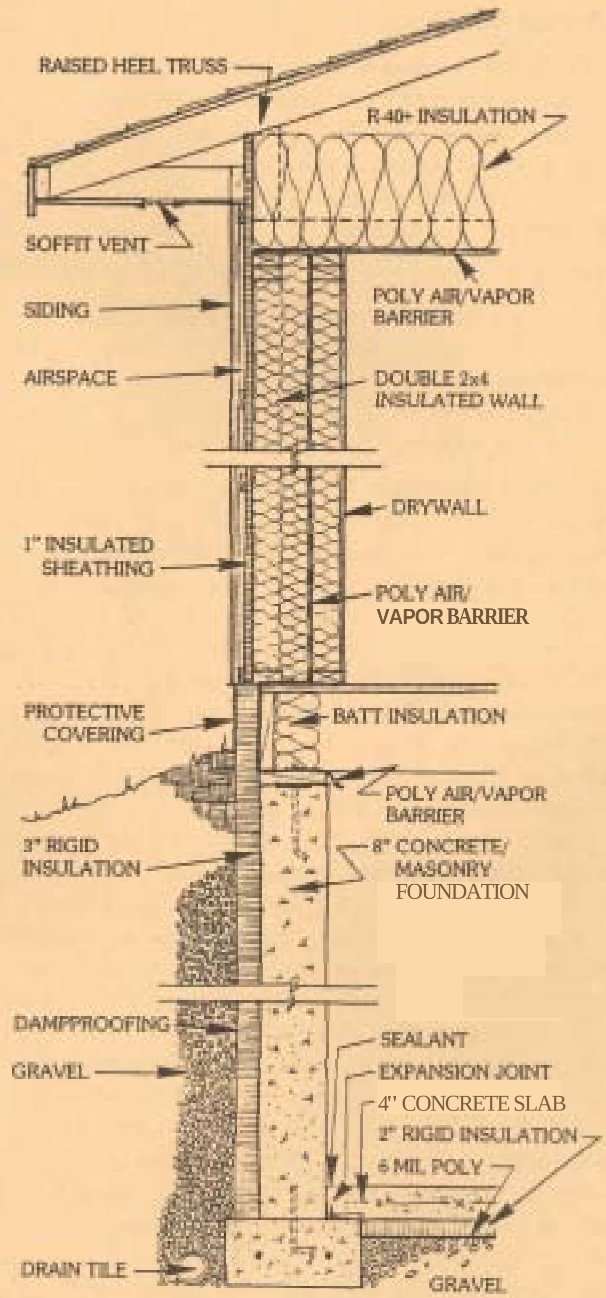


Detail 1 Airtight Drywall Approach

The Strapped 2x6 Approach: The Strapped 2x6 Approach relies on polyethylene as an airlvapor barrier. When builders started relying on polyethylene to make their homes airtight, they soon discovered it was very difficult to seal the polyethylene around penetrations such as electrical outlets and switches. They solved the problem by installing the polyethylene and then strapping the interior with 2x2's horizontally 16 inches on center. See Detail 2. This allowed space to run electrical and plumbing systems without having to cut holes in the air/vapor barrier. A 2x4 is usually positioned at the bottom of the wall for mounting the baseboard



Detail 2 Strapped **2x6** Approach



Detail 3 Double **2x4** Approach

with another **2x4** positioned at the **4** foot level for ease of mounting the drywall. The strapping space can be insulated with 3 1/2 inch batts ripped down the middle or 1 1/2 inch rigid insulation, if desired.

The Double 2x4 Approach: The double **2x4** construction concept originated in the mid 1970's. After the energy crisis of 1973, several groups started developing ideas on how to design and build an energy efficient home. Wayne Schick, an architect with the Small Homes Council at the University of Illinois, helped develop a double **2x4** construction concept in 1976. He called it the Lo-Cal House. David Eyre of the Saskatchewan Research Council headed a team that built the Saskatchewan Conservation Home in 1977.

The Double **2x4** Approach presented here, puts the polyethylene on the back of the inside wall as shown in Detail 3. As long as two thirds of the R-value is on the cold side of the vapor barrier, condensation will not occur. The double **2x4** wall stops the thermal transfer that occurs through the studs with ordinary construction. To further increase the wall's thermal performance, studs can be placed **24** inches on center and staggered. □

FOUNDATIONS

Foundation construction can be divided into three sections: General Considerations involving materials, insulation and drainage; Construction Details with detailed construction schematics; and Sealing Penetrations explaining how to seal common penetrations in the air barrier.

General Considerations

There are several general considerations to take into account before you begin building the foundation. The following information should help you choose the best foundation material, the best type of insulation, and the best drainage system for your foundation.

Foundation Materials: Three types of foundation materials are commonly used in residential construction today. They are preserved wood, poured concrete, and concrete block. For energy savings, the preserved wood foundation stands out because it's easy to insulate. Although opinions differ, most energy efficient builders feel that, when building an well-insulated foundation, the preserved wood foundation is least expensive to build. However, wood foundations have several drawbacks. Lack of thermal mass makes them a poor choice for a home with a large amount of south glass, and special steps must be taken to insure proper drainage. Other drawbacks include the fact that arsenic from the treated wood could potentially contaminate the air inside a tight house. Also, a wood foundation is combustible and insurance companies often don't include the cost of replacing a wood foundation in their policies because they assume it is noncombustible concrete. Special precautions must be used when handling or sawing treated wood, and both the basement floor and upper floor must be in place before backfilling a basement. For more detailed information on constructing a preserved wood foundation, contact the American Plywood Association or the National Forest Products Association.

Poured concrete and concrete block foundations have good thermal storage mass for passive solar if insulated on the outside. Poured concrete is more airtight than concrete block and would do a better job of keeping radon gas out of the home if it was present in the soil. Also, convective air currents can occur in the cavities of concrete block foundations tranferring heat from the bottom of the wall up and out the top. Both poured concrete and concrete block foundations are noncombustible and should last for many years. However, control joints should be installed in both to prevent cracking.

Insulation Options: Foundations can be insulated on the inside or outside. Two common methods of insulating on the inside are 1) putting expanded polystyrene (beadboard) between furring strips or 2) installing fiberglass in a stud wall, When insulating on the outside, two types of insulation are commonly used, 1) extruded polystyrene and 2) high density (greater than 4 pounds/cubic feet) rigid fiberglass. Both are durable underground. Avoid using expanded polystyrene (beadboard) on the outside of the foundation because it absorbs water and loses much of its R-value. Extruded polystyrene exposed above grade must be protected from the ultraviolet effects of the sun which can cause it to deteriorate. It can be covered with aluminum flashing, treated plywood, fiberglass impregnated bonding cement, acrylic stucco, or other durable material. Rigid fiberglass insulation also doubles as a drainage material; it acts similar to a thatched roof, directing the water down toward the drainage tile.

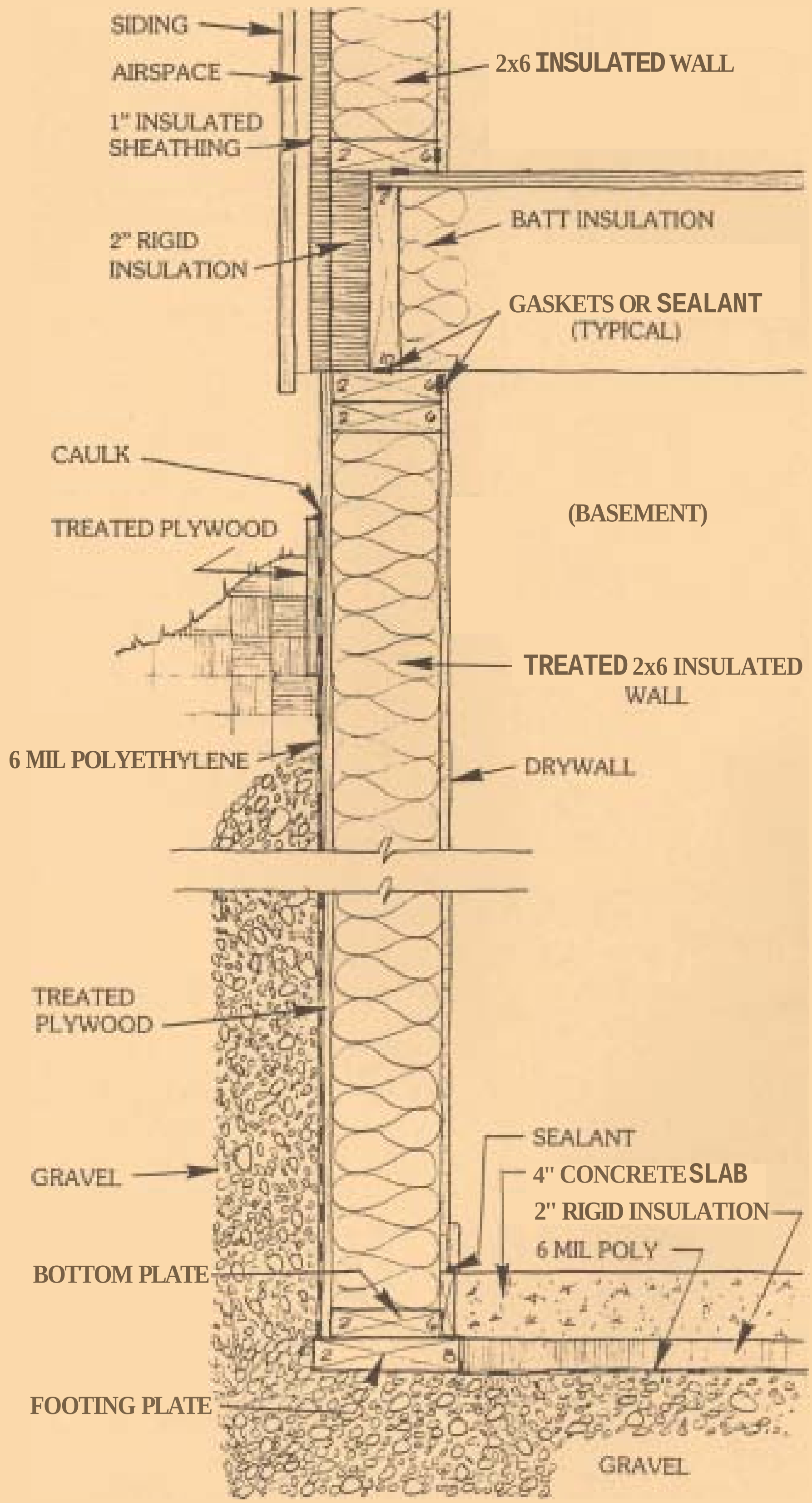
Drainage: Proper drainage is essential to any foundation, not only to prevent wet basements, but also to protect the foundation from the effects of frost heave. Uninsulated foundations allow interior heat to escape preventing the surrounding ground from freezing. Insulated foundations, on the other hand, keep the heat within the home and permit the adjacent ground to freeze down to the frost line. The expansion of water when it freezes can cause the ground to crack the foundation if adequate drainage is not present. For proper drainage, place a drain tile all the way around the foundation and run it to a sump pump or to daylight. Cover the drain tile with pea gravel or washed river rock. For best drainage, extend the gravel to within a foot of the surface. If the home will be located in an area where water could be a problem, put in 6-8 inches of gravel underneath the house as a storage reservoir and place the footings on top of this.

Construction Details

With a little planning, insulating a foundation doesn't have to be a big headache, Different types of foundations should be insulated in different ways. Here are some points to keep in mind:

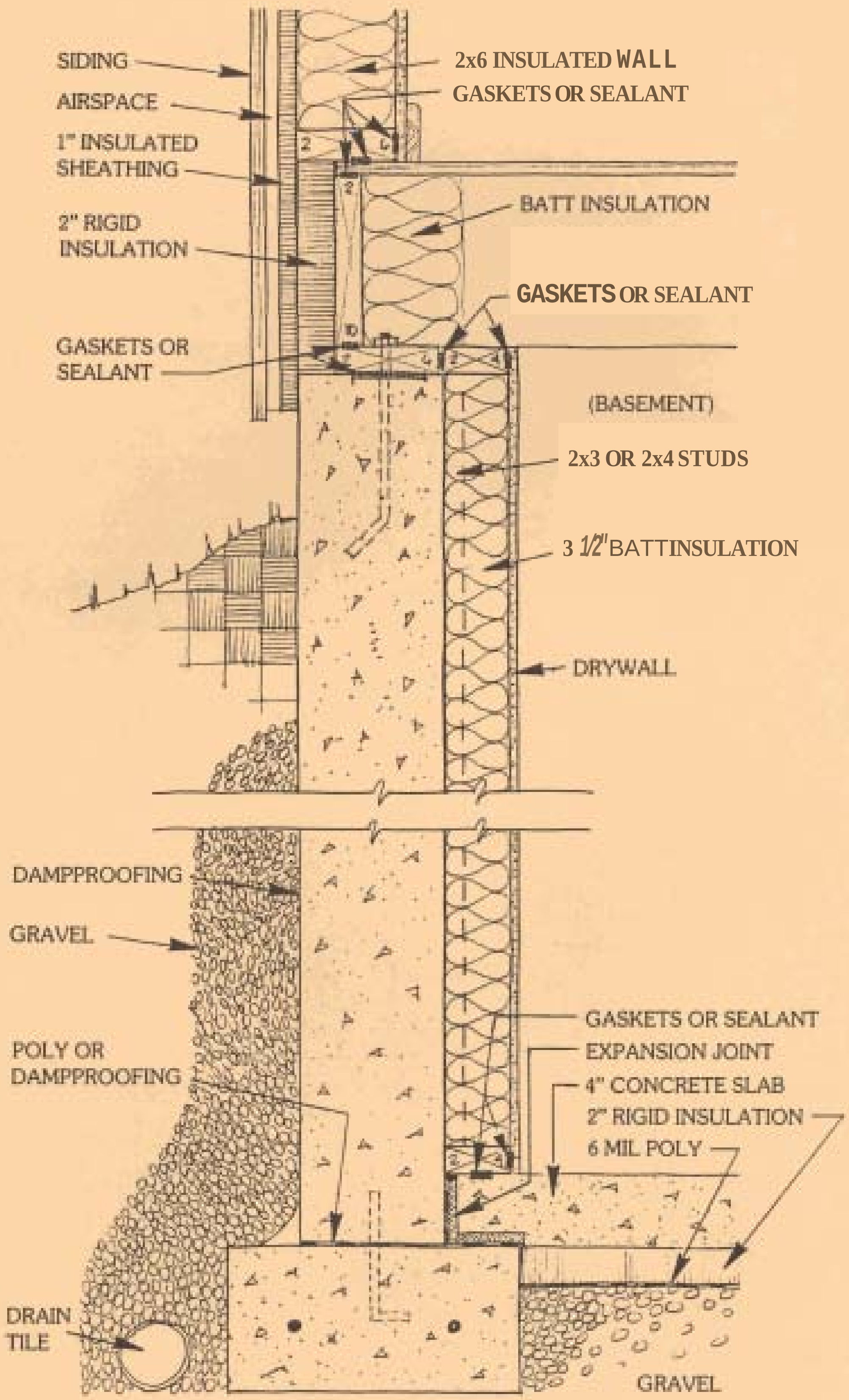
Basements: Detail 4 shows an insulated wood foundation. Detail 5 shows concrete/masonry basements insulated on the inside. Insulating on the interior results in a finished basement wall with space to run the wiring, but exposes the foundation wall to the outside environment and isolates the thermal mass, The exterior options shown in Detail 6, isolate the foundation from the outside environment and keep the thermal mass of the foundation wall inside the home where it can temper the inside environment. The main disadvantage of exterior insulation is it must be protected above ground. If more insulation is desired on the exterior, add flashing over the insulation where it juts out from beneath the siding.

Detail 4 Preserved Wood Basement

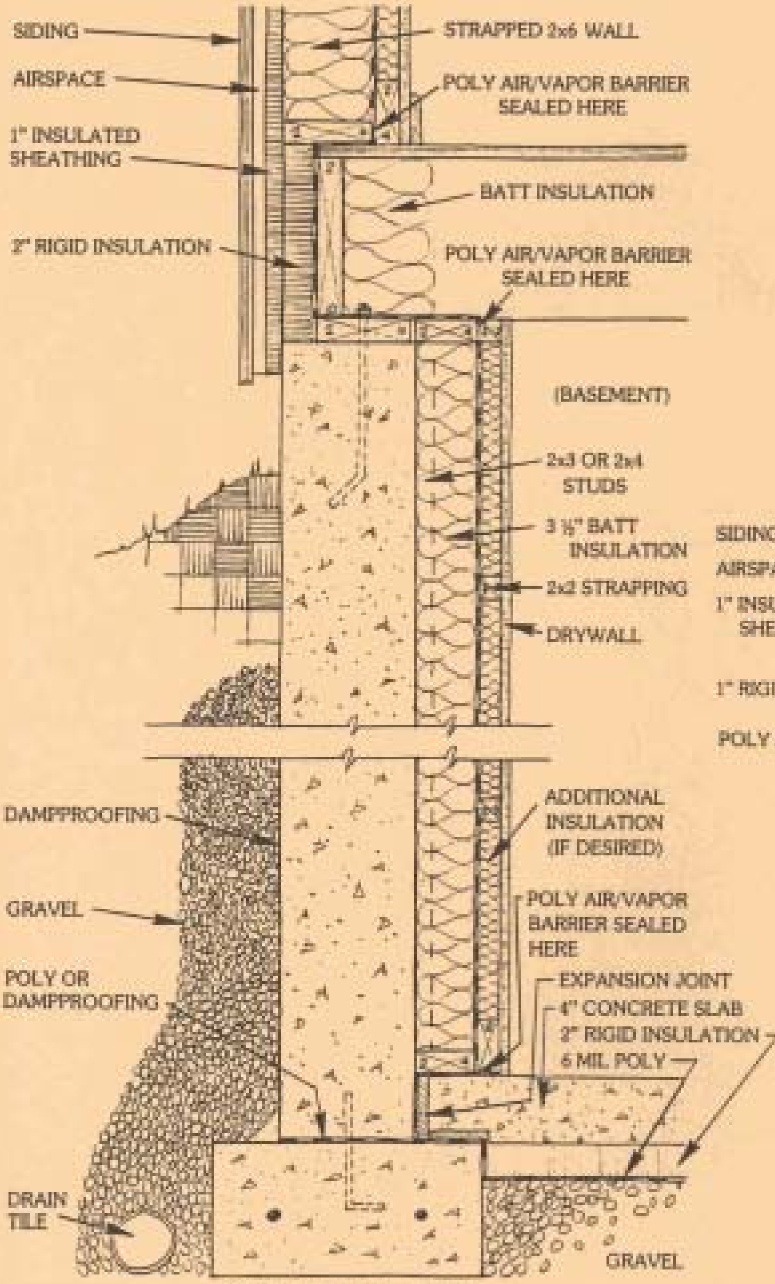


AIRTIGHT DRYWALL APPROACH

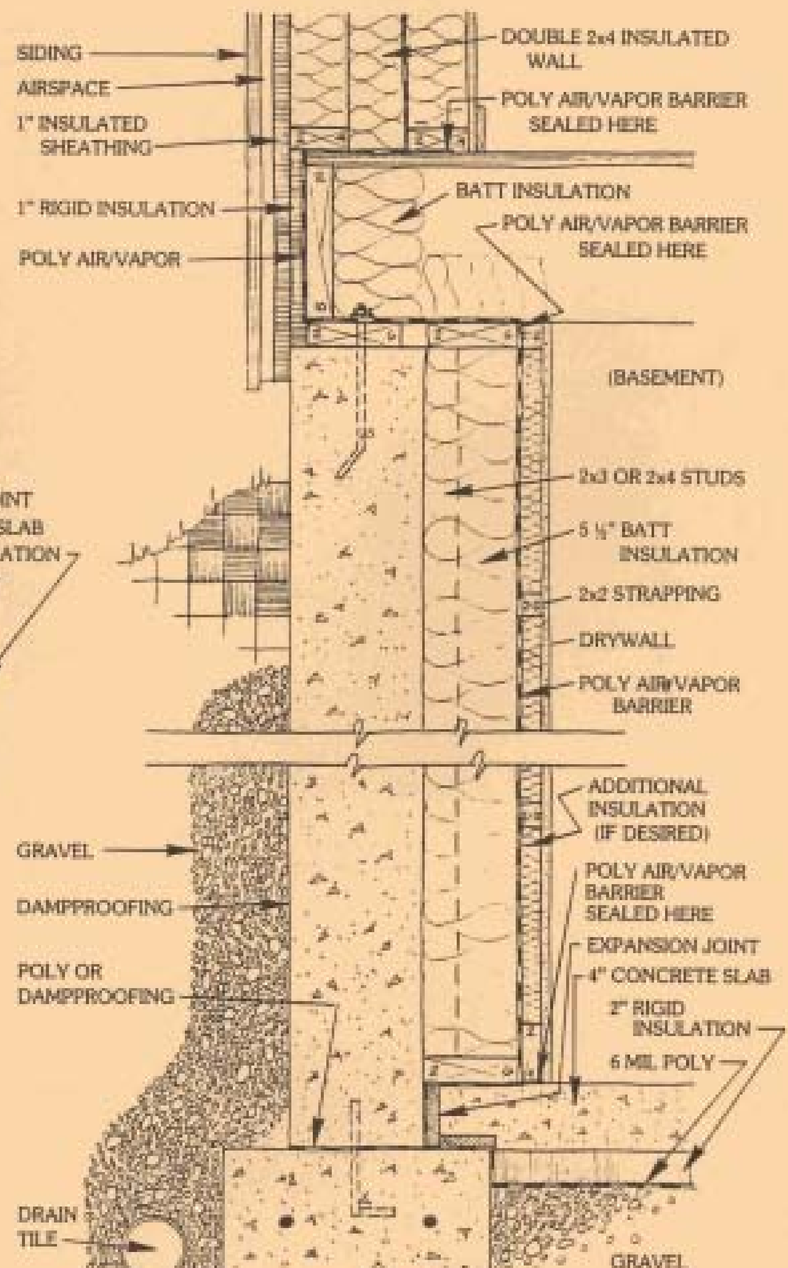
Detail 5 Interior Basement Insulation



AIRTIGHT DRYWALL APPROACH

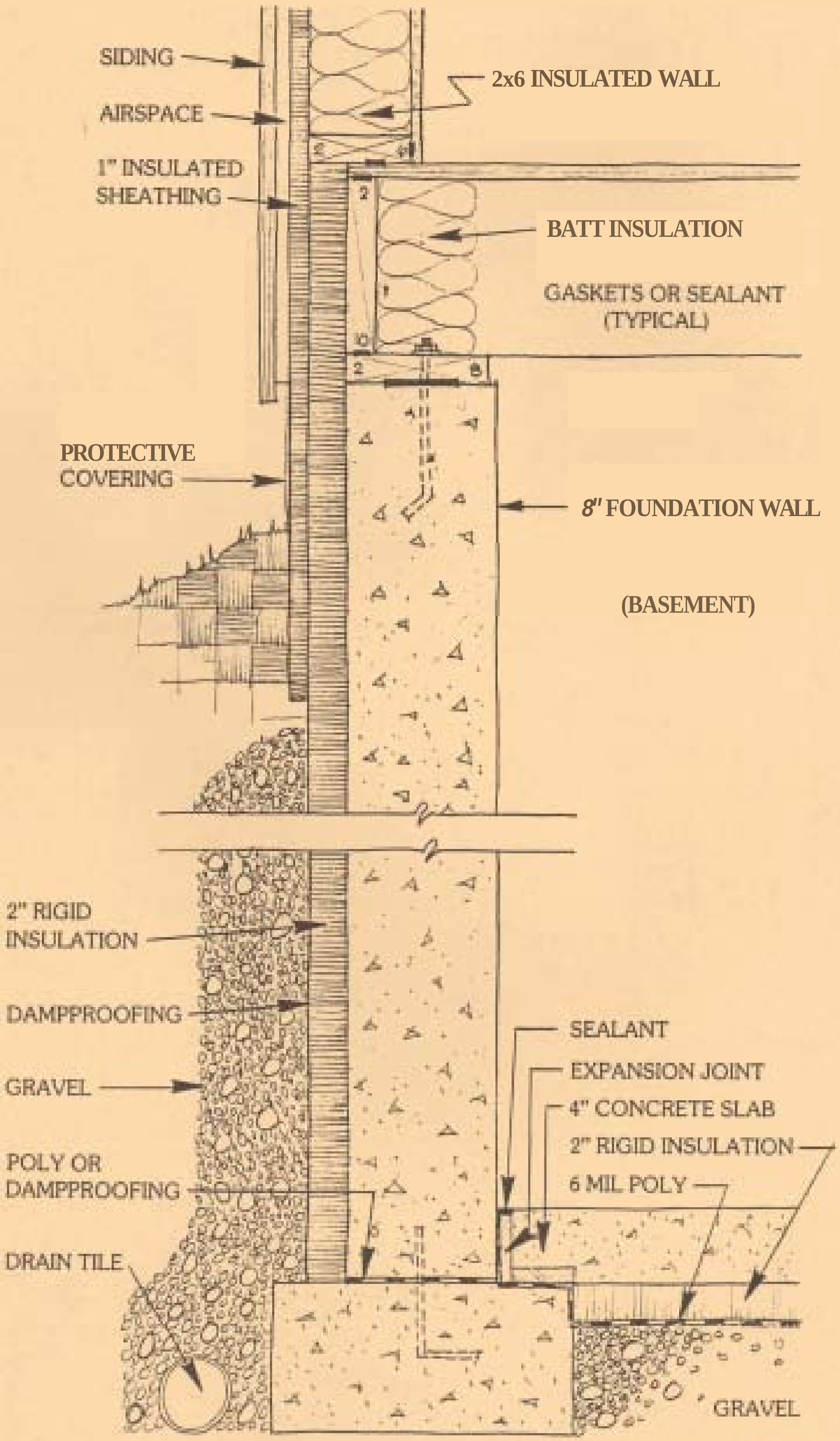


STRAPPED 2X6 APPROACH

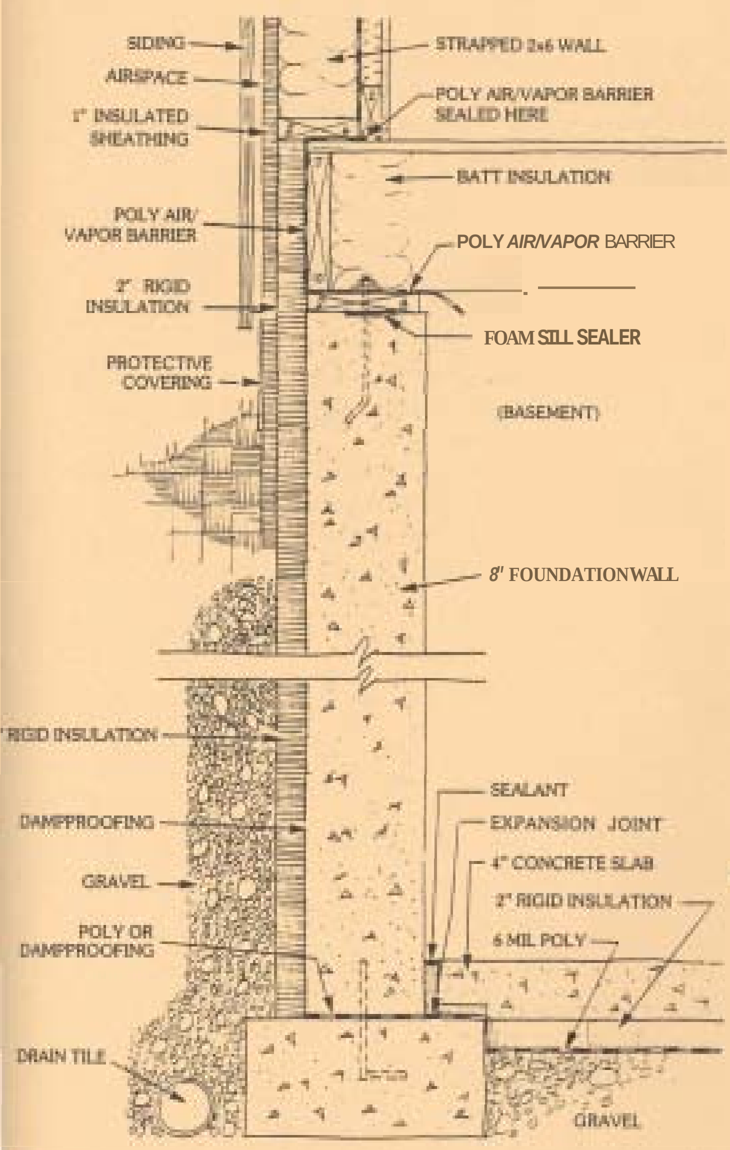


DOUBLE 2X4 APPROACH

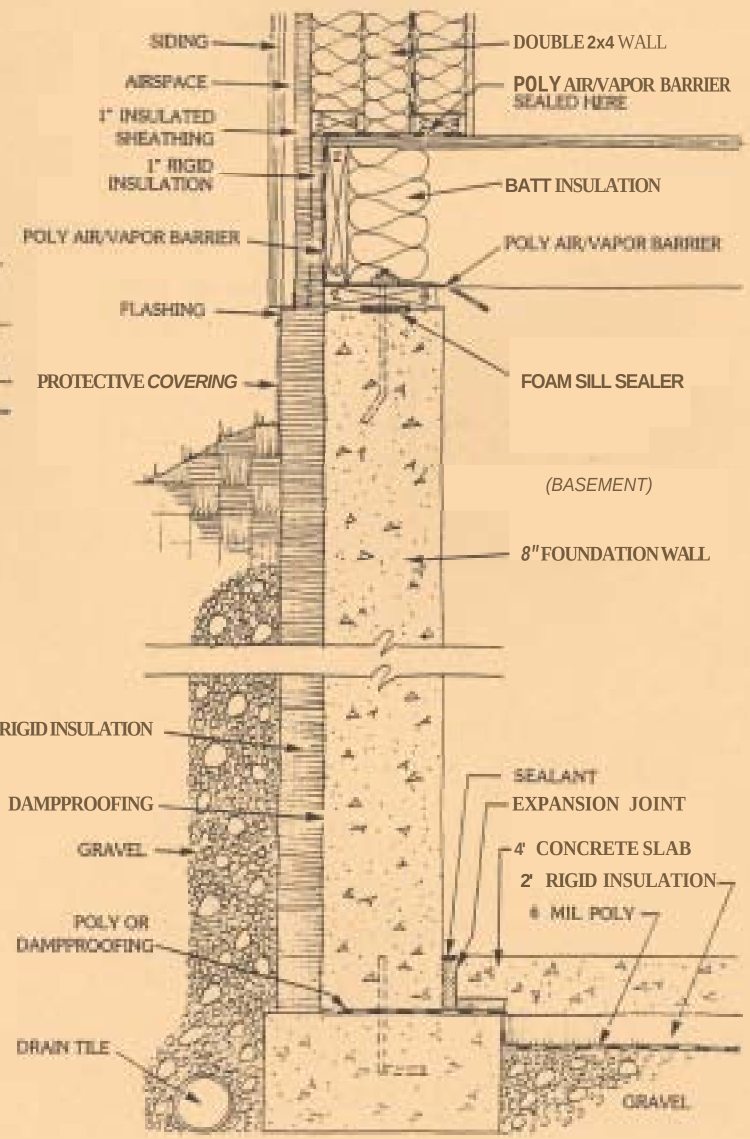
Detail 6 **Exterior Basement Insulation**



AIRTIGHT DRYWALL APPROACH



STRAPPED 2x6 APPROACH



DOUBLE 2x4 APPROACH

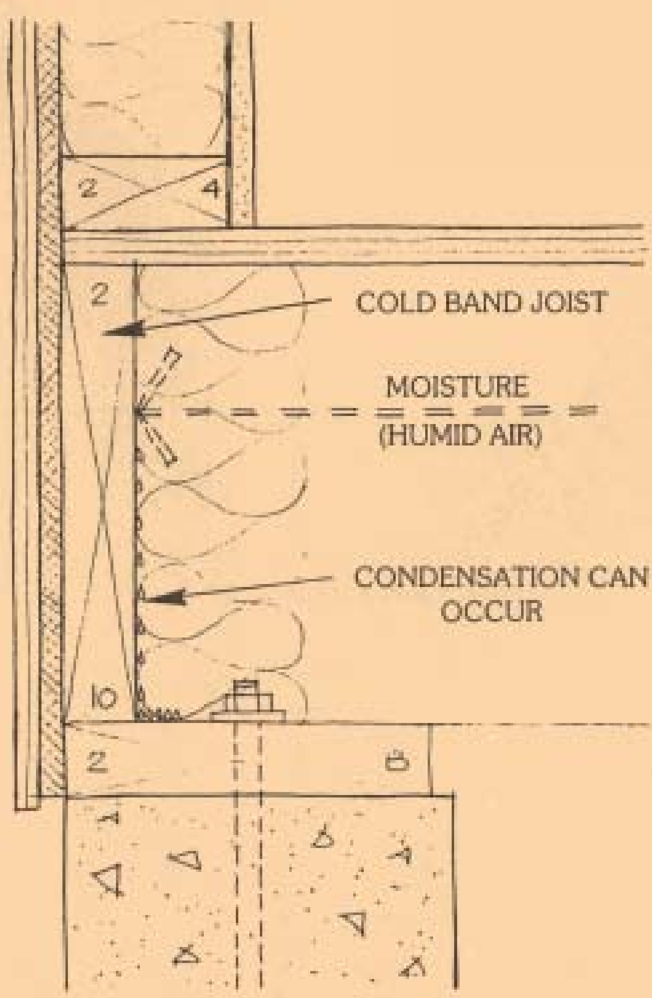
Basement Floors: Insulating beneath a basement floor is controversial. On the positive side, subfloor insulation will result in greater comfort by eliminating a cold slab. The floor will be warmer, more comfortable and will not suffer from summer condensation problems. On the negative side, subfloor insulation is probably not cost effective on energy savings alone and will deprive the basement of the ground-coupled cooling that an uninsulated slab provides in the summer. Considering arguments on both sides, the benefits of comfort and condensation control suggest that it be done. You can use two inches of expanded or extruded polystyrene to insulate a basement floor.

Research has not indicated that radon gas from the soil is a problem in Iowa yet, but you may choose to plan for controlling it. Pouring the floor over 4 inches of pea gravel will allow the air under the slab to be ventilated if it becomes necessary. It is also a good idea to cut control joints in the concrete floor to control cracking and to seal these joints to reduce the potential of radon gas penetration.

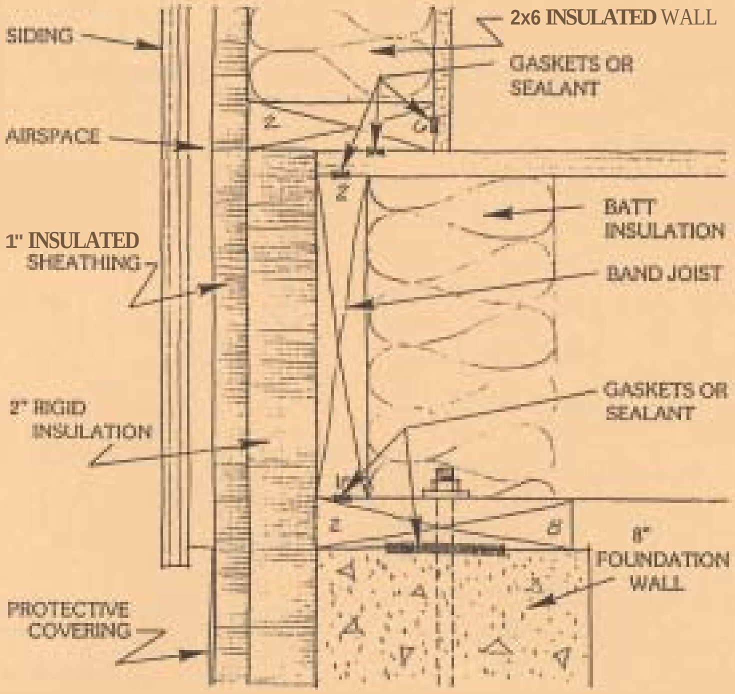
Band Joist: The band joist is the area where the floor joists sit on the foundation. The trouble spot for energy efficient builders is trying to insulate this area to prevent condensation from forming. Detail 7 illustrates the condensation that can occur when insulation is placed on the warm side of a conventional band joist. By placing rigid insulation on the outside, the band joist is kept warm, preventing condensation.

Detail 8 shows how the Aiiight Drywall Approach relies on gaskets to seal the band joist area. The Strapped 2x6 Approach and Double 2x4 Approach use polyethylene wrapped around the band joist.

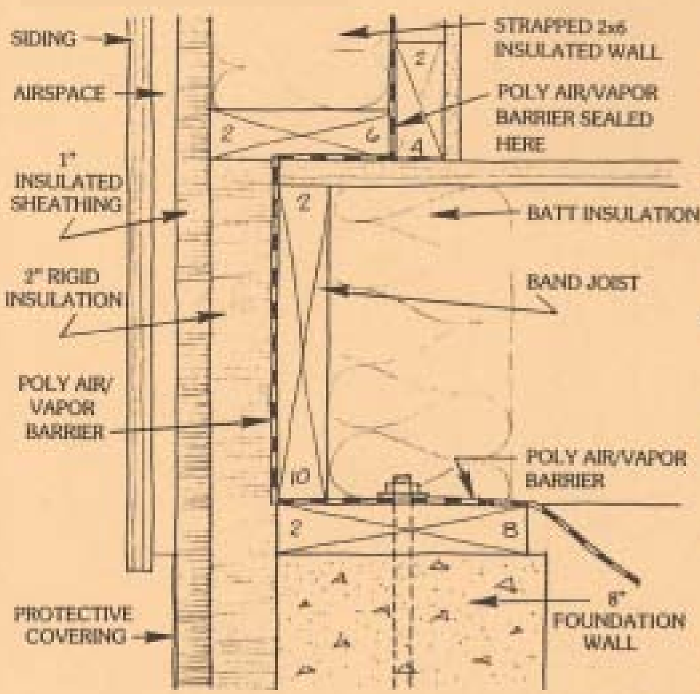
Detail 7 Condensation on Conventional Band Joist



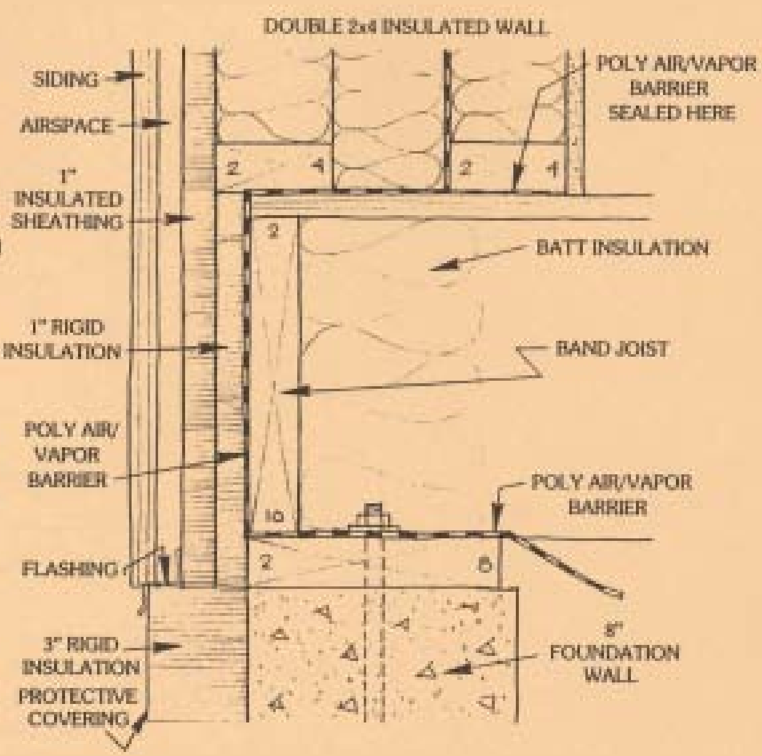
Detail 8 Band Joist Sealing



AIRTIGHT DRYWALL APPROACH



STRAPPED 2x6 APPROACH

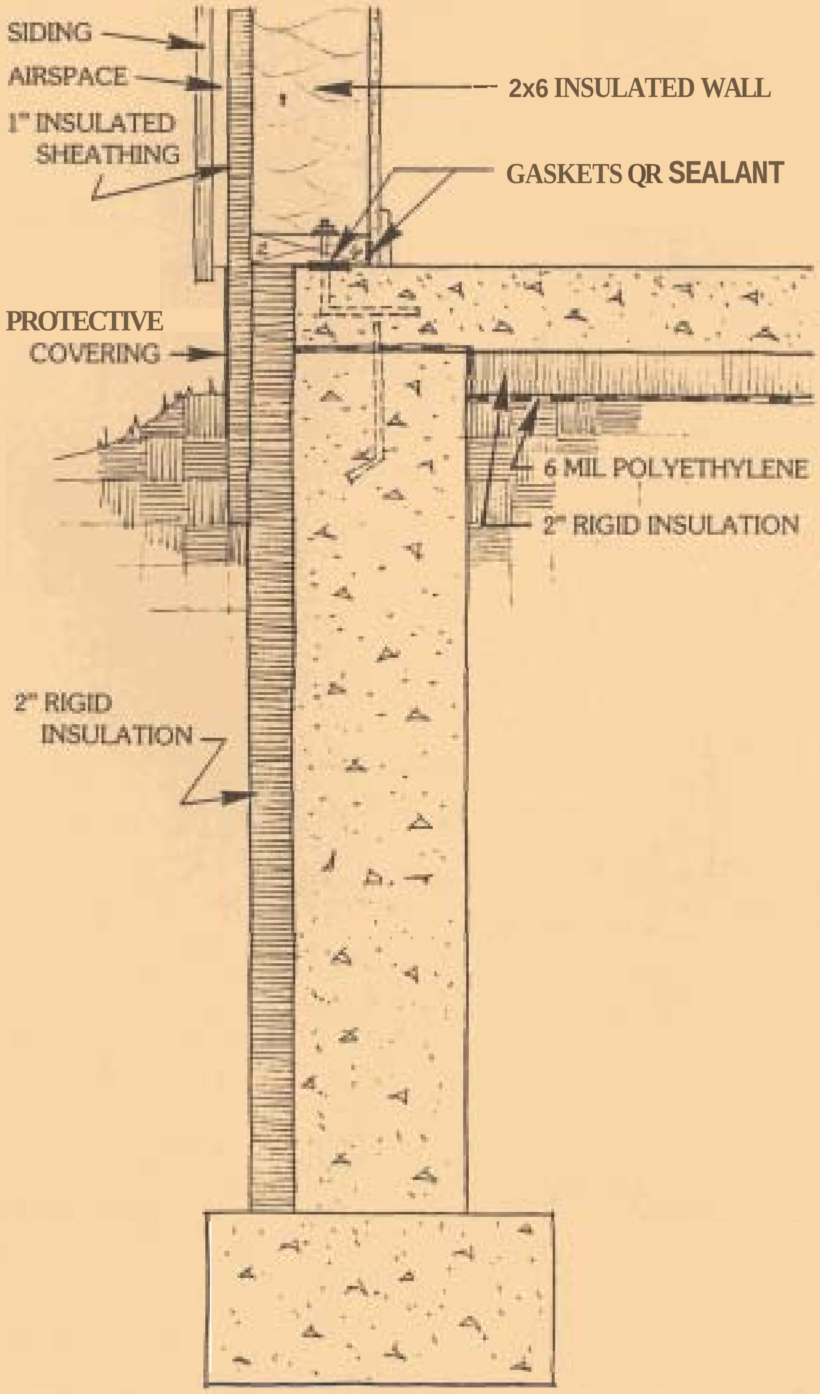


DOUBLE 2x4 APPROACH

Slab on **Grade:** Detail 9 shows the best way to insulate a slab on grade. Notice that the floor is **also** insulated. This keeps the floor warm and comfortable and saves energy.

Crawl **Spaces:** The first step in insulating a crawl space is to lay a sheet of polyethylene (6-mil or thicker - one mil equals a thousandth of an inch) on the exposed dirt floor and tightly seal all joints and penetrations.

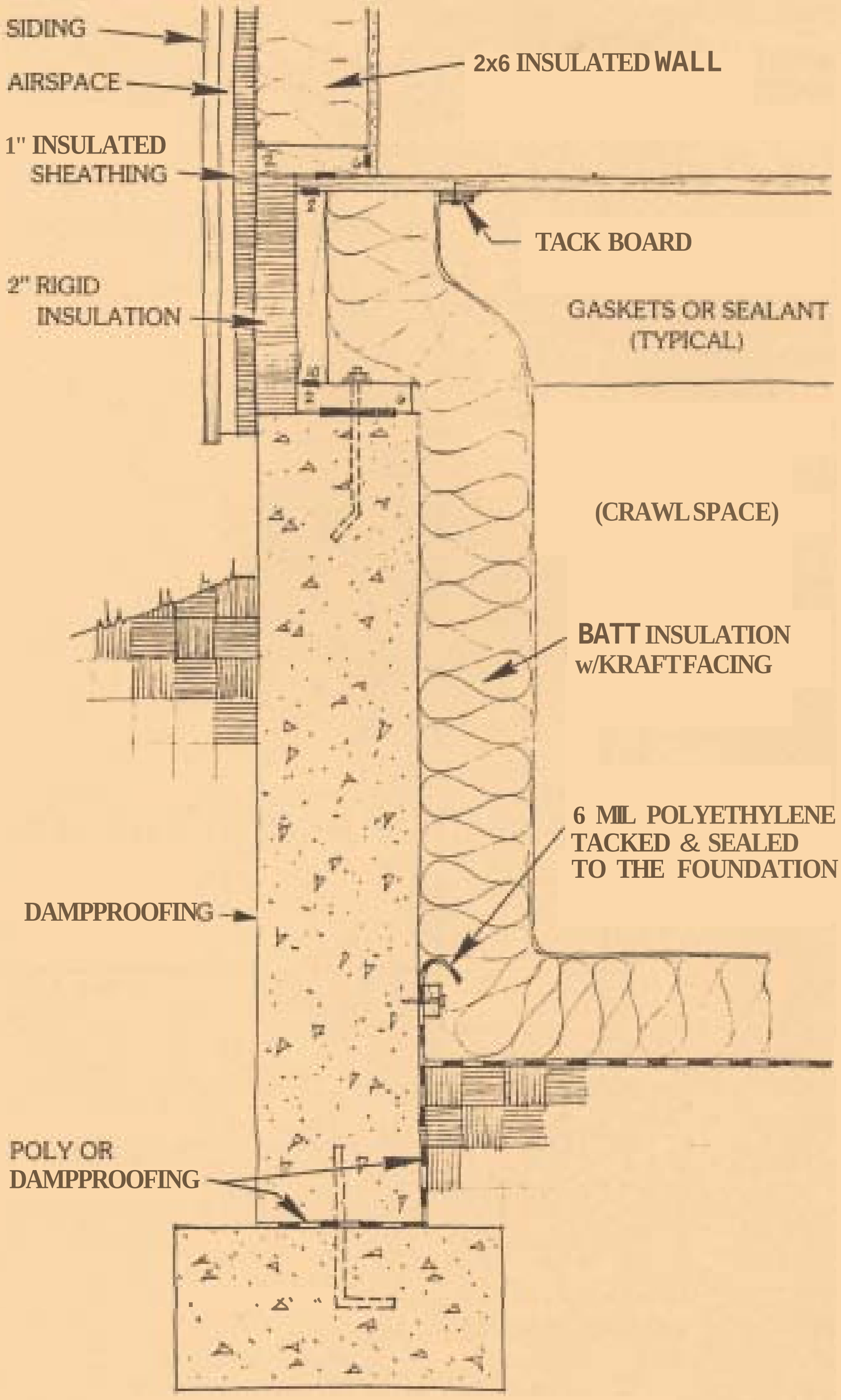
Detail 9 Slab on Grade



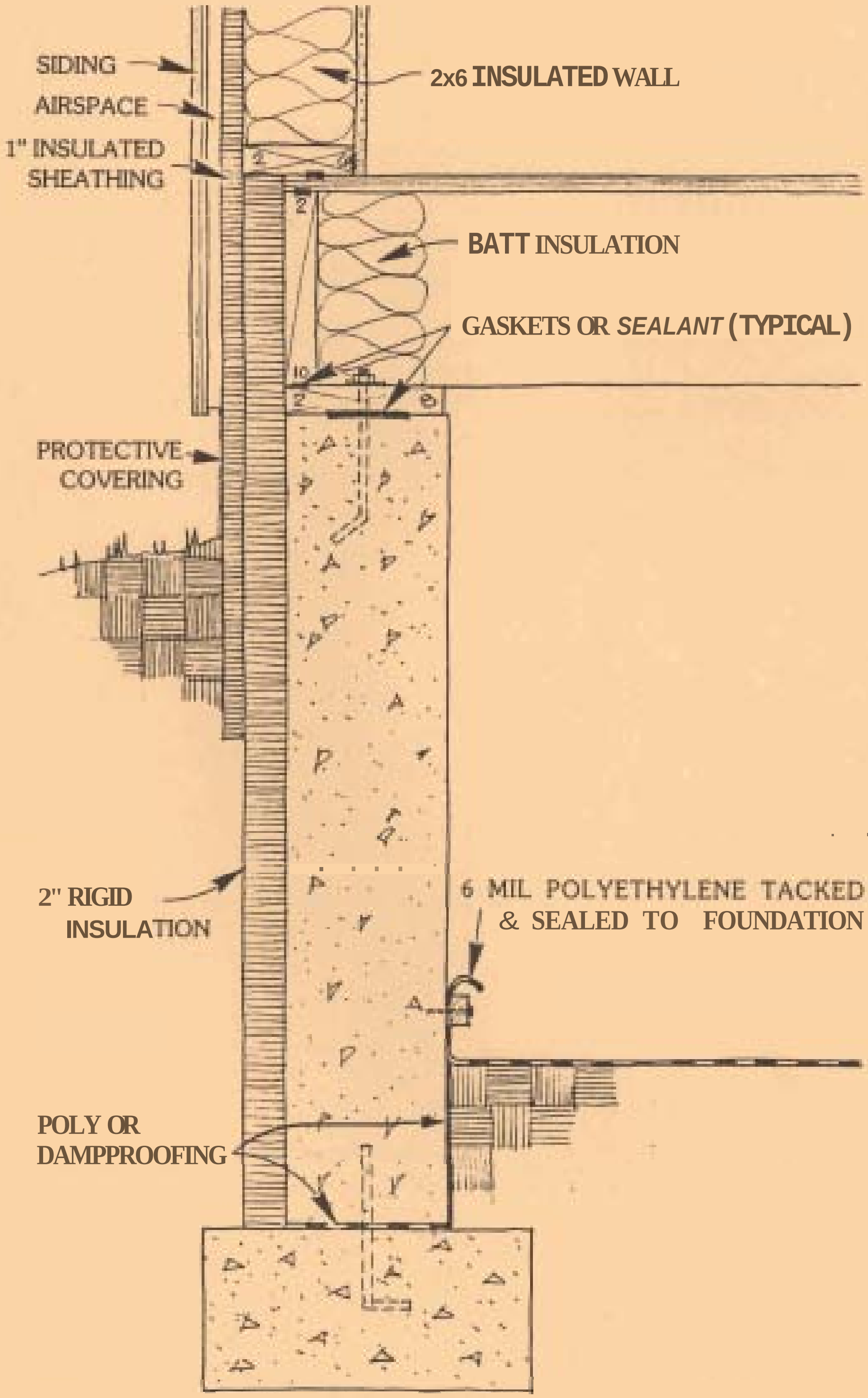
AIRTIGHT DRYWALL APPROACH

This prevents moisture from rising up from the ground and eliminates the need to ventilate the crawl space. The crawl space becomes part of the heated building envelope and the problems of freezing pipes and heat losing ducts are avoided. Detail 10 shows interior and exterior insulation options for concrete/masonry crawl spaces. If there are no water pipes or ductwork in the crawl space, the floor can be insulated instead.

Detail 10 Crawl Space Insulation Options



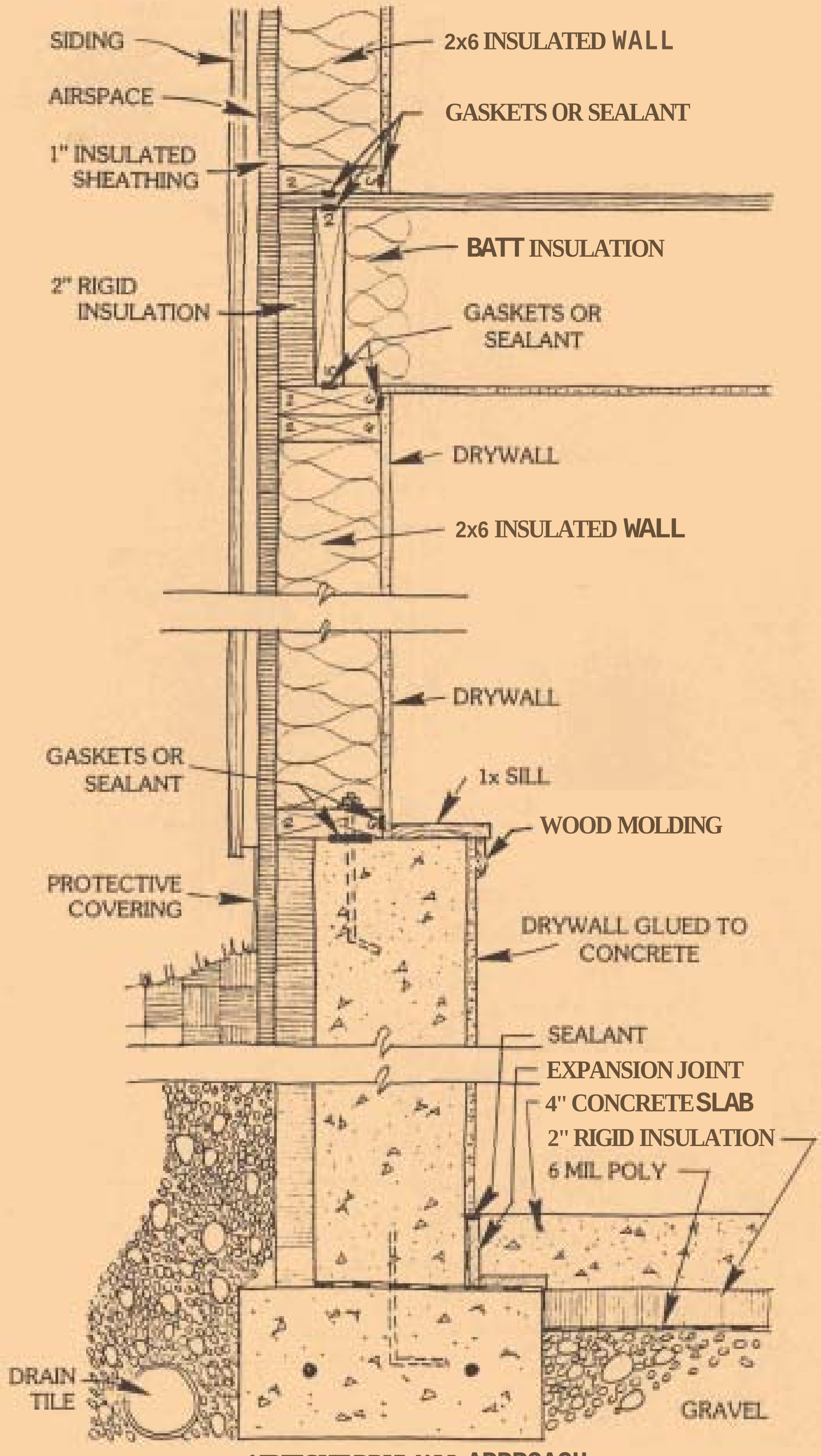
AIRTIGHT DRYWALL APPROACH



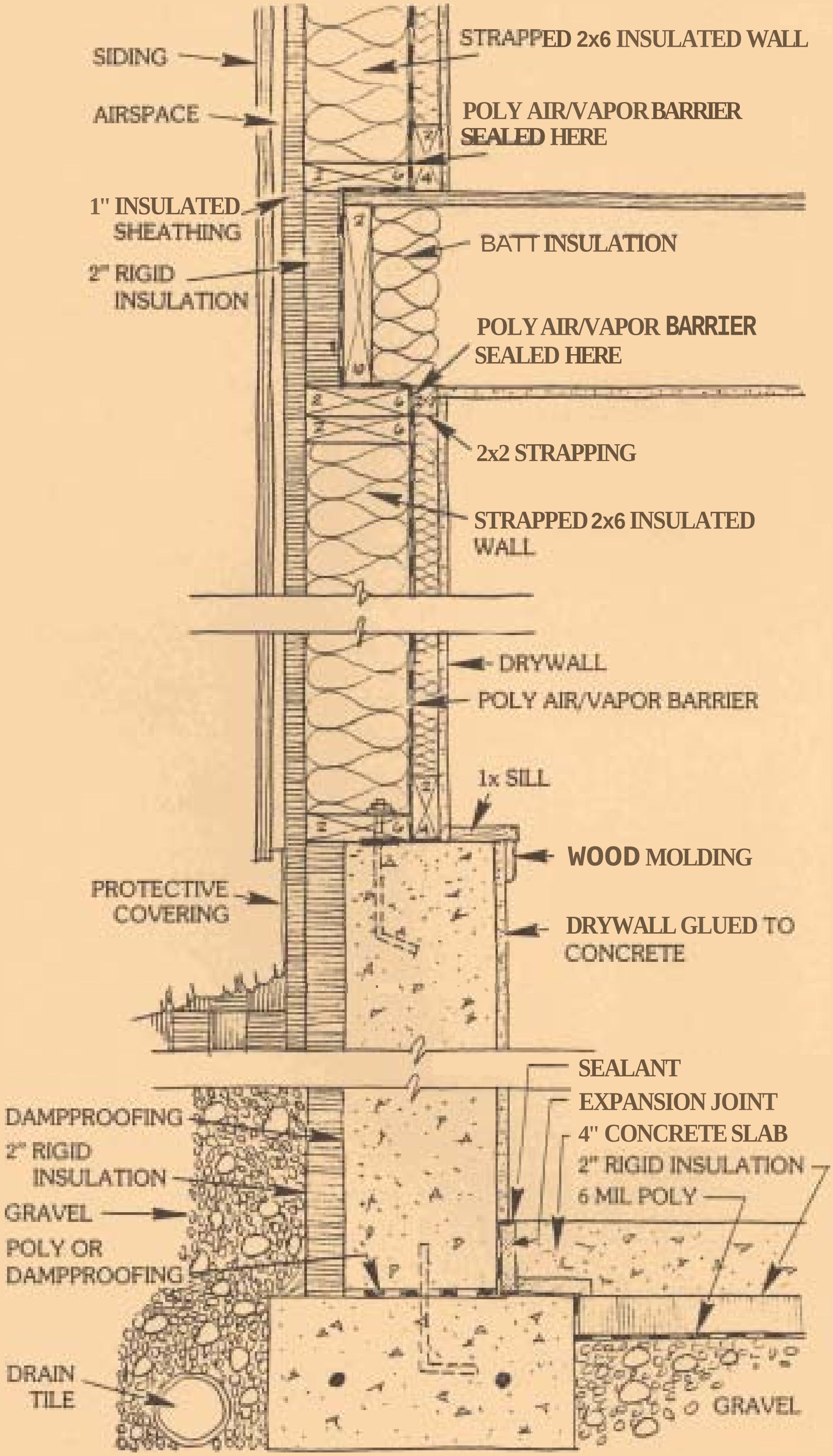
AIRTIGHT DRYWALL APPROACH

Half Basement Walls: If over half of the foundation is exposed, use a half basement wall with an insulated wall above to increase the wall's thermal performance as shown in Detail 11. Notice how the band joist is set back to albw additional insulation on the exterior.

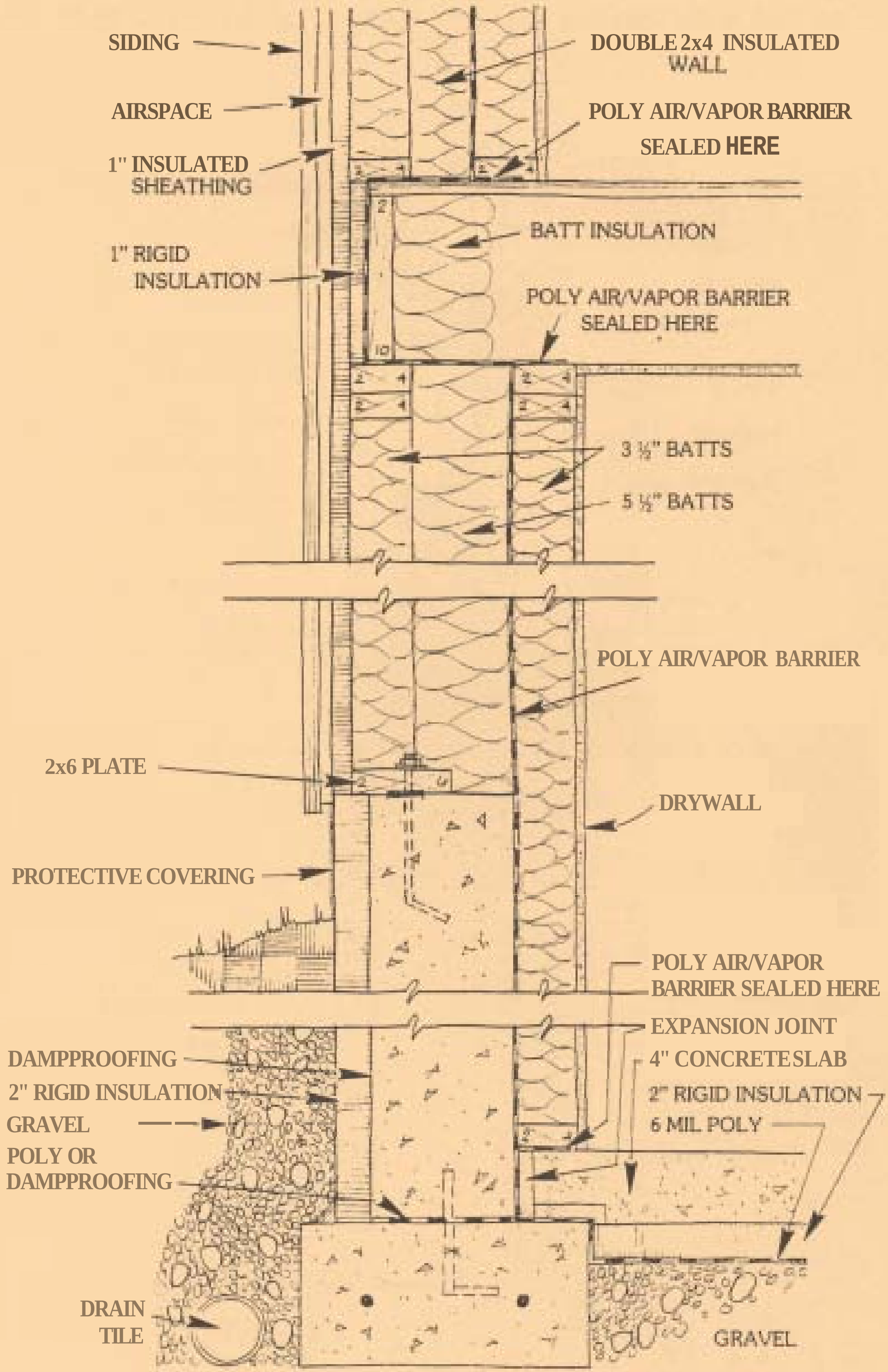
Detail 11 Half Basement Walls



AIRTIGHT DRYWALL APPROACH



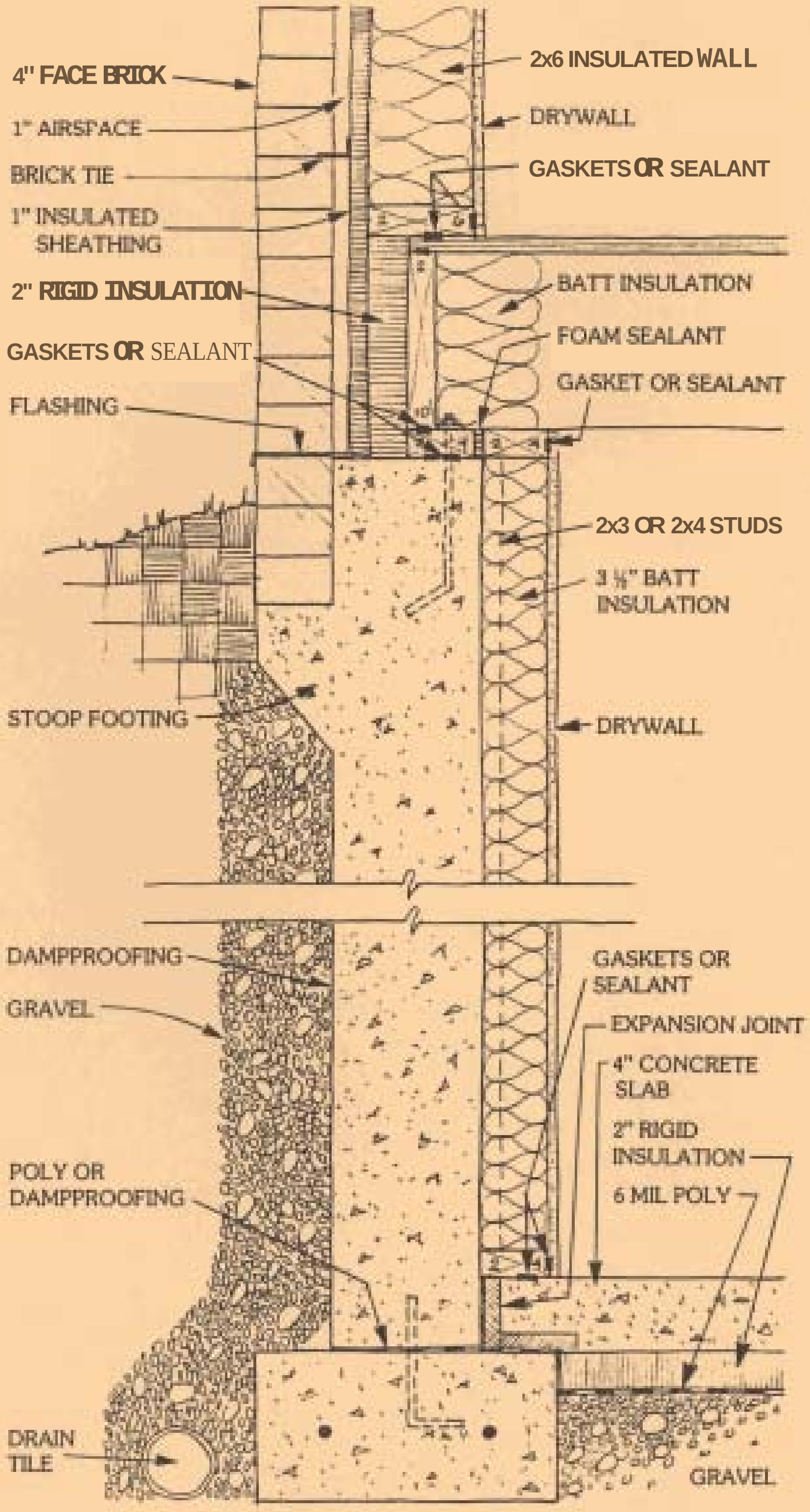
STRAPPED 2x6 APPROACH



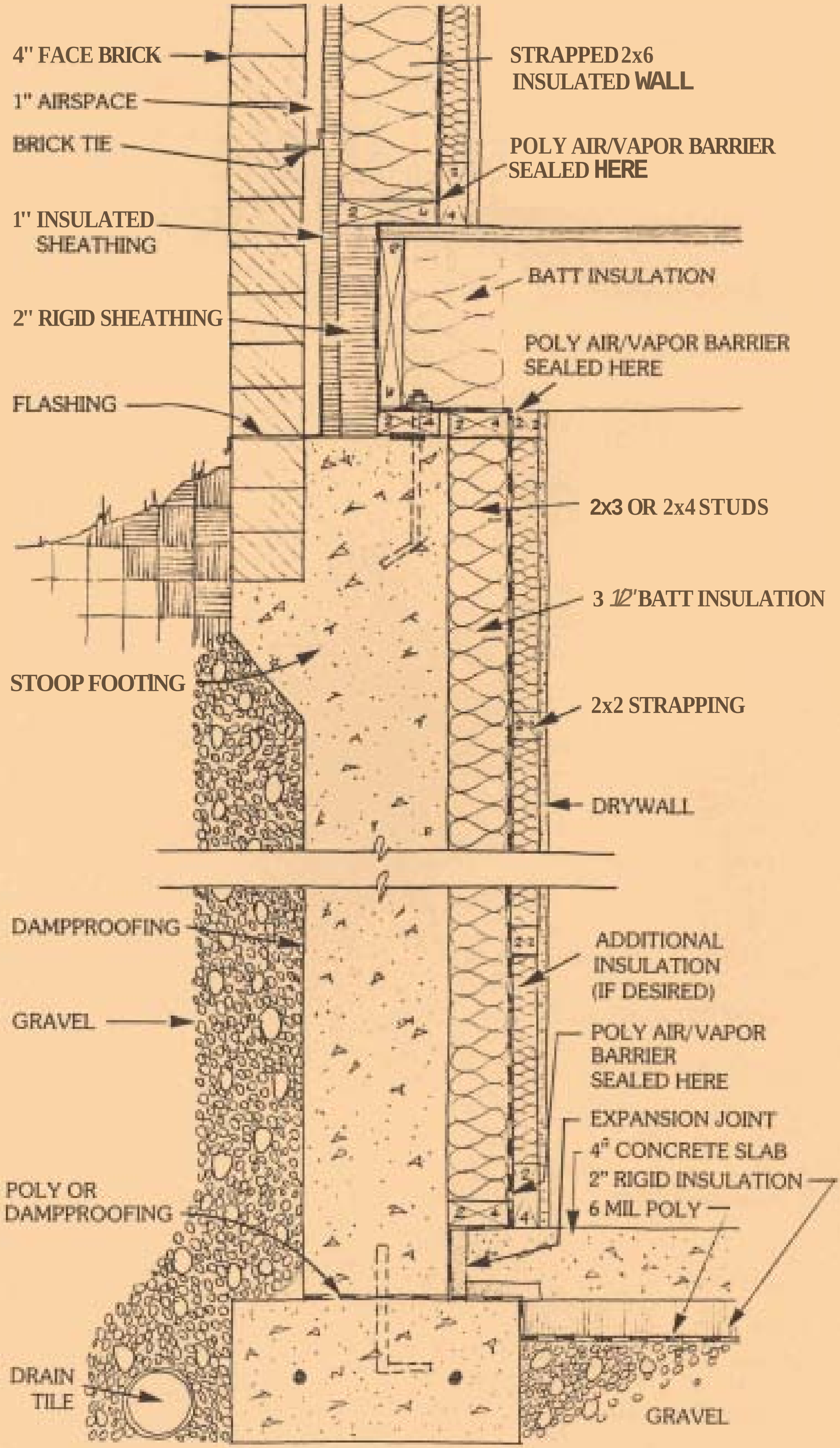
DOUBLE 2x4 APPROACH

Brick Veneer: Interior insulation is probably the best approach to insulating a brick veneer foundation as shown in Detail 12. Any brick support extending out from the foundation should be located below the frost line to prevent frost heave from lifting the brick off the wall.

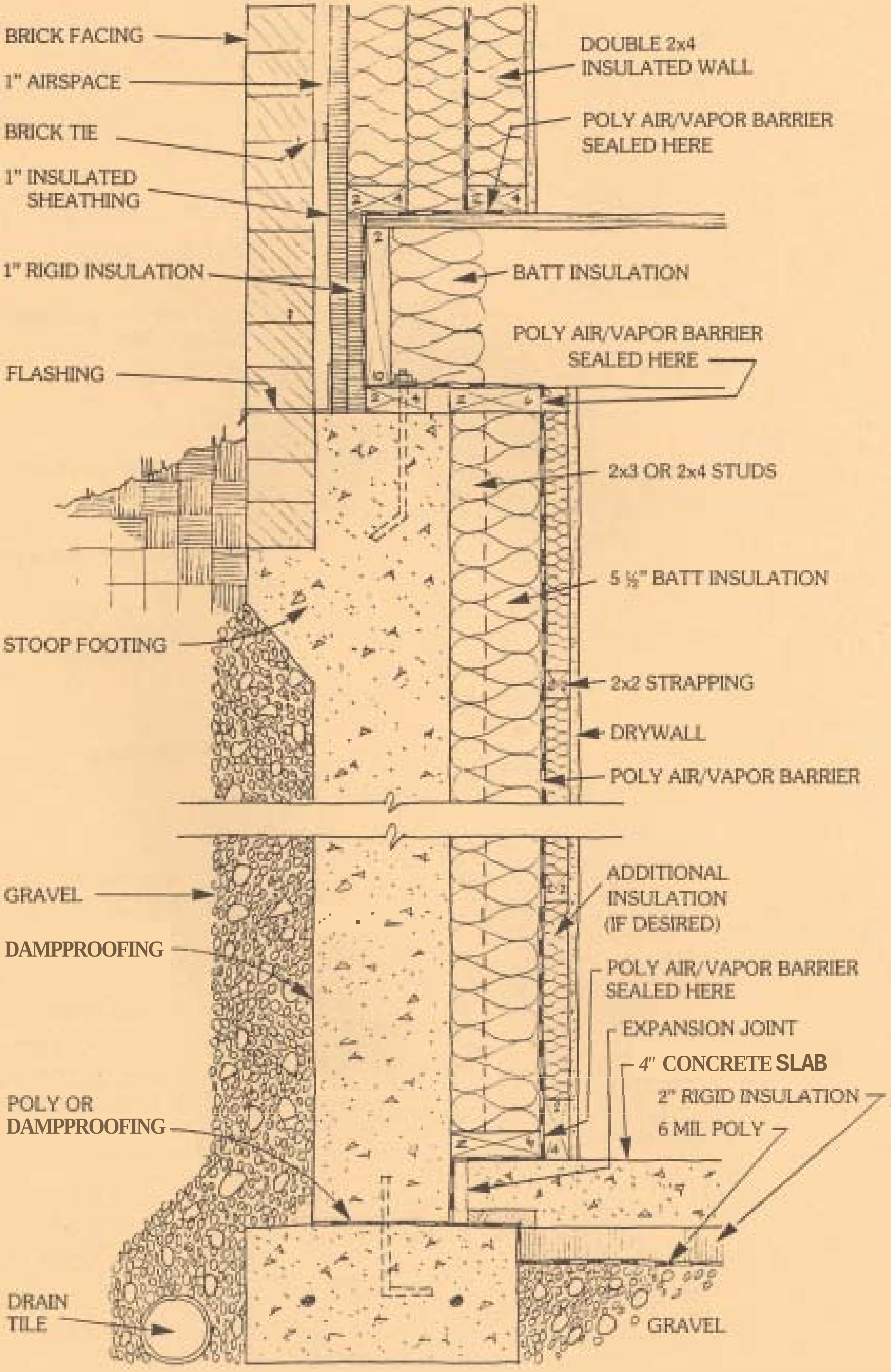
Detail 12 Foundation for Brick Veneer



AIRTIGHT DRYWALL APPROACH



STRAPPED 2x6 APPROACH



DOUBLE 2x4 APPROACH

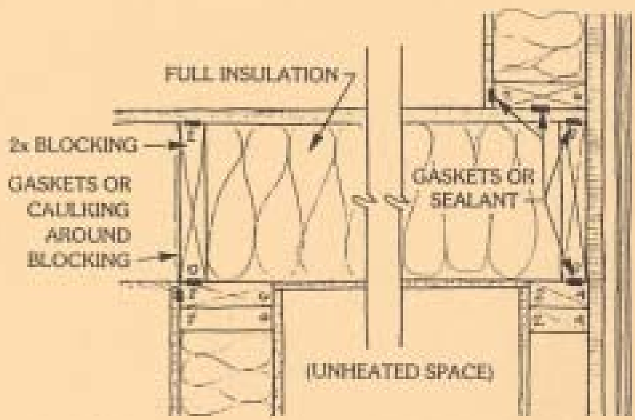
Floors Over Unheated Spaces: Detail 13 shows how to insulate a floor over an unheated space. The mast common areas are cantilevered floors (shown in Detail 14) and floors over tucked-under garages.

Sealing Penetrations

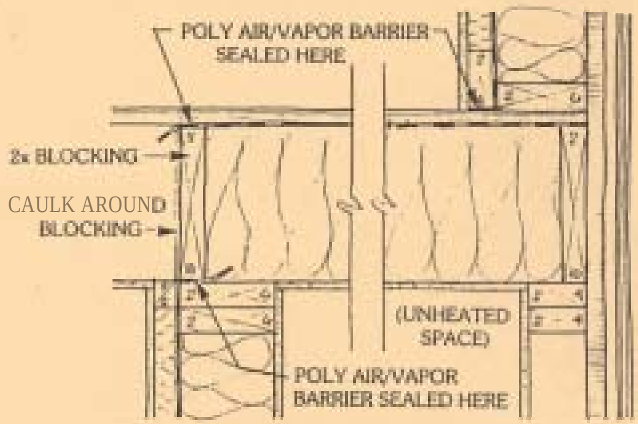
Sealing penetrations is an important energy saving measure often overlooked during construction. The most common foundation penetrations are utility service penetrations, vents, outside faucets, and basement windows.

Utility Service Penetrations: The electrical and gas service entrances will enter the house either at the band joist or underground. They must be caulked wherever they come in. If you have a basement that is insulated on the inside, mount the electrical panel to a sheet of plywood and seal the drywall and/or the polyethylene air/vapor barrier to the plywood. If wires must run into

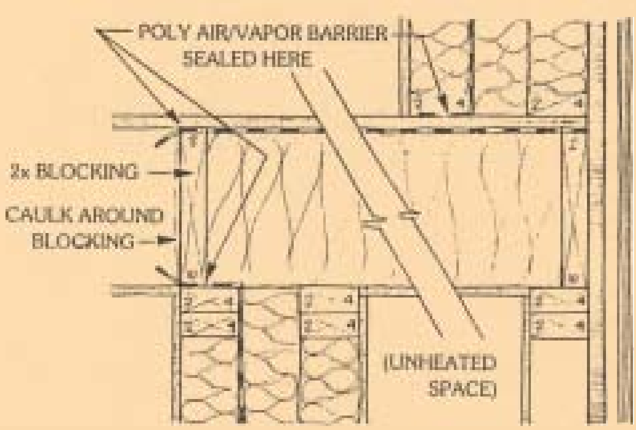
Detail 13 Floor Over Unheated Space



AIRTIGHT DRYWALL APPROACH

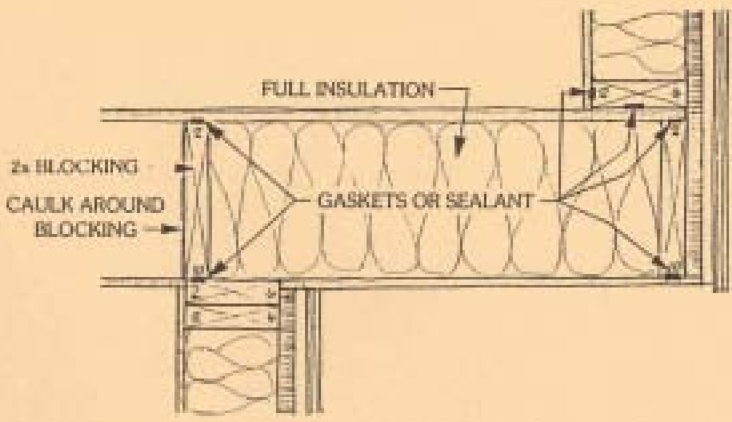


STRAPPED 2x6 APPROACH

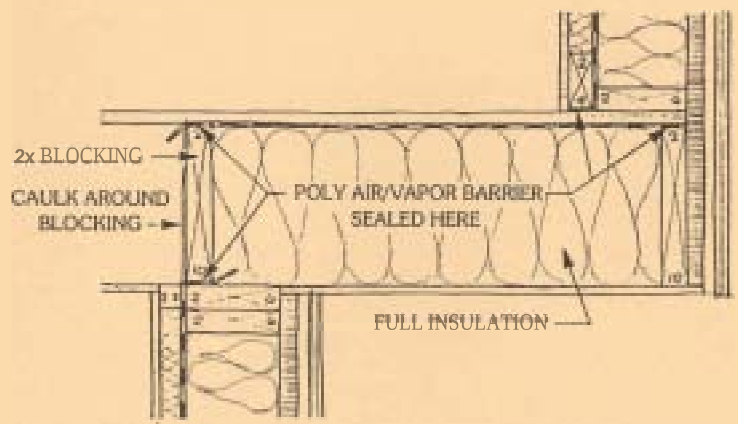


DOUBLE 2x4 APPROACH

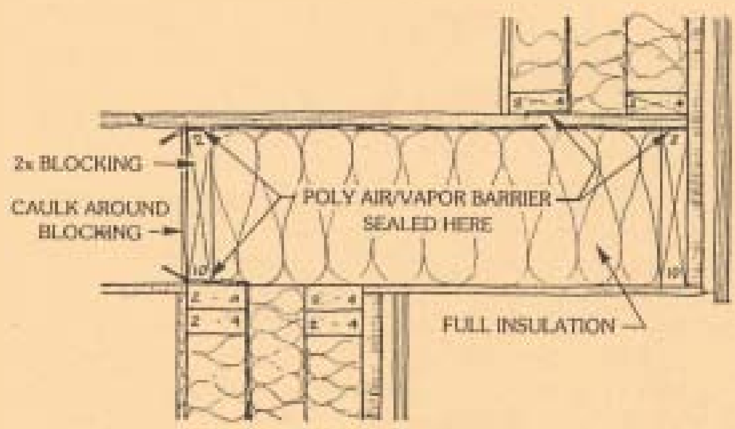
Detail 14 Cantilevered Floors



AIRTIGHT DRYWALL APPROACH



STRAPPED 2x6 APPROACH



DOUBLE 2x4 APPROACH

the wall, run them through the plywood and seal around them. Telephone and cable TV service always come in at the band joist; seal around the wires with caulk. The water supply always comes in below ground and should be sealed where it penetrates the foundation wall.

Vents: Vents from the dryer and controlled ventilation system will exit at the band joist. Caulk well around the pipes. Install a dryer vent with a good damper to prevent air from coming in through the dryer.

Outside Faucets: Install a freeze proof outside faucet and seal around the pipe where it penetrates the band joist.

Basement Windows: **On** a wood foundation, seal as if it were an upper level window. (See Windows under Construction Details in the Walls section). On a concrete/masonry foundation, seal around the window frame with foam sealant and cover with caulk. □

WALLS

As we mentioned earlier, the design approach you choose for the walls will actually determine choices you make throughout the construction process. The following sections, General Considerations, Construction Details and Sealing Penetrations can help you make this important decision.

General Considerations

There are several general considerations to take into account before you decide which approach to use when constructing an airtight wall. These considerations include the wall approach, insulation options, insulated sheathing, exterior air barriers, and siding.

Wall Approach: Which construction approach you choose depends on the length of time an individual plans to spend in the home and the experience of the builder. Since the price of energy resources will most likely rise in the future, the longer a homeowner plans to live in the home, the more insulation the walls should have because adding additional insulation to walls at a later time is difficult and expensive.

The less experience a builder has with energy efficient construction, the more the Airtight Drywall Approach would be the better choice. It is the closest to conventional construction, and eliminates the hassle of using polyethylene as the air barrier which builders have had a problem with in the past. The Strapped 2x6 Approach and Double 2x4 Approach, though more complicated and slightly more expensive, also solve many of the common polyethylene hassles by placing the air/vapor barrier back into the wall instead of on the interior surface. (See the Construction Details section for schematics of each wall approach.)

Insulation Options: Walls are most commonly insulated with fiberglass batt insulation, but other types, such as blown-in cellulose, rock wool or fiberglass, can also be used. Fiberglass batts must be carefully installed. Leaving even 3 percent voids lowers the overall R-value of the wall 17 percent and promotes thermal convection loops. Over compression also lowers the batts effective R-value. (See the Insulation section for detailed insulation comparisons.)

Insulated Sheathing: Insulated sheathing ranges in R-value from R-4 to R-7 per inch. Install at least one inch of rigid insulated sheathing on all exterior walls. Use metal diagonal bracing instead of plywood at the corners. This minimum R-4 insulation value will help keep the wall cavity warm and will increase its potential to dry out if it gets wet from condensation. Insulated sheathing also short circuits the heat path through the wall studs. The top of the insulated sheathing should be sealed with a gasket or caulking and the seams should be taped to stop convective loops from making the sheathing ineffective.

Exterior Air Barriers: There are exterior air barrier sheets that can be added at the time of construction under the siding. These barriers allow moisture vapor to pass through, but not air. Since most insulated sheathing products are also air barriers if their seams are taped, the additional air barrier may not be necessary.

Siding: Which siding you choose will not significantly affect the energy consumption of the home. If you choose wood siding over insulated sheathing, one recommendation is to install the siding over furring strips as shown in all the illustrations in this book. This approach, called the vented rain screen, prevents rain and moisture from being drawn into the wall by equalizing the pressure on both sides of the siding. It also helps prevent the siding from overheating and buckling when the sun shines on it. The vented rain screen should be sealed at the top but should remain open at the bottom. An insect screen should be installed at the bottom. The vented rain screen is designed to help increase not only the life of the paint or stain but also the life of the wood siding. This approach can also be used for other types of siding, but is not as critical.

If you do not choose to use the vented rain screen approach, contact the manufacturer of the insulated sheathing you choose for special instructions for installing different types of siding over their product.

Construction Details

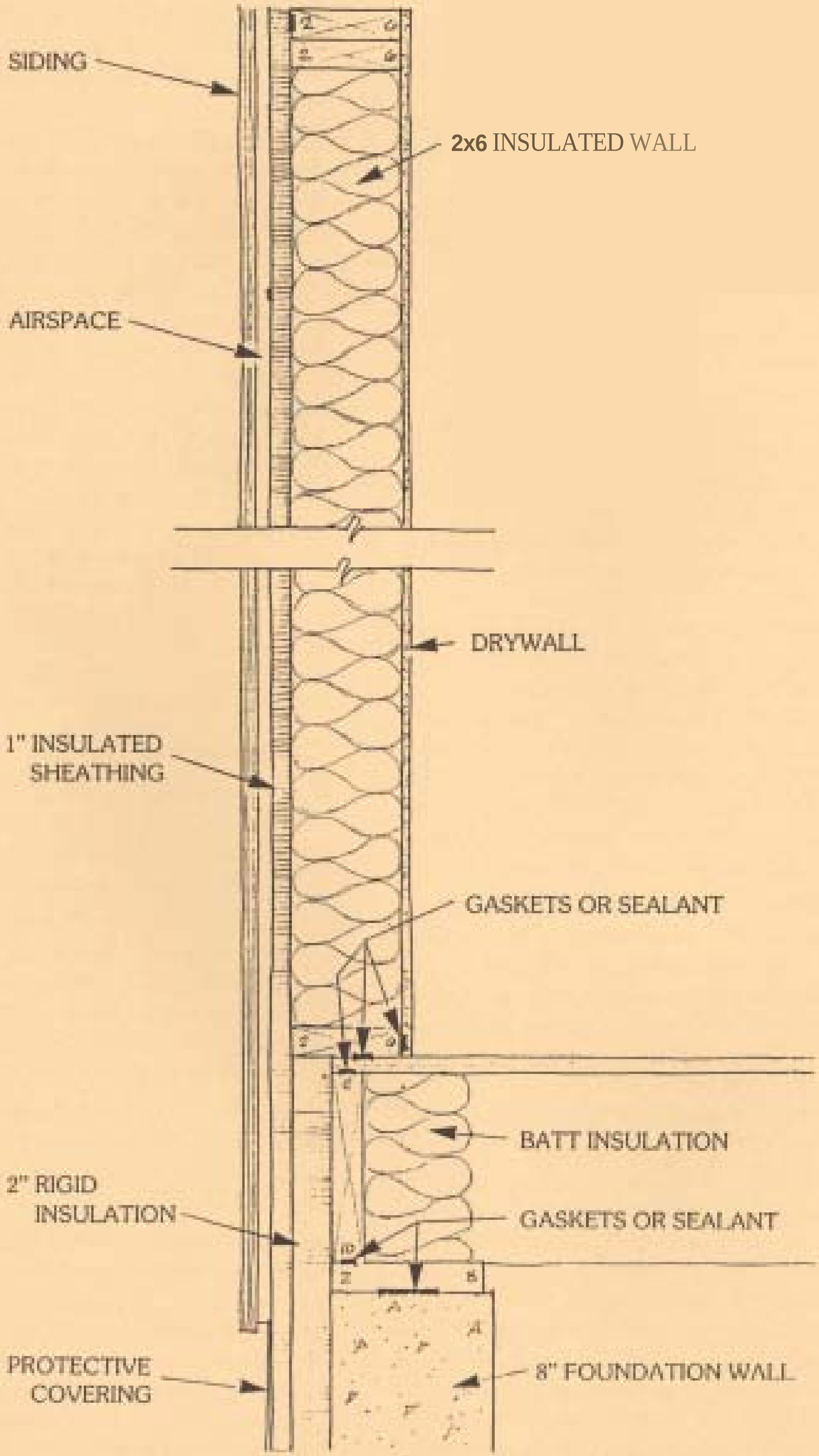
Wall Details: Detail 15 shows the three wall approaches. The Airtight Drywall Approach uses the drywall and the building materials as the air barrier. The Strapped 2x6 Approach and Double 2x4 Approach rely on a polyethylene air/vapor barrier.

Corner Details: Detail 16 shows corner framing details for the three wall approaches. Drywall clips can be used at corners to eliminate a stud for the Airtight Drywall Approach. The Strapped 2x6 Approach needs the extra stud to support the 2x2 strapping.

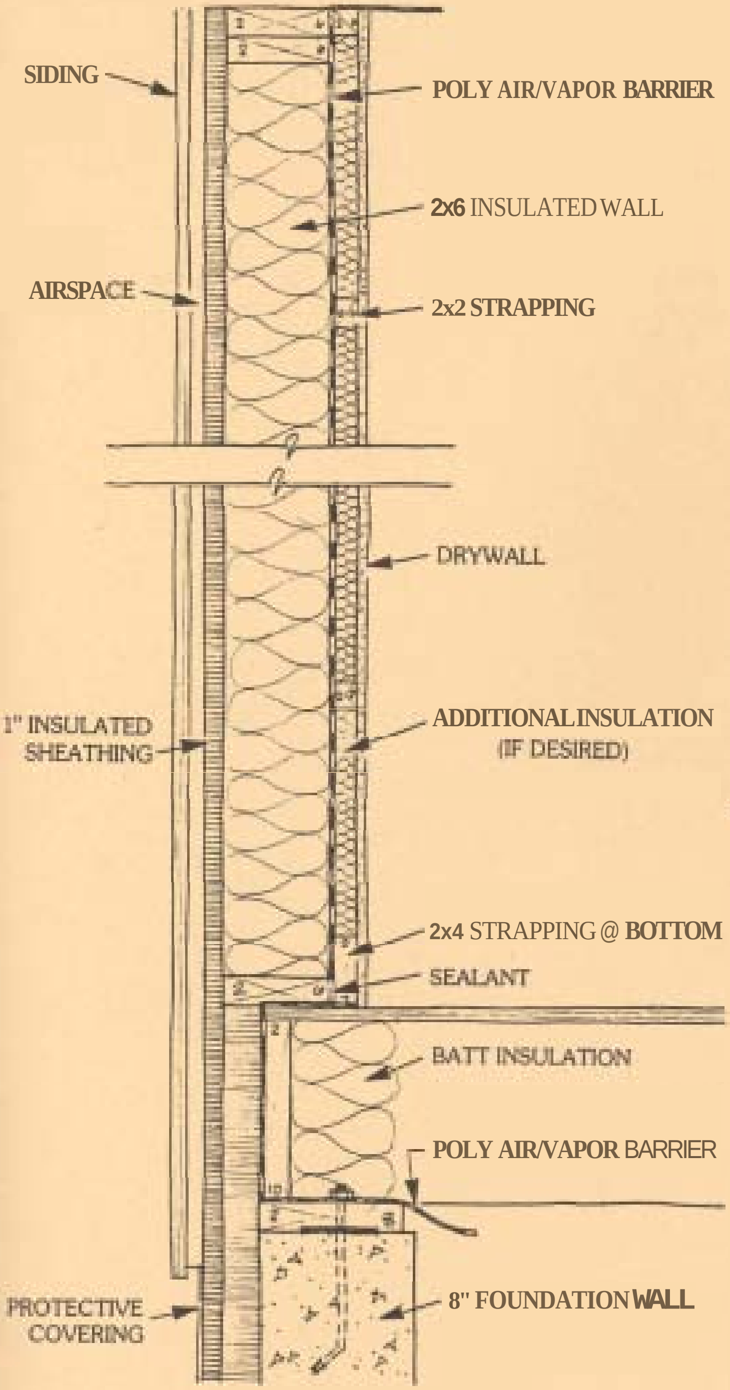
Strapping: The strapping on the Strapped 2x6 Approach should be applied horizontally at 16 inches on center with a 2x4 at the bottom and at the 4 foot level. See Detail 17.

Interior/Exterior Wall Junctions: The joint where the interior partion meets the exterior wall has always been a difficult joint to seal. Detail 18 shows how the Airtight Drywall Approach seals it and how the other two approaches avoid the problem. The Airtight Drywall Approach uses gaskets placed on the ouside stud of the inside partition to keep the air barrier continuous. Any electrical penetrations from the exterior wall to the interior wall must be sealed. To avoid these gaskets, the exterior walls and ceiling can be drywalled before building the interior partitions; the drawback is the drywaller must come twice. The Strapped 2x6 Approach and Double 2x4 Approach avoid problems with sealing wall junctions by running the polyethylene air/vapor barrier behind the interior partitions.

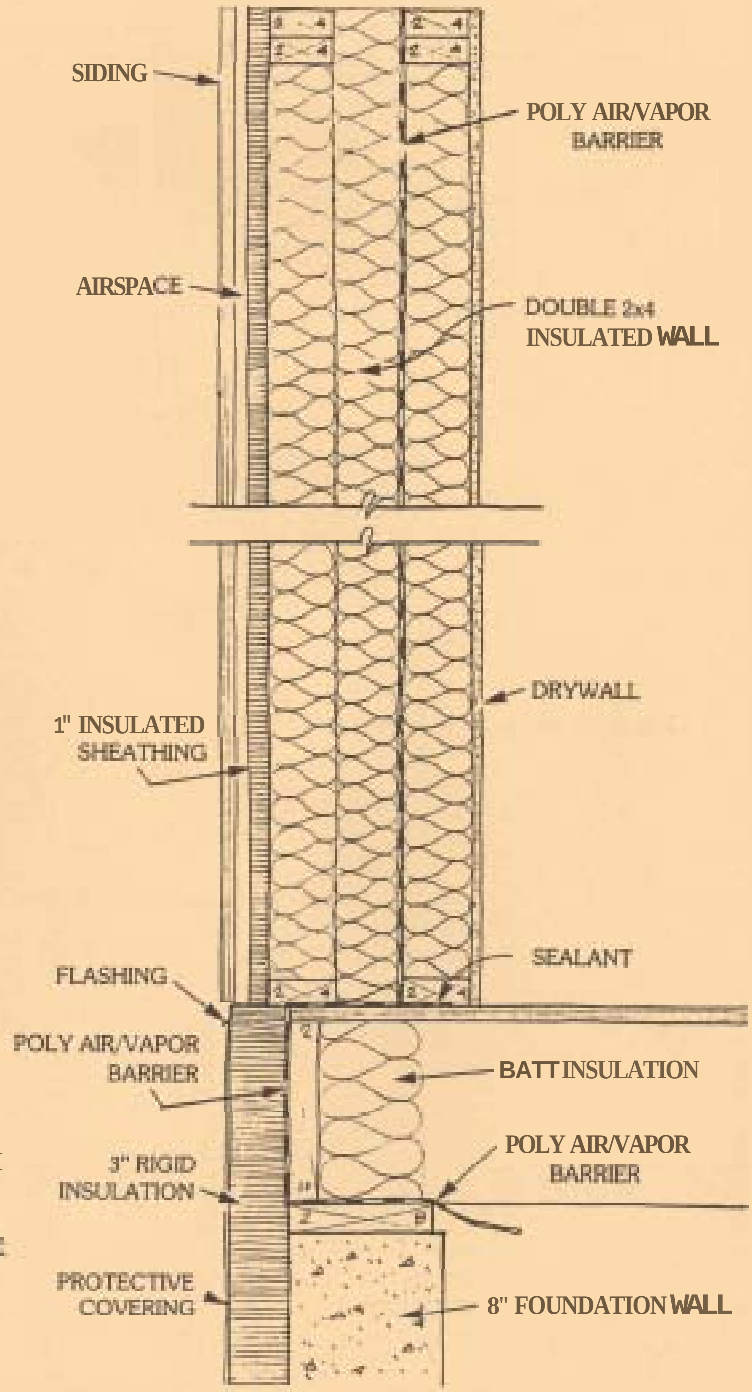
Detail 15 Wall Options



AIRTIGHT DRYWALL APPROACH

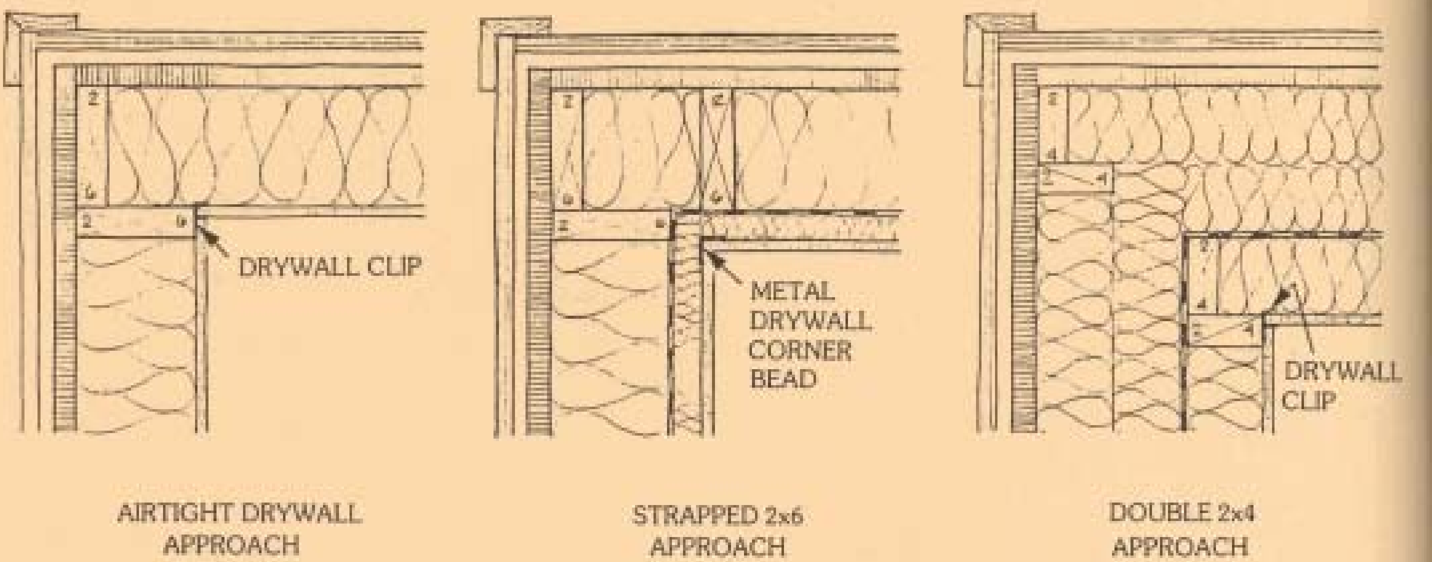


STRAPPED 2x6 APPROACH

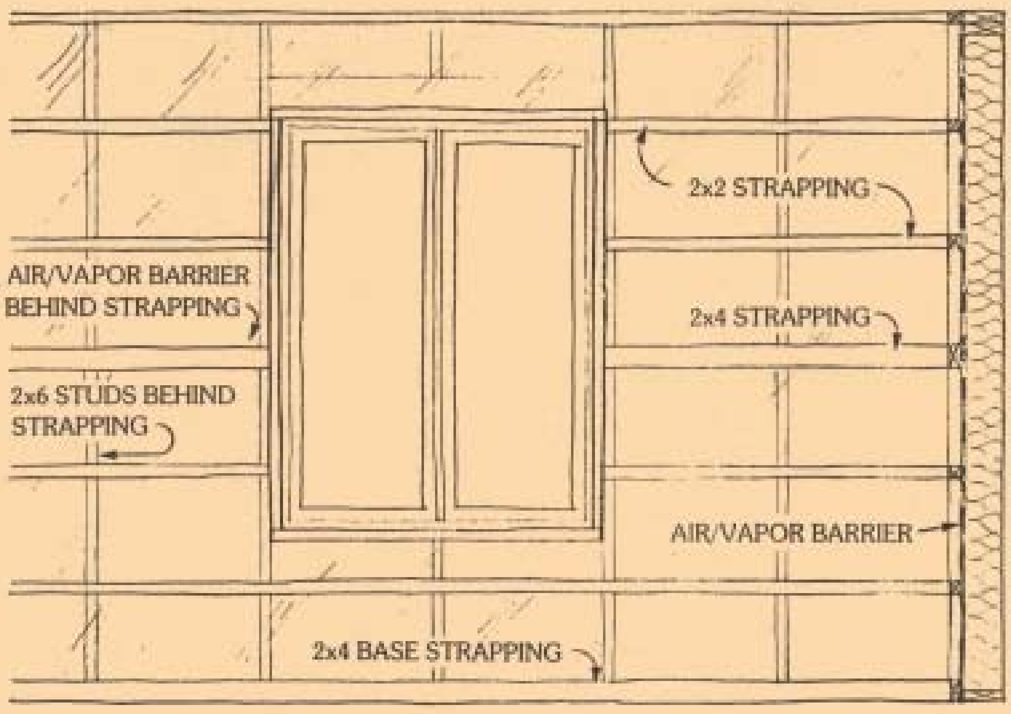


DOUBLE 2x4 APPROACH

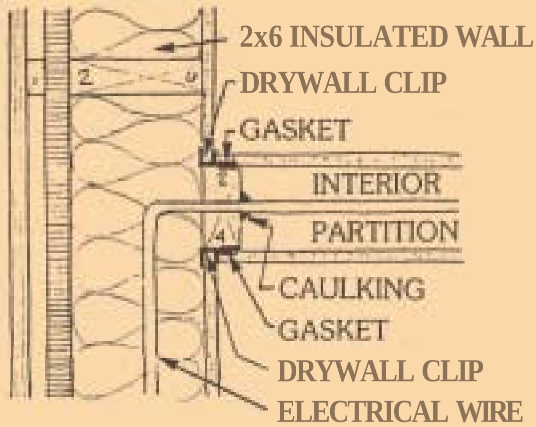
Detail 16 Corner Details



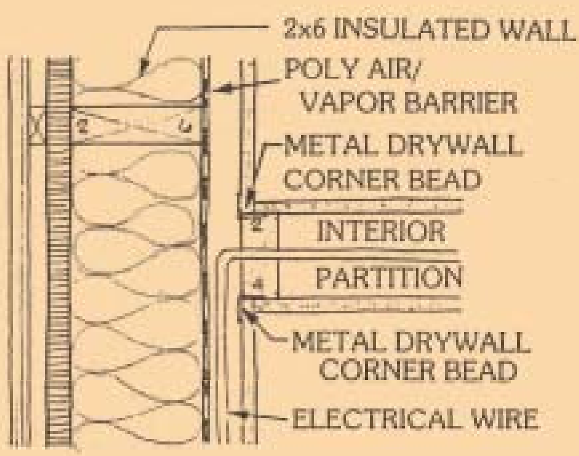
Detail 17 Strapped 2x6 Wall



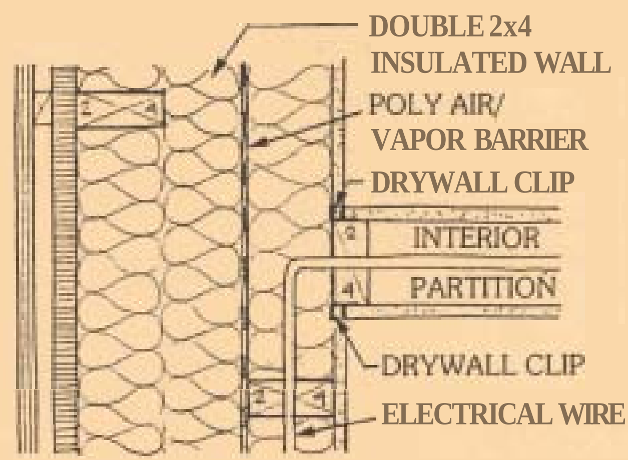
Detail 18 Interior/Exterior Wall Junctions



AIRTIGHT DRYWALL
APPROACH



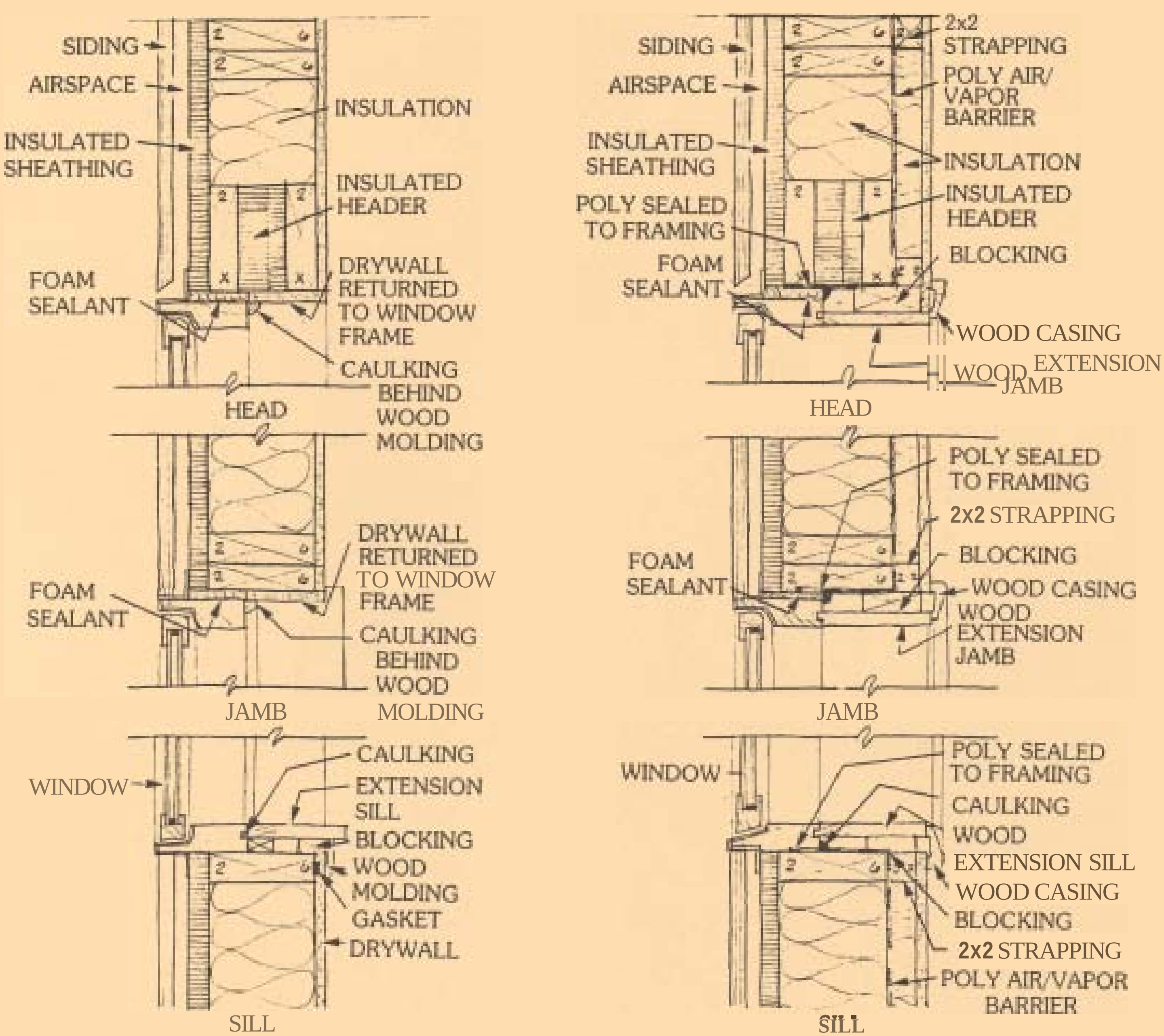
STRAPPED 2x6
APPROACH



DOUBLE 2x4
APPROACH

Windows: Detail 19 show methods of sealing around windows. The Airtight Drywall Approach shows the drywall wrapped around the corners and back to the windows. The drywall is then sealed to the window frame with caulk and can be covered with wood molding if desired. Another option for those people who want wood casing around the windows is shown in the Strapped 2x6 Approach with extension jambs. Foam sealant

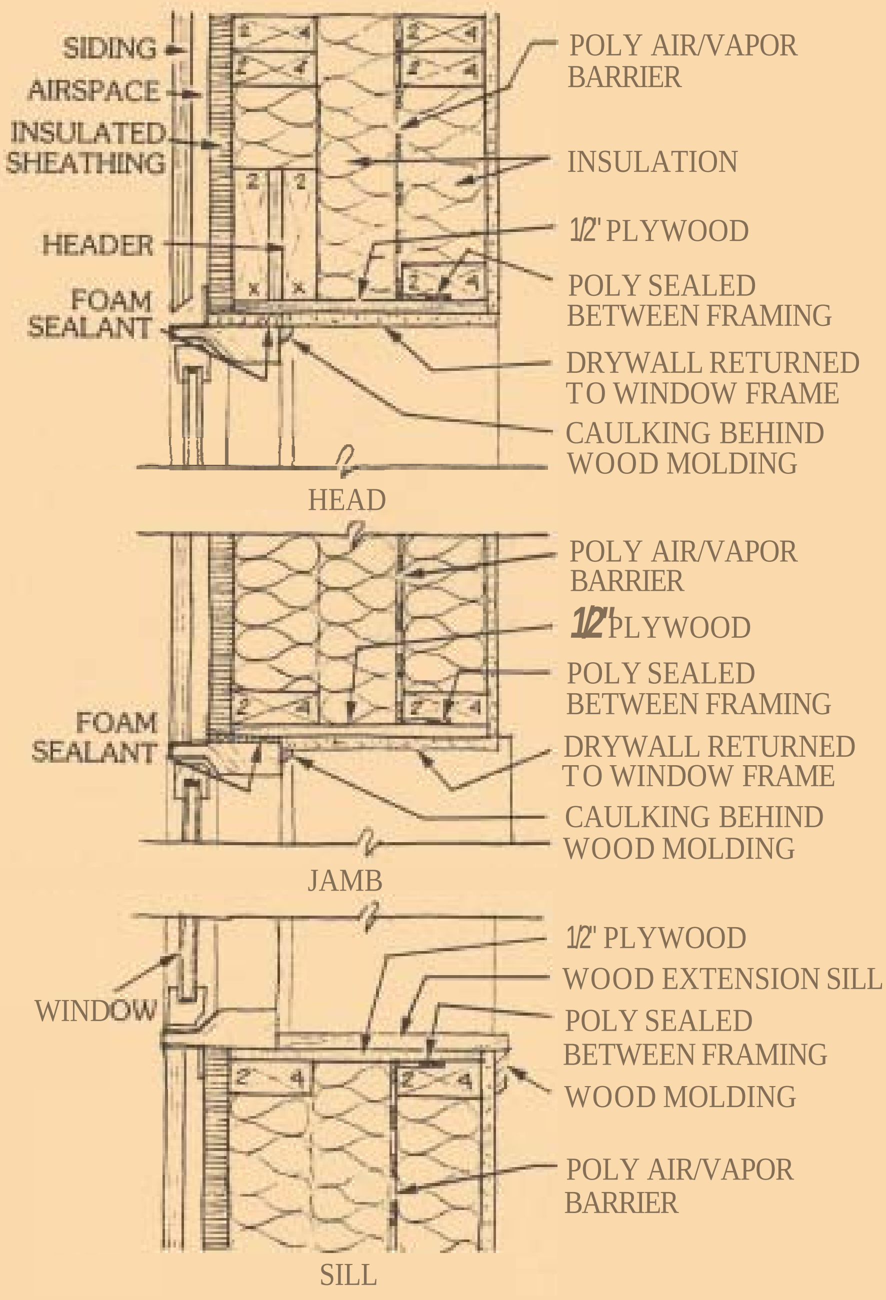
Detail 19 Sealing Around Windows



AIRTIGHT DRYWALL APPROACH

STRAPPED 2x6 APPROACH

should be applied carefully in the joint around the window and the polyethylene air/vapor barrier should be sealed to the window rough opening. The window rough opening in the double 2x4 wall should be 1 inch larger to allow for the 1/2 inch plywood that connects the interior and exterior walls. Blocking may be needed in the strapped 2x6 and double 2x4 walls to provide a mounting surface for curtains.



DOUBLE 2x4 APPROACH

Doors: Detail 20 shows door sill details for the three wall approaches. For the thick wall of the Double 2x4 Approach you may want to widen the rough opening as shown in Detail 21, to keep from scraping your knuckles when opening the door. (See the windows section for header details.)

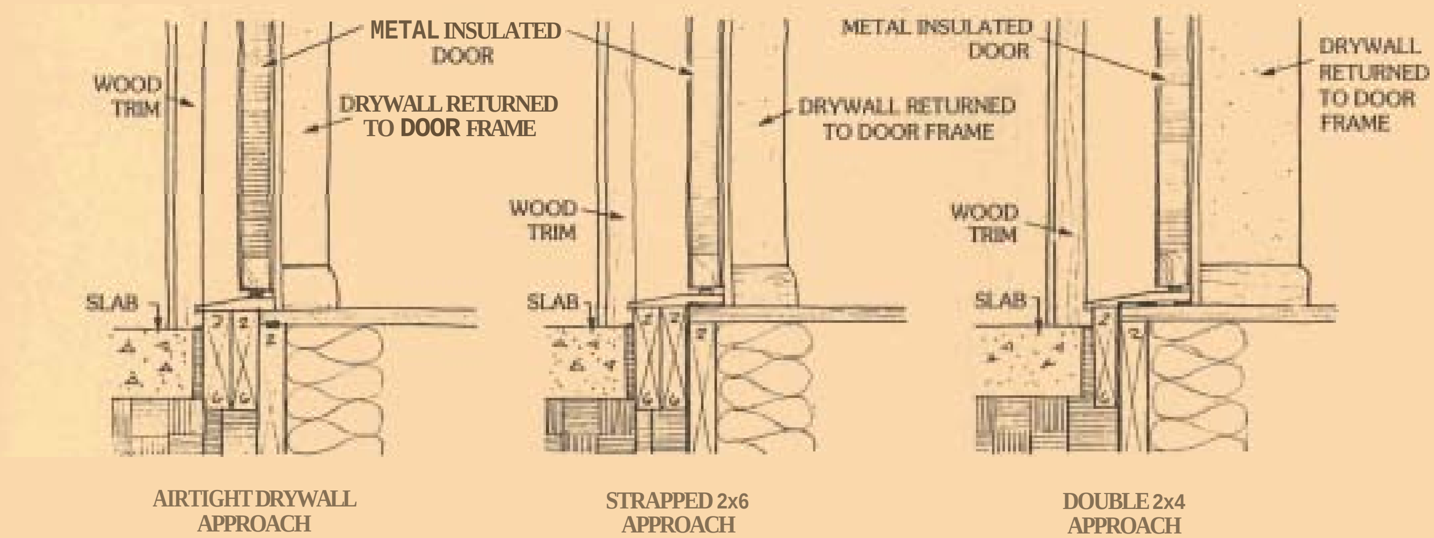
Bathtub: Only the Airtight Drywall Approach needs a special detail for sealing around a bathtub. Before installinga bathtub or tub/shower unit against an outside wall, the outside wall should be insulated, the bottom plate gasketted, and a sheet of drywall or plywood nailed up. All the joints in the drywall or plywood should be caulked. This simplifies a difficult air sealing situation. If a bathtub has a lip designed to fit behind the drywall, another layer of drywall will have to be installed over the first as shown in Detail 22. If a soap dish is desired, it should be installed on an interior wall or surface mounted.

Sealing Penetrations

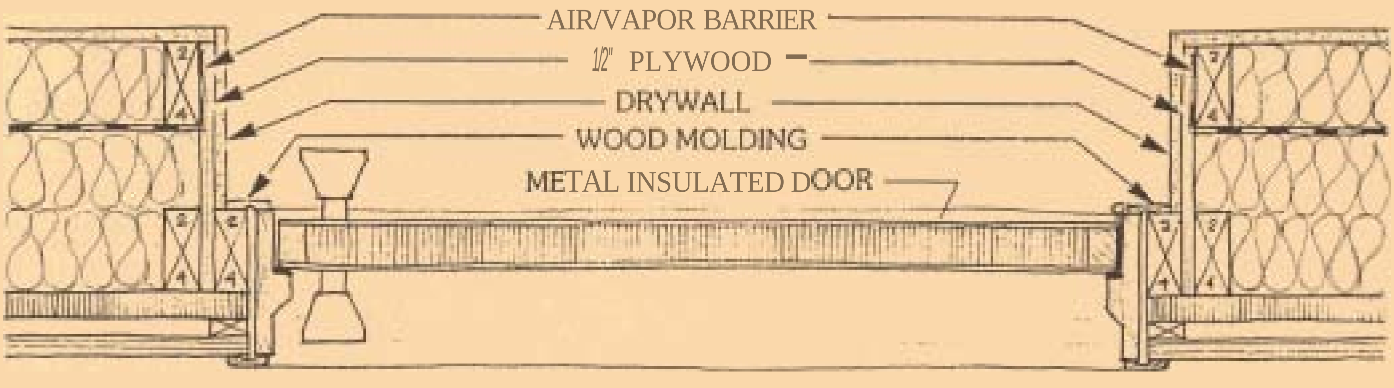
The main penetrations in exterior wails are electrical boxes for outlets and switches.

Electrical Boxes in Exterior Walls: Detail 23 shows why electrical boxes in exterior walls are not a problem with the Strapped 2x6 Approach and Double 2x4 Approach due to the space provided. But, in the Airtight Drywall Approach, special steps must be taken. First, locate as many outlets and switches on interior walls as possible. Then, where outlets and switches are necessary in exterior walls, use sealed plastic or

Detail 20 Door Sill Details



Detail 21 Door Installation in Double 2x4 Wall

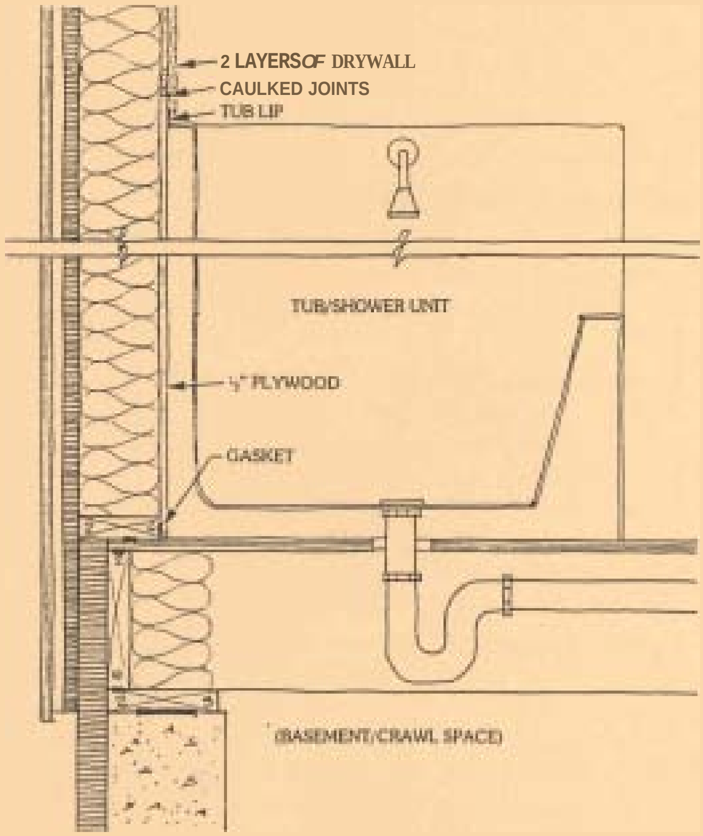


fiberglass boxes and seal around the wire with caulk. The drywaller should mud the drywall to the box. Foam outlet and switch gaskets should be installed beneath the cover plates. If fiberglass batt insulation is going to be used, the wires should run along the bottom plate instead of at outlet height, to keep from compressing the insulation.

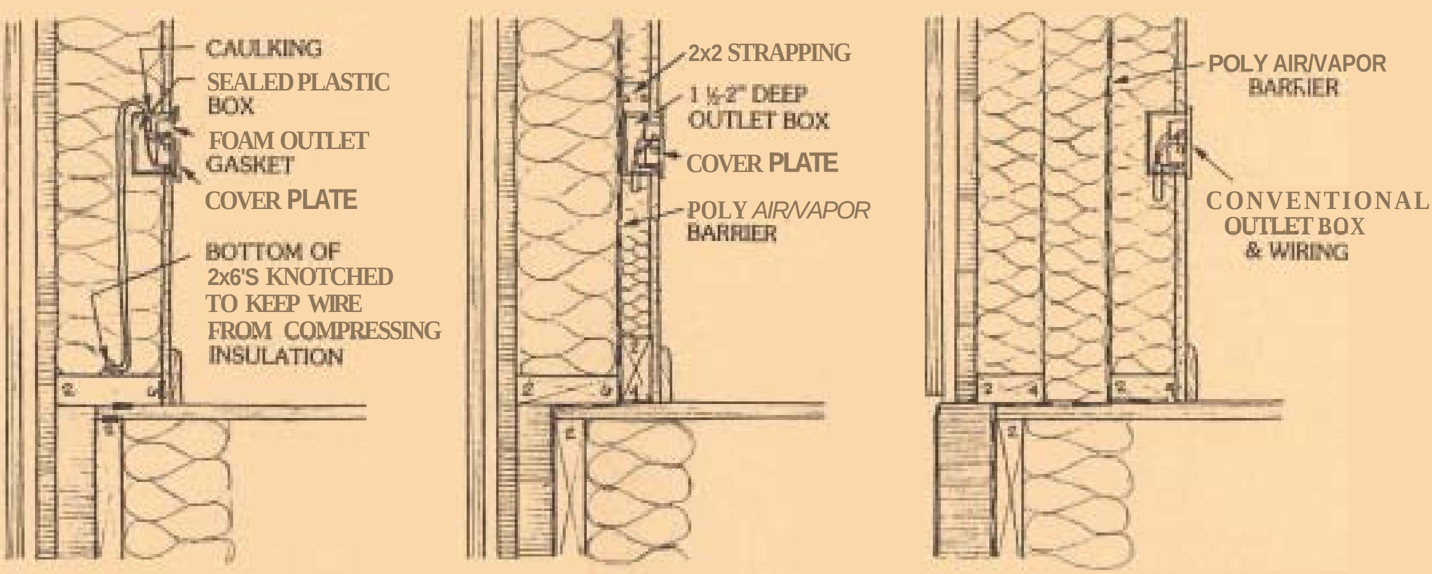
The Strapped 2x6 Approach requires shallow electrical boxes. They can be nailed to the strapping that is 16 inches off the floor. Wires running up the wall should also be run behind the strapping and not drilled through it. Also, when running the wire up through the floor, it may be better to run it up into an interior wall instead of drilling through the 2x4 strapping at the bottom. If you choose to drill through the 2x4 strapping, you'll need to put a metal plate on the front face to keep nails from puncturing the wire. The Double 2x4 Approach can be wired conventionally. Just make sure you don't poke holes in the air/vapor barrier.

Other Penetrations: Occasionally, plumbing pipes and drains may need to penetrate exterior walls. They need to be sealed where they penetrate the drywall. □

Detail 22 Bathtub Installation



Detail 23 Outlets in Exterior Walls



AIRTIGHT DRYWALL APPROACH

STRAPPED 2x6 APPROACH

DOUBLE 2x4 APPROACH

ROOF SYSTEMS

The final step in construction is choosing the roof system. This choice can be divided into three sections which include the following: General Considerations involving choices and important considerations; Construction Details providing construction schematics; and Sealing Pentrations explaining how to seal common ceiling penetrations in the air barrier.

General Considerations

The parts of the roof system you'll need to consider in construction are Conventional Trusses, Insulation Options, Sizing Overhangs, Roof Ventilation and Truss Uplift.

Conventional Trusses: The conventional truss or rafter system has two problems. First, it allows very little space for insulation over the top of exterior walls which increases heat loss. Second, it allows the wind to blow into and under the insulation, cooling the interior ceiling surface at the outer walls which causes condensation problems at that point. Raised trusses, which are discussed later, solve those problems.

Insulation Options: A minimum of R-40 insulation is recommended for the attic floor. This can be either 12 inches of batt insulation, 10-12 inches of blown-in insulation or a combination of the two. When using trusses, blown-in insulation will fill in around the truss members better than batt insulation. If batt insulation is used, the upper layer should be placed perpendicular to the bottom layer.

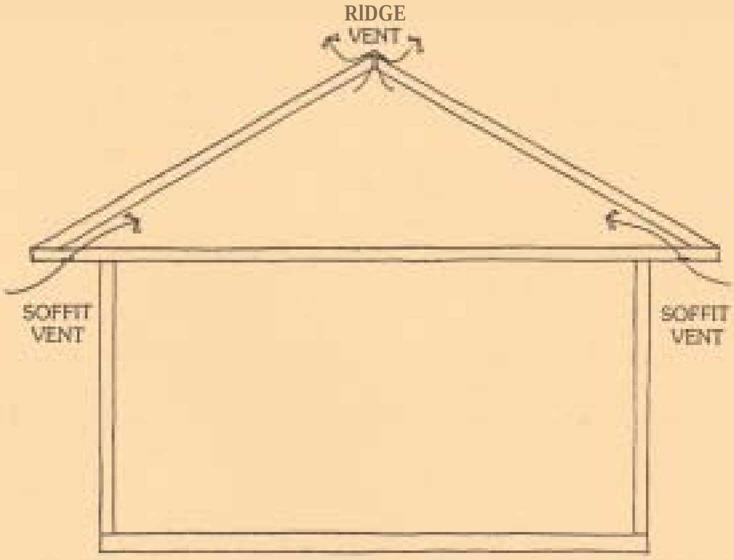
Sizing Overhangs: The height of the soffit above the windows has a great effect on the size of an overhang. In Iowa, an overhang of 30 inches with a soffit at ceiling height would be as close to ideal as you could hope to get. There is no ideal overhang size because size does not allow for temperature differences. You may need solar gain in March and not need it in September, but the sun is at the same angle during these months. The sun angles given in Table 4 can be used to help determine shade lines at different times of the year.

Table 4 Sun Angles at 42 degrees N. Latitude

JAN 21	28	MAY 21	68	SEP 21	48
FEB 21	39	JUN 21	71	OCT 21	39
MAR 21	48	JUL 21	68	NOV 21	28
APR 21	59	AUG 21	59	DEC 21	25

Attic Ventilation: The primary purpose of attic ventilation is to get rid of moisture during the winter and heat during the summer. In the winter, moist air on the inside of the house can rise through the ceiling penetrations, reach the dew point, condense, and get the insulation wet. However, the tight attic floor of an airtight home prevents most of this air leakage and the higher insulation levels keep the summer heat out, making attic ventilation less important. The combination of soffit vents and ridge vents, as shown in Figure 5, provide the best attic ventilation. Power vents should be avoided because they consume more energy than they save.

Figure 5 Attic Insulation

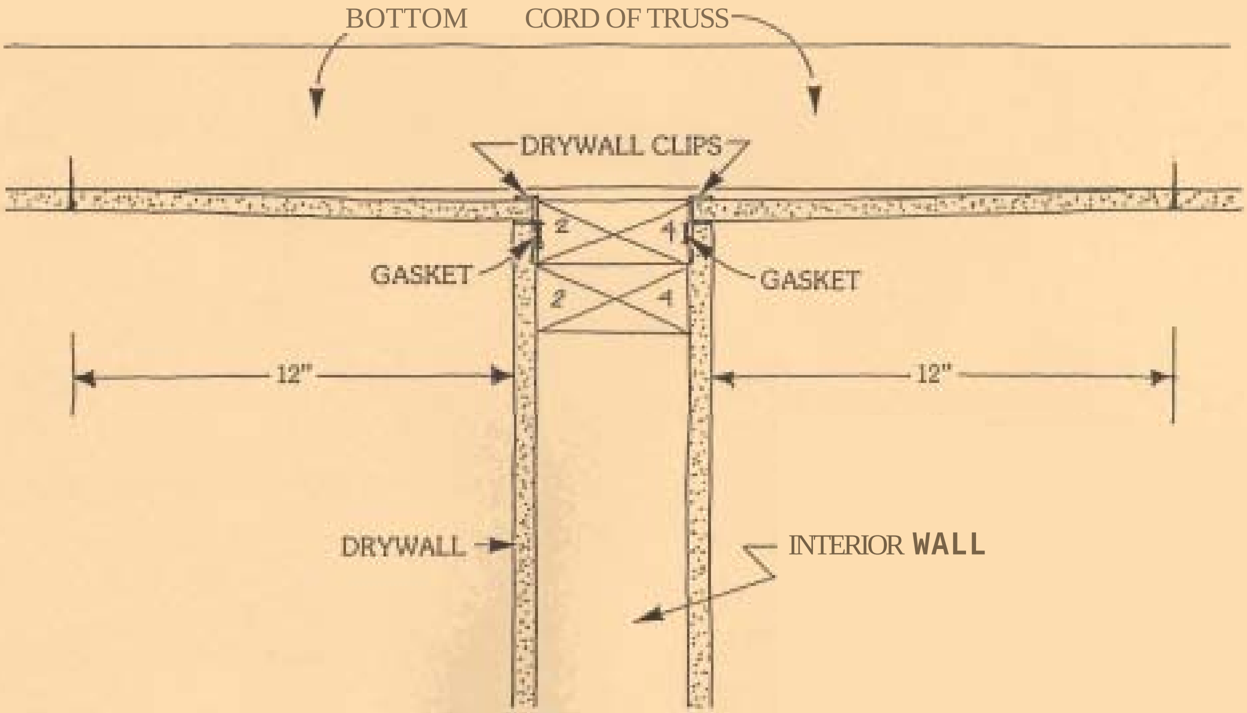


Truss Uplift: Trusses can actually bow up in the middle, leaving a small crack along the tops of interior walls. This usually occurs in the winter and corrects itself in the summer. It is caused by a difference in temperature and relative humidity between the insulated bottom cord and the cold upper cord of the truss. The top cord is surrounded by cold air with a high relative humidity and the bottom cord is surrounded by warm air with a low relative humidity. The top cord tends to absorb moisture and lengthen, while the bottom cord remains the same length or shrinks. The lengthening of the top cord causes the truss to arch upward.

Detail 24 shows a solution that can help prevent the drywall from cracking if there is truss uplift. By using drywall clips at the top of interior walls and nailing the drywall no closer than 12 inches to the interior partition, the drywall can flex if truss uplift occurs.

To minimize truss uplift, choose good quality trusses built with kiln-dried lumber. Keep the trusses covered while stored on the site, and install the roof soon after the trusses are placed to keep them as dry as possible. Sealing all the holes in the attic floor is very important to prevent warm moist air from leaking into the attic, raising the relative humidity, and increasing truss uplift problems. Following these procedures will not always prevent truss uplift, but can minimize its effect.

Detail 24 Planning For Truss Uplift



Construction Details

The following sections show how to increase the energy performance of common roof systems.

Raised Truss Options: Detail 25 shows three raised truss options. These trusses provide adequate insulation over exterior walls and stop air intrusion into the insulation with appropriately placed blocking. When cantilevering the outside 2x6 wall 2 inches, the outside support on the truss should be a 2x6 also.

Cathedral Ceiling Options: Detail 26 shows construction options for a vaulted ceiling. The first is a raised scissor truss; the second is a modified floor truss. A plywood floor truss makes insulating easier. The other alternative is to use 2x12's with an air shoot under the roof sheathing. The cavity can then be insulated with batts or blown full of insulation. If more insulation value is desired, rigid insulation can be added on the lower side of the rafters.

Story-and-a-Half: Detail 27 shows how to insulate a story-and-a-half, or finished attic, for the Airtight Drywall Approach. Blocking pieces with gaskets on the top and bottom need to be placed between the floor joists to stop air from entering under the floor. Rafters larger than 2x6's should be used to allow for additional insulation. Rigid insulation can be added beneath the drywall, on the sloped section of the roof, to further increase the insulation value. Air chutes should be installed as needed for adequate ventilation. A similar approach can be used for the Strapped 2x6 Approach and Double 2x4 Approach.

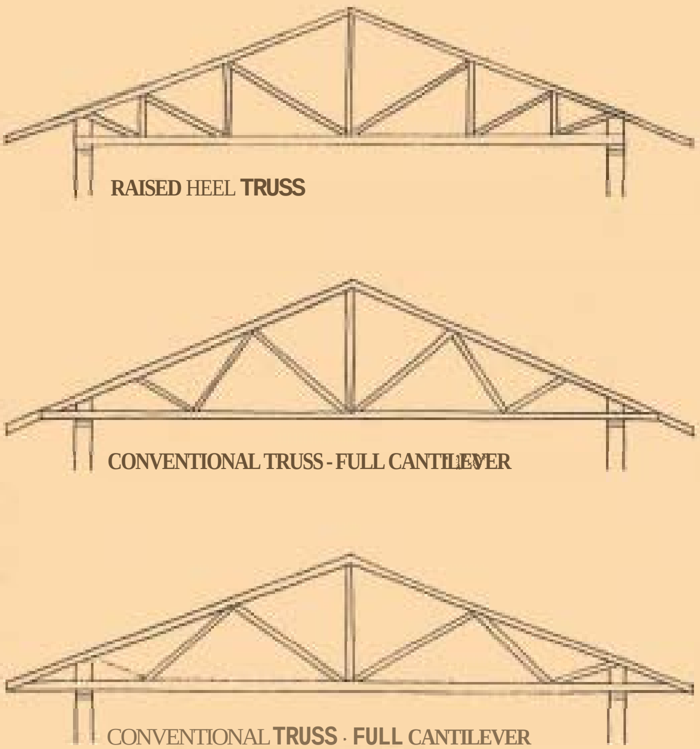
Interior Wall/Ceiling Junctions: The Airtight Drywall Approach uses gaskets along the top plates of interior walls to carry the air barrier through as shown in Detail 28. The Strapped 2x6 Approach and Double 2x4 Approach install the polyethylene air/vapor barrier before the interior walls are constructed. Any tears need to be repaired.

Sealing Penetrations

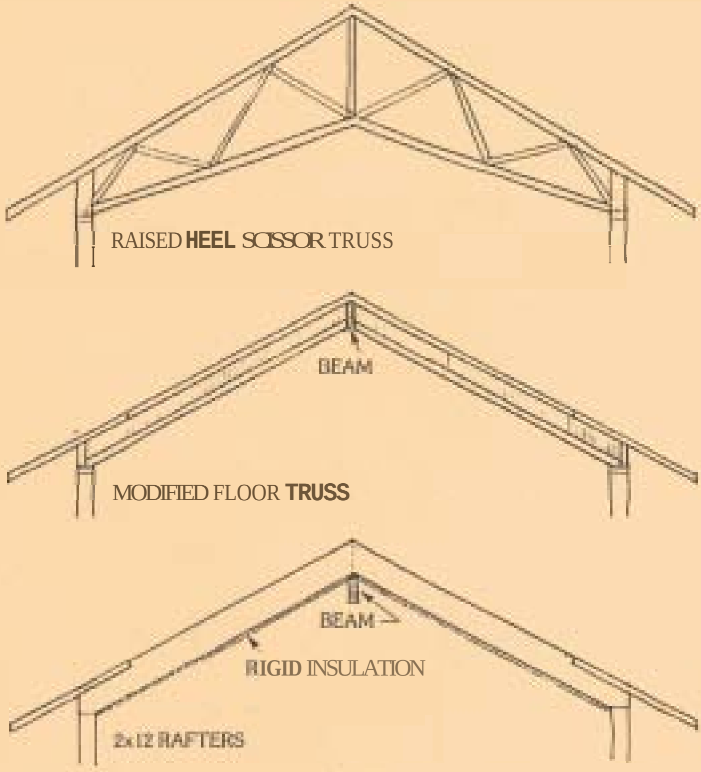
Adequately sealed ceiling penetrations are essential, not only for energy savings, but also to control truss uplift and other moisture related problems. The following shows how to seal common ceiling penetrations.

Light Fixtures: Since air often leaks through ceiling light fixtures, room lights should be mounted high on interior partition walls instead of on the ceiling. Another alternative is to use lamps controlled by switched outlets. If you must have a ceiling fixture, Detail 29 shows two ways to keep it airtight. With the Airtight Drywall Approach, a shallow box should be mounted (after the

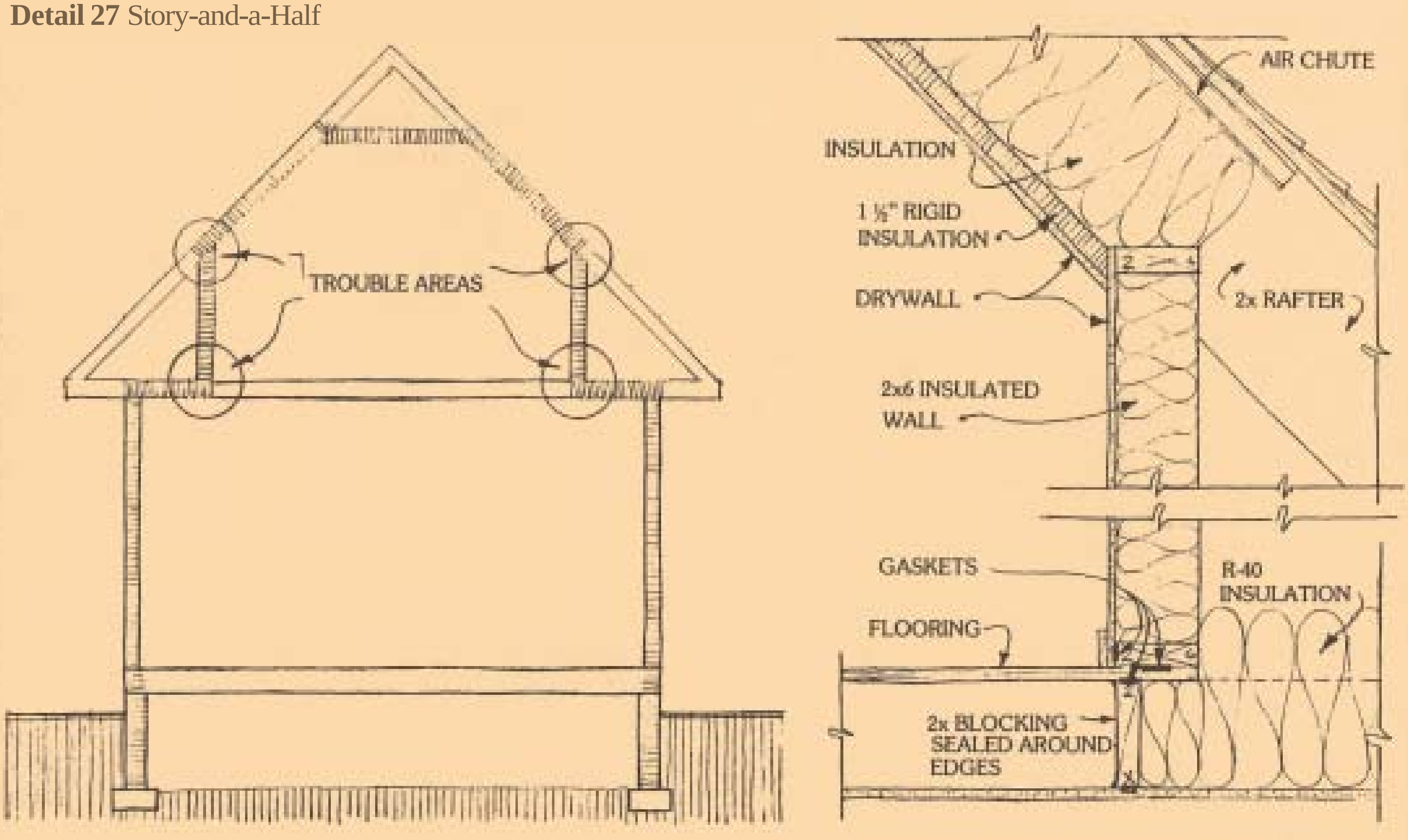
Detail 25 Energy Efficient **Trusses**



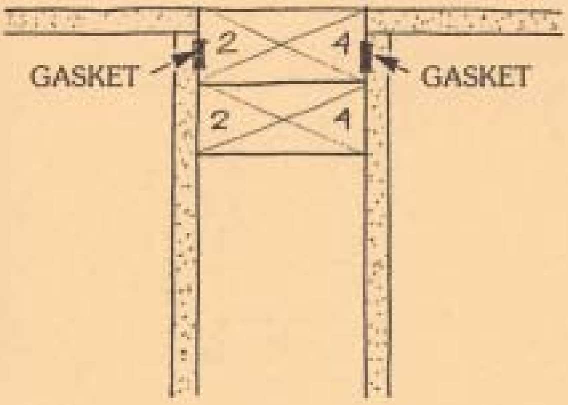
Detail 26 Vaulted **Ceiling** Options



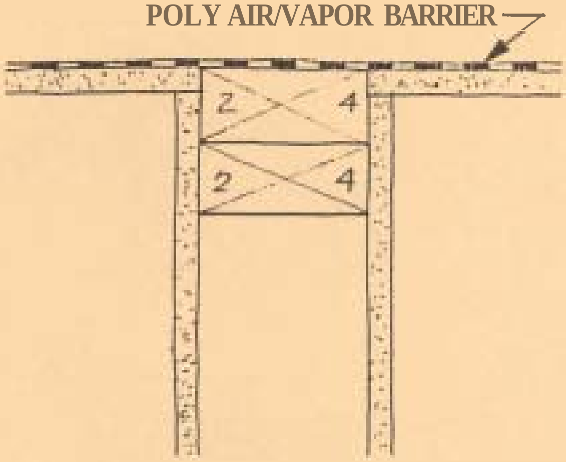
Detail 27 Story-and-a-Half



Detail 28 interior Wall/Ceiling Junction

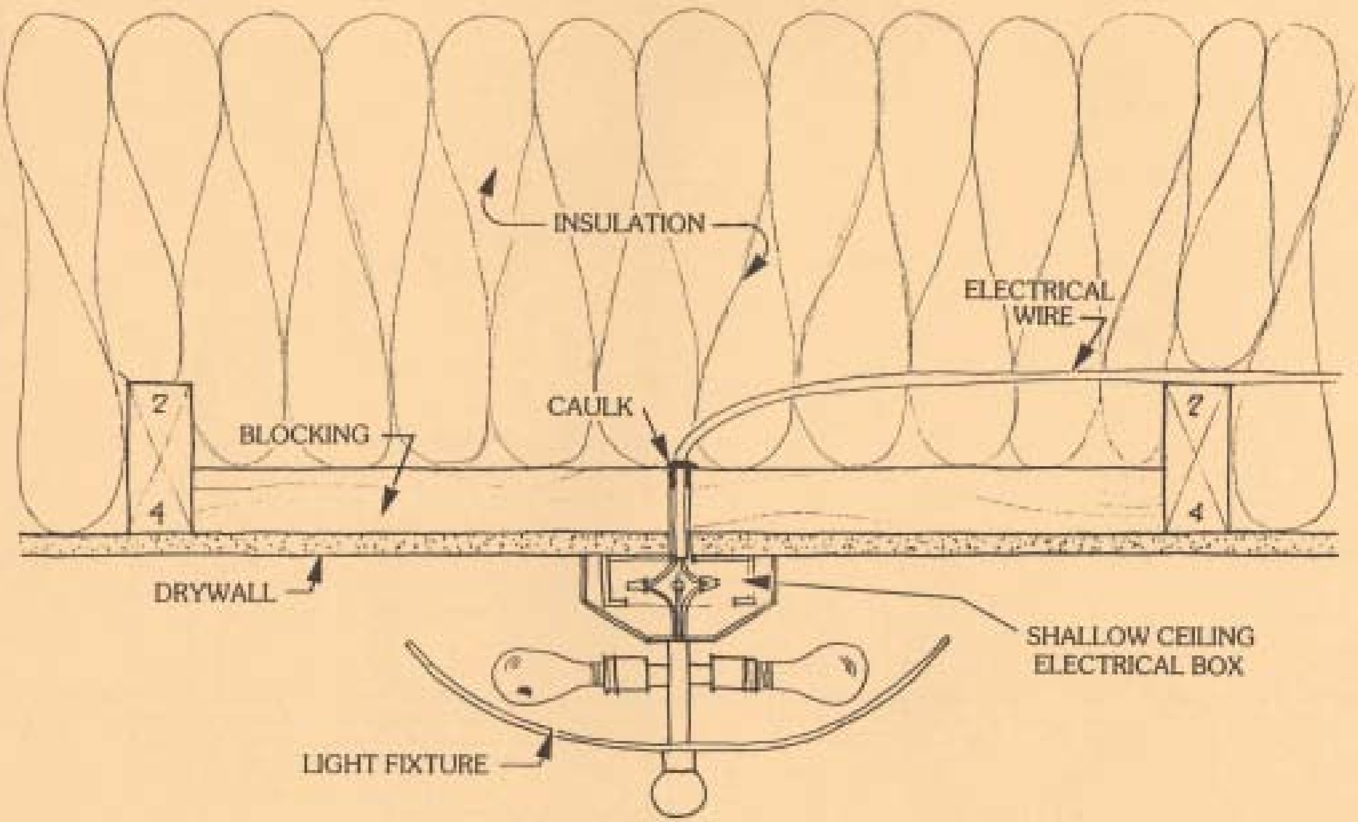


AIRTIGHT DRYWALL APPROACH

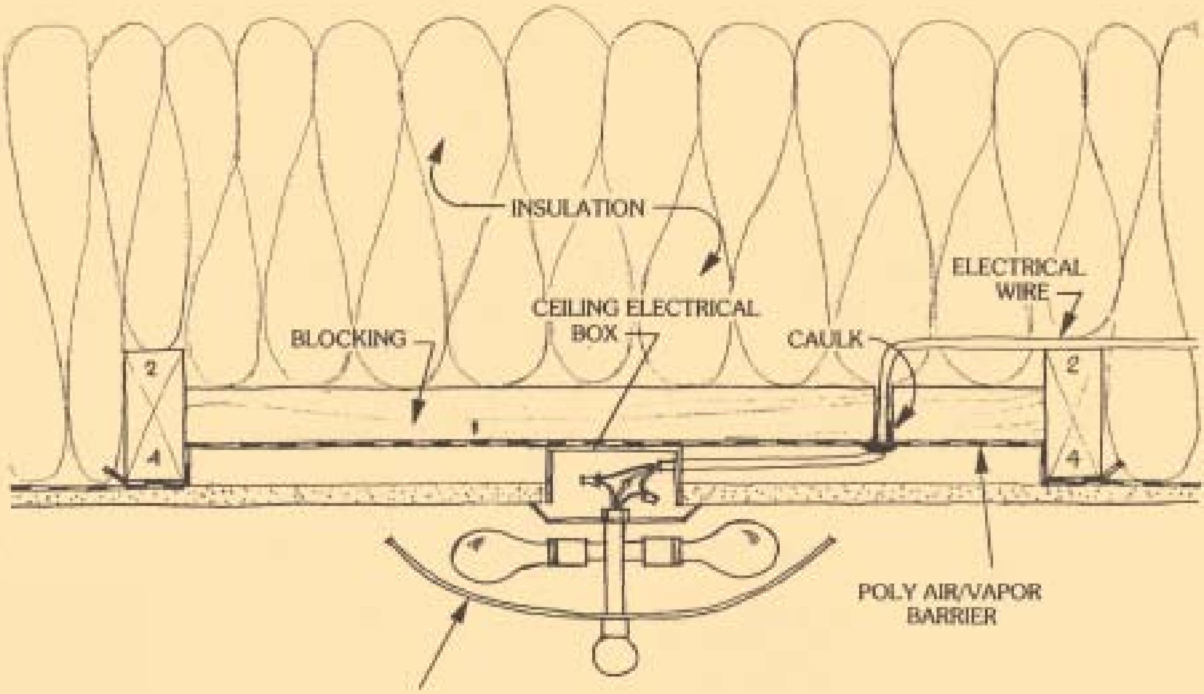


POLY APPROACH

Detail 29 Ceiling Light Fixtures

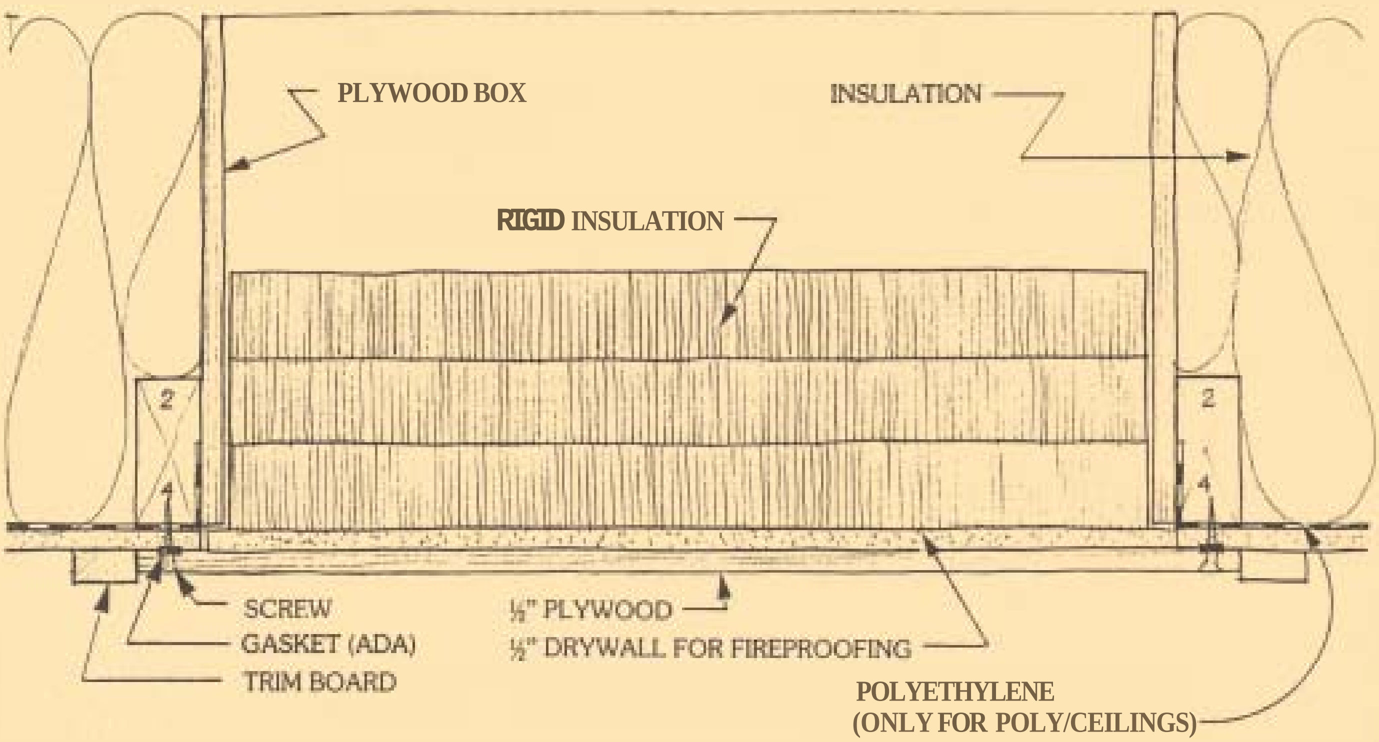


AIRTIGHT DRYWALL APPROACH

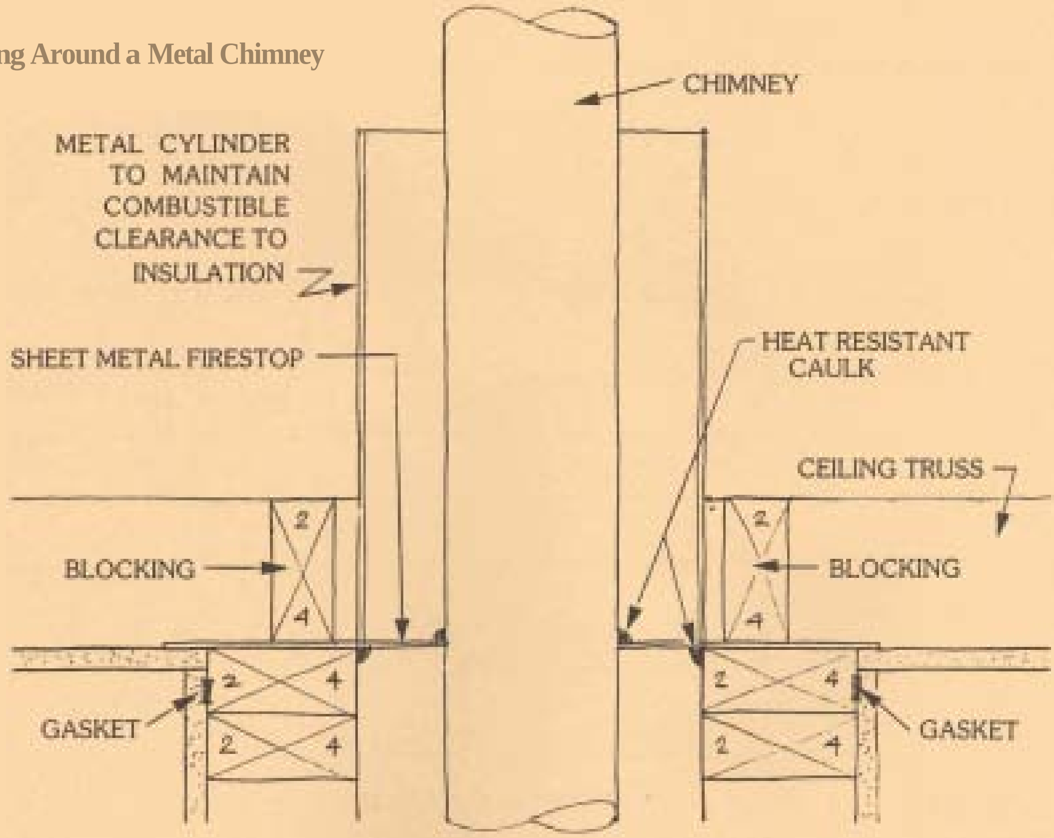


POLY APPROACH

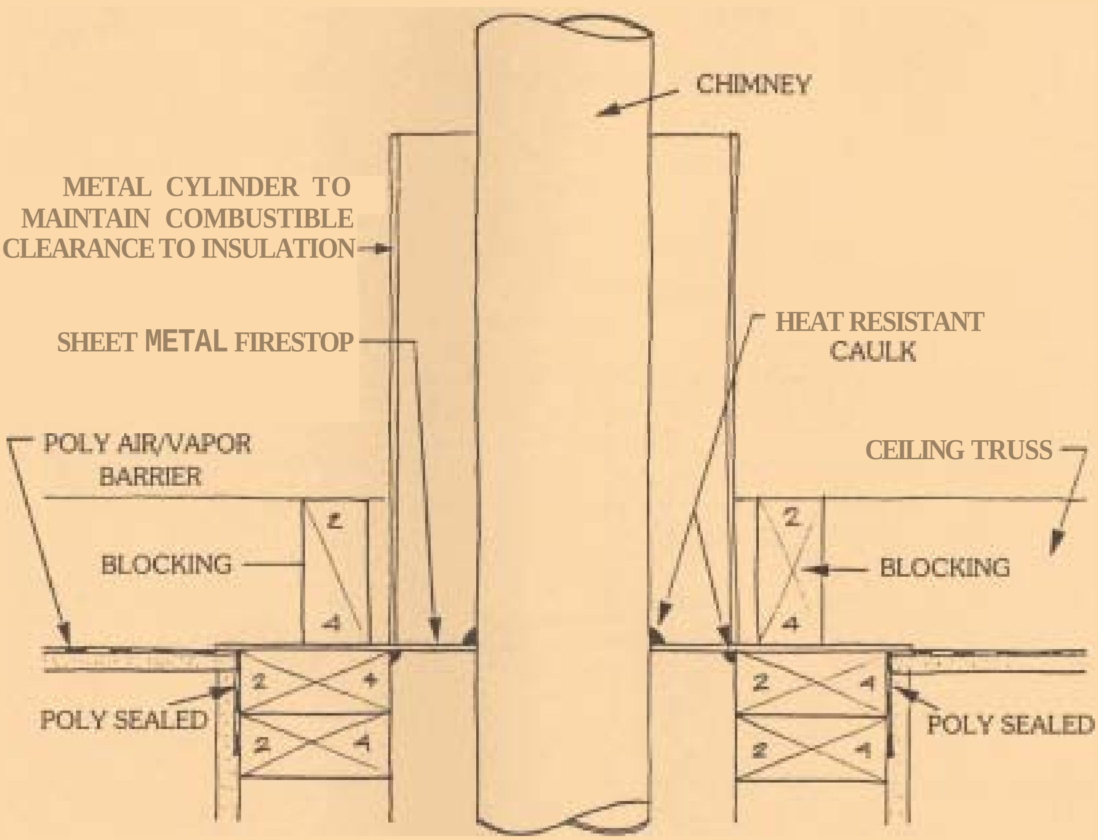
Detail *30* Attic Hatch



Detail 31 Sealing Around a Metal Chimney

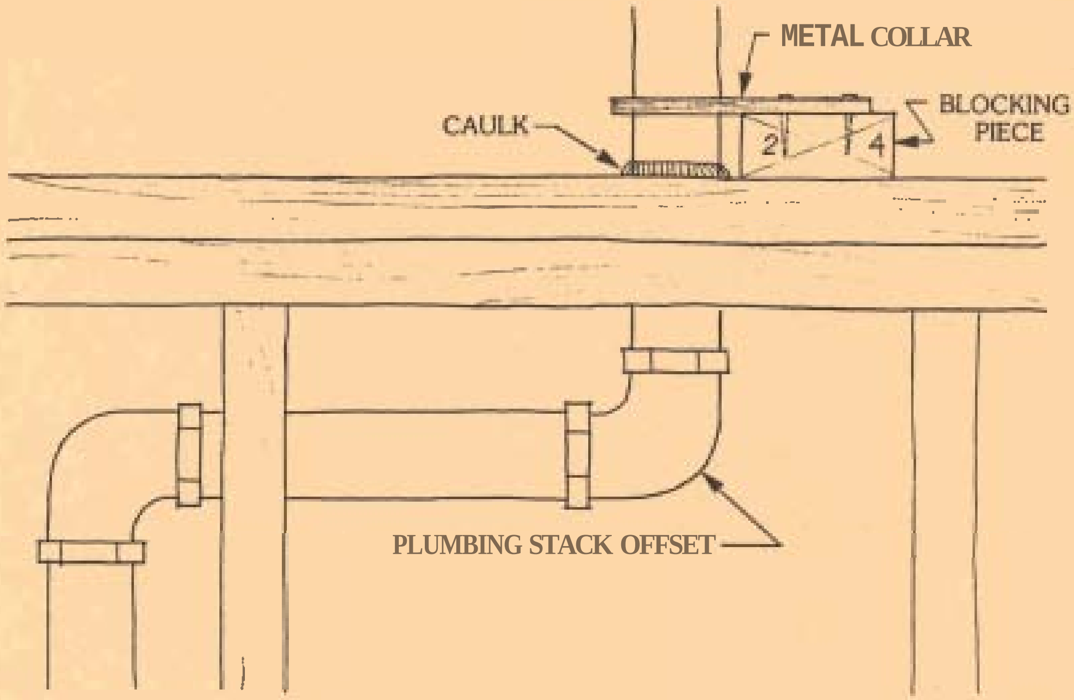


AIRTIGHT DRYWALL APPROACH

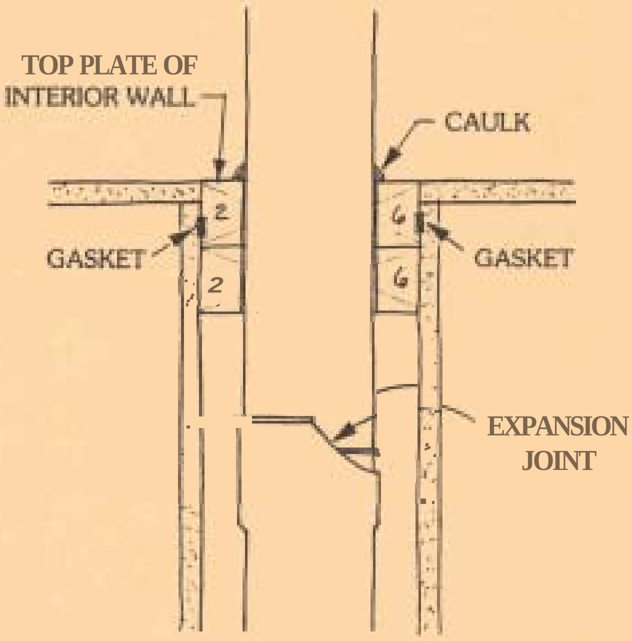


POLY APPROACH

Detail 32 Handling Plumbing Stack Expansion



SMALL PLUMBING STACK



LARGE PLUMBING STACK

drywall is in place) to a blocking piece positioned above the drywall. The hole through the block should be sealed around the wire. With the polyethylene air/vapor barrier ceiling, a box must be constructed and covered with polyethylene. The wire should come into the box through the side or through a blocking piece with the hole caulked.

Recessed lights should be avoided or installed only in bulkheads or lowered ceilings where they do not penetrate the air barrier. Track lights can be used instead of recessed lights.

Attic Hatches: If it's possible and the local building code allows it, place the attic access door in the garage or outside on a gable end. This automatically solves air sealing problems. If the attic access door must be located on the inside of the house, Detail 30 shows how to seal it properly.

Chimneys: Detail 31 shows how to seal a metal chimney with both the Airtight Drywall Approach and the two approaches that use a polyethylene option. If the house will have a masonry covered fireplace, stop the masonry at the ceiling and continue up with wood construction to stop the thermal transfer through the masonry.

Plumbing Stacks: Detail 32 shows how to seal around both small and large plumbing stacks with the Airtight Drywall Approach and the two approaches that use a polyethylene option. □

MECHANICAL SYSTEMS

CONTROLLED VENTILATION SYSTEM

As stated previously, a controlled ventilation system is a must for a well-built IDEAL home. Most researchers suggest .30 to .50 air changes per hour (acph) of continuous ventilation, with intermittent higher rates of air exchange when necessary. The system should run continuously except on days of moderate temperature when the windows can be opened. Although there are several options for controlled ventilation, the central exhaust single intake system is the simplest and the least expensive; it can be used with two types of heat recovery explained later in this section. For clarity, we will refer to the central exhaust single intake system as the "simple system."

Central Exhaust Single Intake System

The simple system uses a two-speed exhaust fan to draw air out of the kitchen, bath and laundry areas. It is not designed to recover any heat. A central timer switch is installed to turn the fan to high speed when more ventilation is required. A humidistat in a central location will trigger intermittent higher rates of ventilation if the humidity rises above a predetermined setting. The setting will vary with the outdoor temperature. If condensation appears on the windows, the humidity setting should be lowered.

The two-speed exhaust fan should be sized to provide a continuous ventilation rate of 0.3 acph on low speed and 1 acph on high speed. The following formula can be used to size the fan:

Volume of House x acph/60 minutes = fan size in cubic feet of air flow per minute (cfm)

The fan must be able to deliver the desired cfm at a static pressure of 0.2 inches. You will probably not be able to find a fan that meets each requirement exactly. You'll have to choose one closest to the right size.

Intake vents for the kitchen, bath and laundry should be located high on interior walls. Lining a stud cavity with plastic and sealing the joints can make an adequate duct. The kitchen exhaust vent should not be located directly over the range to keep grease out of the system. Use a recirculating range hood to catch the grease. The filter in the range hood should be cleaned or replaced regularly. The dryer should be vented directly outdoors and not into the controlled ventilation system.

Fresh air can be returned to the house in three different ways depending on the type of heating system installed. If a forced air heating system is used, fresh air is returned to the cold air return on the furnace where it is distributed by the duct system as shown in Figure 6. The fresh air duct should connect to the cold air return at least 6 feet from the furnace to spare the furnace the shock of the incoming cold air. A damper should be placed in the fresh air duct to regulate the incoming air. If the furnace fan overpowers the exhaust fan and pressurizes the house, installing a flow restrictor, which regulates the cfm regardless of the pressure difference, will keep this from happening.

If you choose a heating system without ductwork, the fresh air can enter through a supply air duct that comes in at one location and branches into three smaller ducts to distribute the fresh air to three different parts of the house. Or through-the-wall inlet vents can be placed in each room for adequate fresh air supply. Care should be taken not to release the colder fresh air where it could make the occupants uncomfortable. One solution is to dump the colder air into closets with louvered doors to temper it.

The fresh air intake vent is best located on the south side of the house where it can benefit from warmer winter temperatures. Do not locate it near other exhaust vents or where automobile exhaust can enter. Locate the exhaust and intake vents at least 10 feet apart and high enough off the ground so they cannot be blocked by snow in the winter. Cover the openings with a rain cap and insect screen.

Exhaust ductwork should be at least 5 inches in diameter with as few elbows as possible. The fresh air duct should be at least 4 inches in diameter and insulated to prevent condensation. Table 5 lists the components necessary for a simple controlled ventilation package. Figure 7 shows how to wire the system.

Table 5 Materials List for a Simple Controlled Ventilation System

- One 2-speed fan sized as needed
- One dehumidistat (attic humidity control switch 20-80%)
- One duct damper
- One 60 minute timer
- Two outside vent covers with screens, one with damper
- Grills for kitchen, laundry and each bath
- Ducts to kitchen, laundry and each bath
- Enough duct insulation to insulate the fresh air duct(s)

Heat Recovery Ventilation Options

Figures 8 and 9 show two heat recovery alternatives that can be added to the simple controlled ventilation system, the air-to-air heat exchanger and the air-to-water heat pump. These can be added either at the time of construction or later as higher energy prices make them more cost effective. The air-to-air heat exchanger preheats the intake air with the exhaust air. The air-to-water heat pump extracts the heat from the exhaust air in the winter and heats water with it. This hot water can be used for domestic purposes and/or tied into the heating system. In the summer the unit can be set up to take the heat and humidity out of the intake air. The heat pump heat recovery system appears to have the most potential for future heat recovery systems. □

Figure 6 Controlled Ventilation

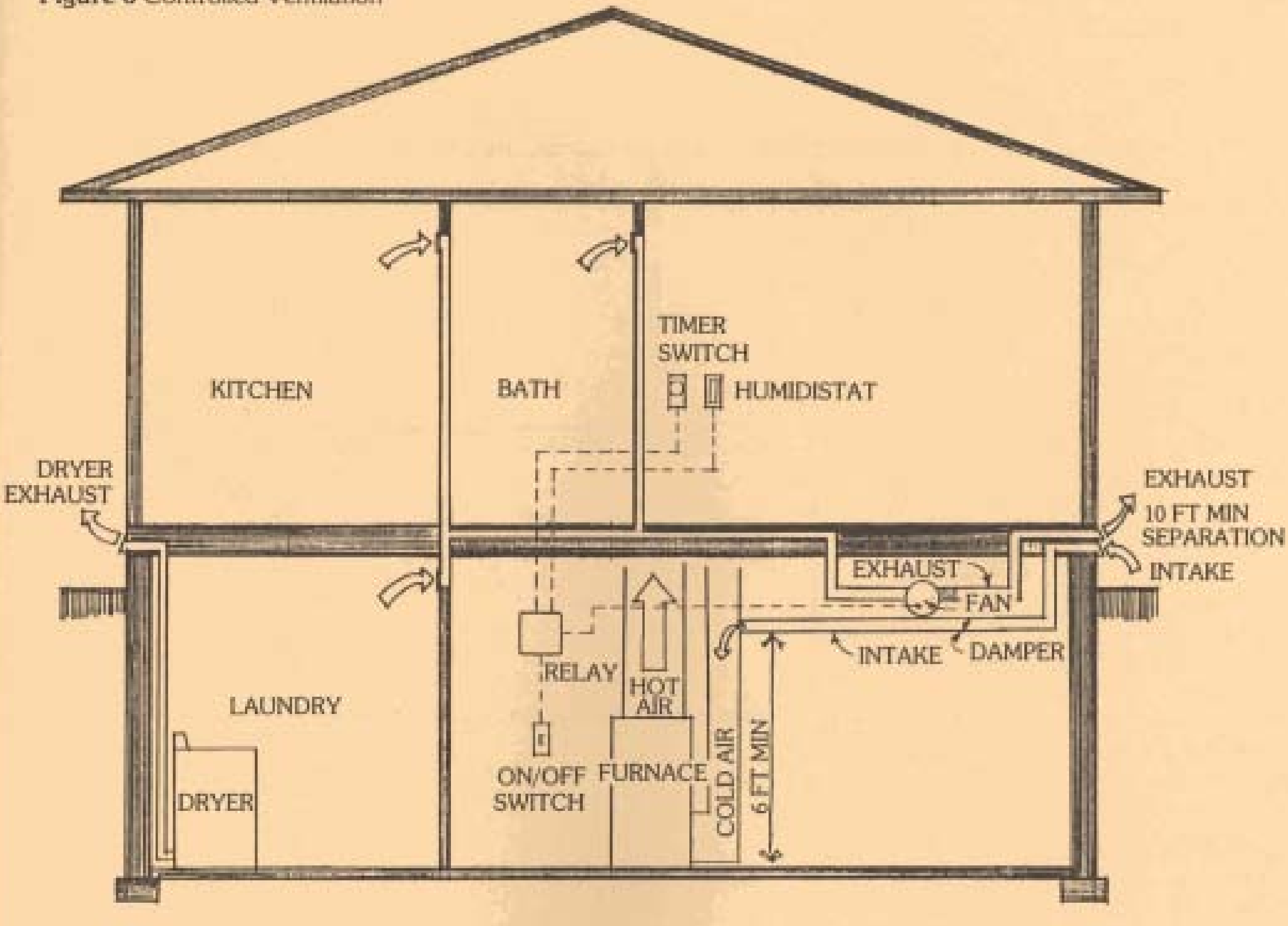


Figure 7 Controlled Ventilation Wiring Diagram

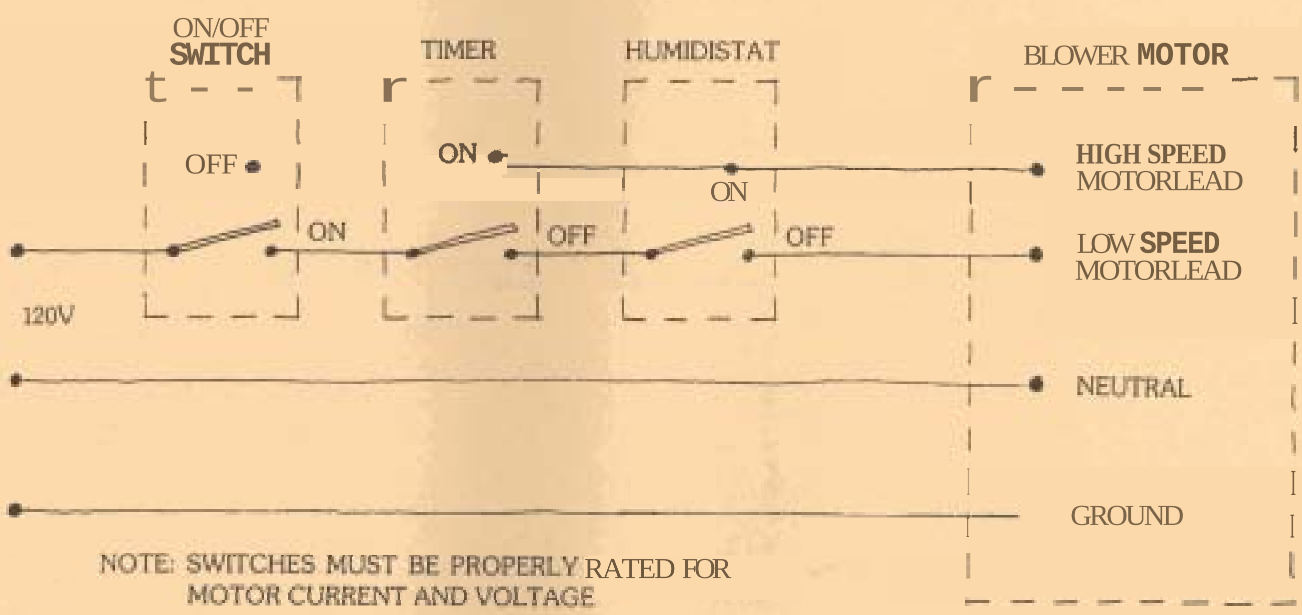


Figure 8 Air-to-air Heat Exchanger

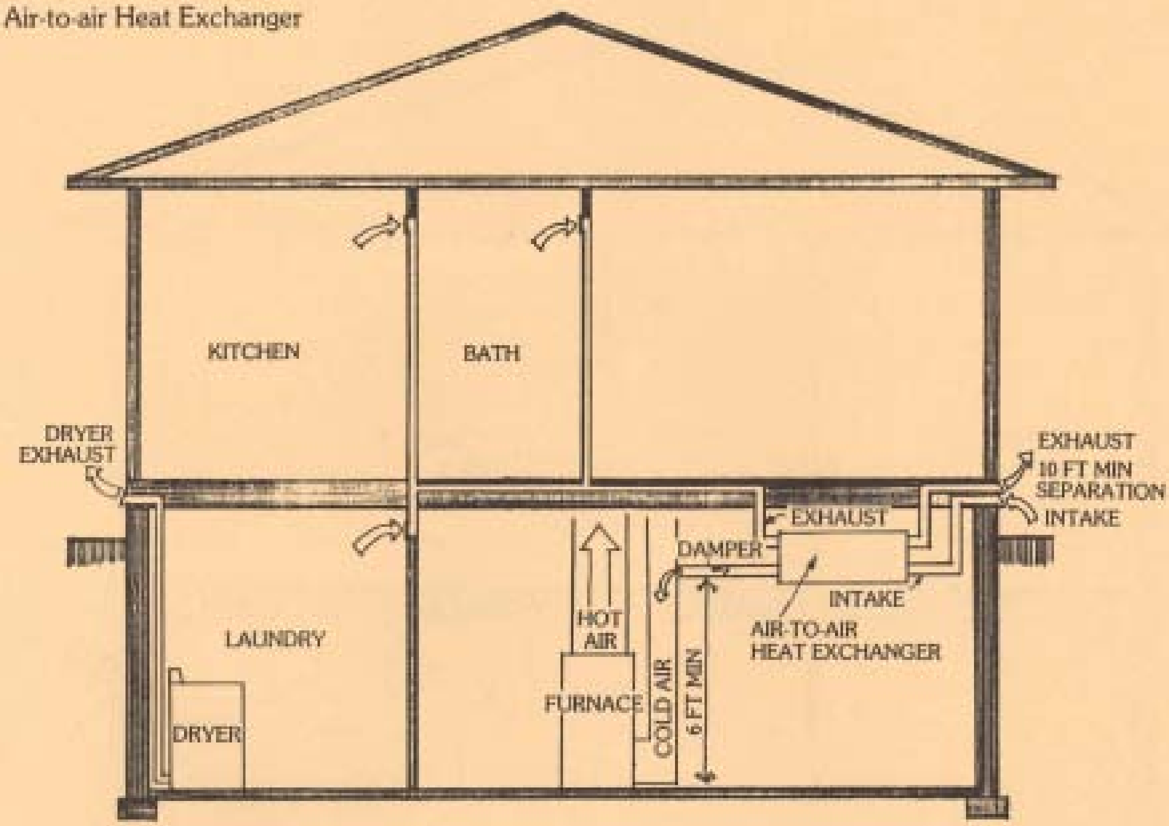
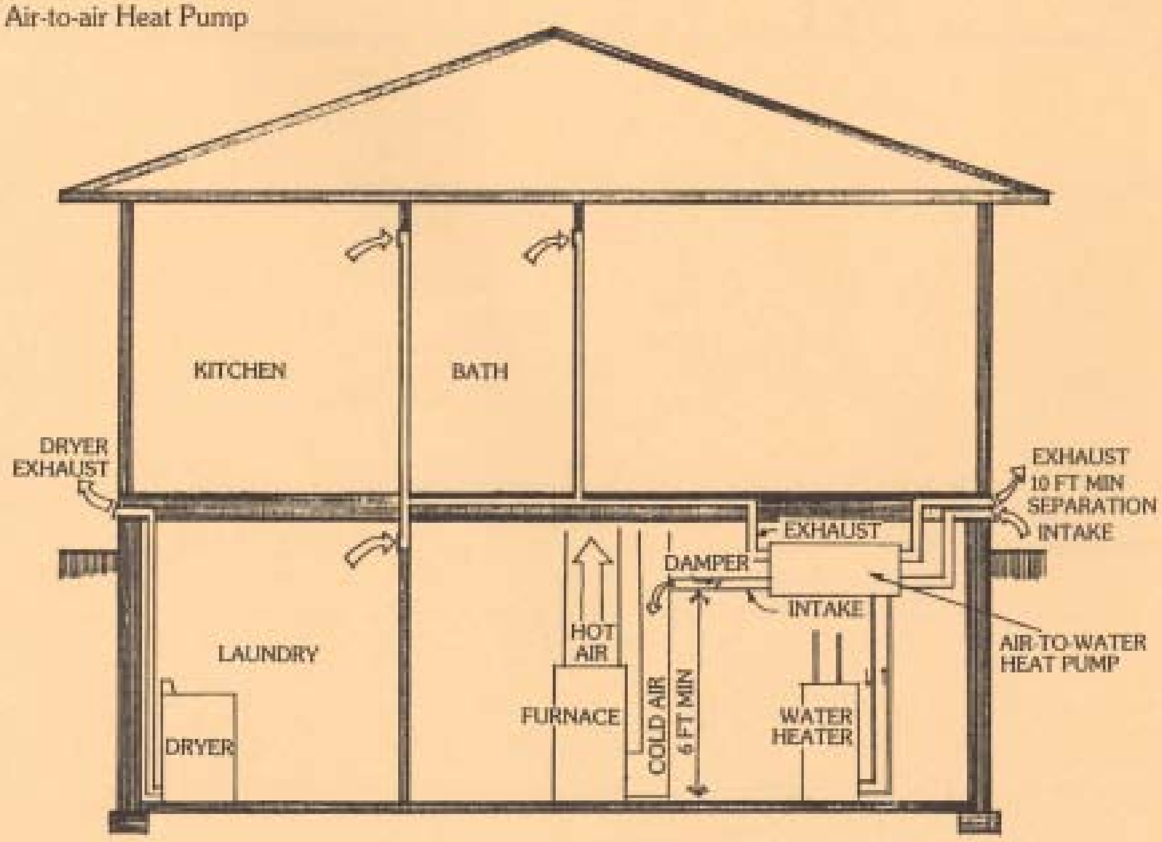


Figure 9 Air-to-air Heat Pump



HEATING SYSTEM

Choosing a heating system involves decisions on fuel type, distribution method, and system type. As you make these decisions, keep in mind how each decision will affect other systems within your home.

Fuel Type

Choosing a fuel type is a major decision. The costs of water heating and clothes drying are directly affected by the choice of heating fuel. In an energy efficient home, the annual cost of operating these two appliances may be larger than the annual heating cost.

The four types of fuel that can be used for heating new homes are electricity, natural gas, propane, and fuel oil. The following chart lists some advantages and disadvantages of each type:

Table 6 Advantages and Disadvantages of Fuel Types

Fuel Type	Advantages	Disadvantages
Electricity	No chimney or vent needed No indoor air pollution Adapts to wind and photovoltaics	Must buy from one source Relatively expensive heat source
Natural Gas	Delivered right to your home Relatively inexpensive fuel Clean burning fuel	Must buy from one source Needs chimney or vent Potential indoor air polluter Adequate combustion air needed
Propane (LP)	Competitive purchasing Clean burning fuel	Price fluctuates greatly Needs chimney or vent Needs outdoor storage tank Outdoor tank may not be allowed Must monitor your own fuel level Potential indoor air polluter Adeauate combustion air needed
Fuel Oil	Competitive Purchasing	Needs chimney or vent Needs **indoor** storage tank Must monitor your own fuel level Potential indoor air polluter Adequate combustion air needed

Simply comparing the advantages and disadvantages of each fuel type does not give you enough information to base a decision on. The installed cost of the heating system, the cost of a gas versus an electric water heater and clothes dryer, and the yearly operating costs of each, should be examined.

Distribution Methods

There are two methods to distributing heat within a new home. One method, called forced-air, uses a fan to blow air across a heat source then distributes the hot air produced through a ductwork system. The ducts typically supply hot air to the outside perimeter of the house, with cold air returns positioned on inside walls. This was done in the past to increase comfort because the outside walls were cold and the windows were leaky. But, this increases the cost of the ductwork, decreases heating efficiency, and may not be necessary in an IDEAL home. Because the walls of an IDEAL home are well insulated and the windows are tight, the hot air ducts could just as well be installed on the inside walls without a loss of comfort.

The second type of distribution method, called radiant heating, uses warm objects to radiate heat to cold objects. Most radiant heating systems use electricity to heat up an electric resistance element, which radiates heat to other objects in the room. Hot water heat is also a form of radiant heat. Because there is no air movement, houses with radiant heat often feel more comfortable at a lower temperature.

The type of distribution method chosen depends primarily on the type of air conditioning system desired. With central air conditioning, a forced-air heating system is probably the best choice. If you choose a radiant heating system, you'll have to install ductwork for central air conditioning or use a room air conditioner of some type.

Heating System Types

Heating systems fall into two categories, electric and gas. There are several different options within each of these categories.

Electric Heating System Options

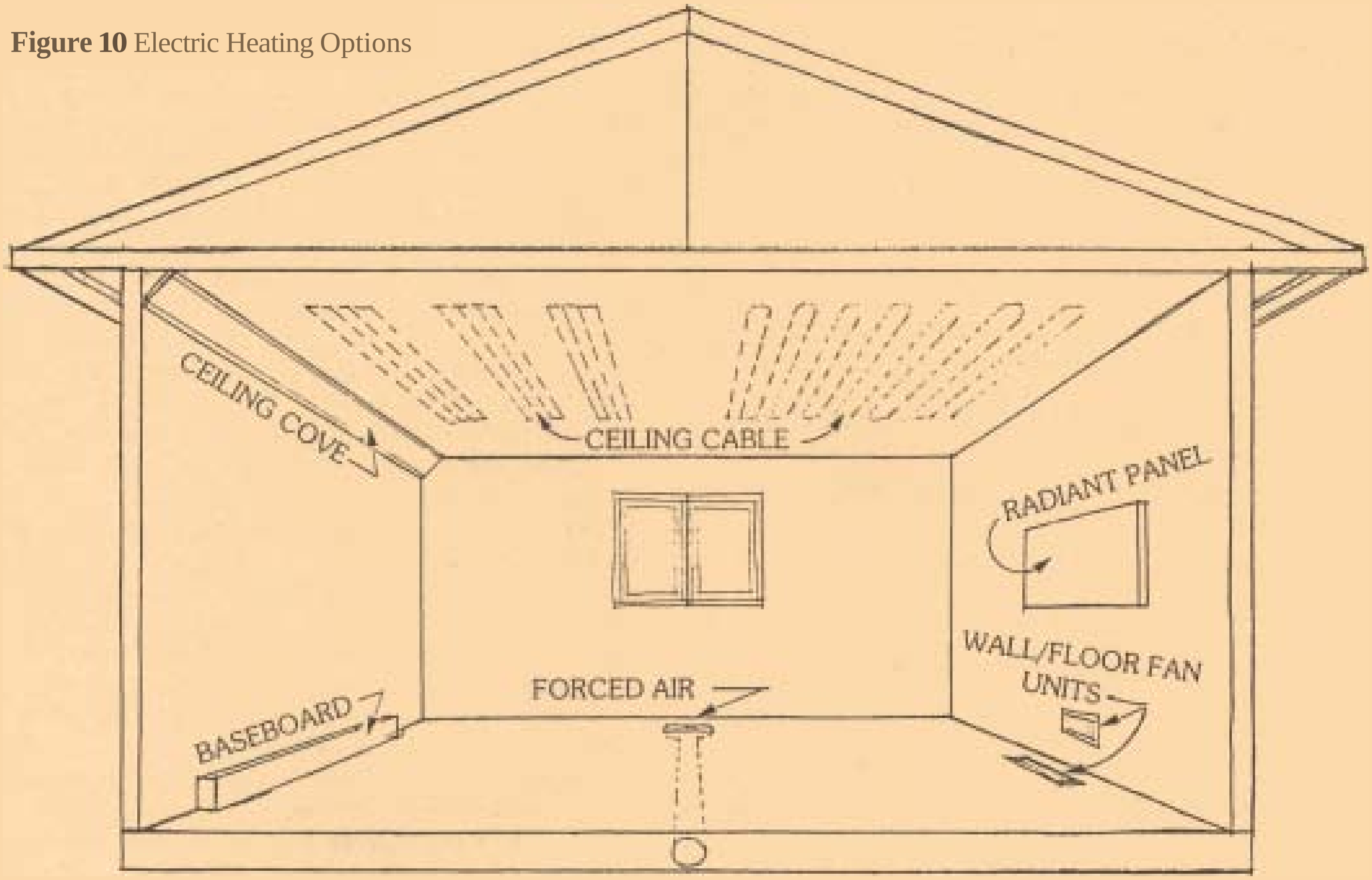
(See Figure *10)*

Although electric resistance heating systems may have higher operating costs, they may be a good option to consider for the low energy house due to their low installed cost.

Central Forced-Air: The electric forced-air furnace uses electric heating elements to heat air blown through the house. It is less expensive to install than a gas furnace, doesn't require a chimney, and has low maintenance costs. It can be used with a setback thermostat and can have central air conditioning added easily. However, it is currently the most expensive to operate.

Zoned Forced-Air: A zoned forced-air system uses small self-contained boxes that contain electric heating elements and a small fan. These boxes can be mounted in the floor with a conventional floor grill or in an inside

Figure 10 Electric Heating Options



wall. They were previously used to heat bathrooms or other hard to heat areas but are now catching on for energy efficient housing. They are relatively inexpensive to install and give you the benefits of zoned heating with the air movement of a forced-air system.

Baseboard: Like the electric resistance forced-air furnace, the electric resistance baseboard is inexpensive to install and requires little maintenance. It requires no ductwork or chimney. The heating elements are mounted along the baseboard. Its main advantage is that it allows the temperature in each room to be individually controlled. Heat can be turned off in any room not being used. This zoned heating ability typically reduces heating requirements 10-20%. A master thermostat can also be used to control all the rooms at the same time. Two drawbacks of this system are: 1) furniture must be arranged so it does not block the heating elements and, 2) there is no ductwork for central air conditioning.

Ceiling Cable: Ceiling cable has all the advantages and disadvantages of electric baseboard, but places no restrictions on furniture placement. Installing the ceiling drywall requires extra care to avoid damaging the heating elements.

Ceiling Cove: Ceiling cove is similar to electric baseboard except that it is mounted at the top of the wall instead of at the bottom. This allows free placement of furniture.

Radiant Panels: Radiant panels are panels with electric heating elements that can hang on the wall or ceiling. They can be plain or decorative. They offer the same advantages and disadvantages as ceiling cable or ceiling cove systems.

Air Source Heat Pump: An air source heat pump is a forced-air electric heating system. Instead of getting its heat from electric elements, it extracts heat from the outside air and transfers it indoors. Normally, the air source heat pump is about twice as efficient as electric resistance systems, but its efficiency decreases as the outdoor temperature drops. It operates most efficiently in **mild** weather when an energy efficient home requires very little heat. In extremely cold weather, the heat pump switches to back-up electric resistance elements.

The price of an air source heat pump is similar to a high efficiency gas furnace with central air. The air source heat pump requires no chimney and can use a setback thermostat, though it requires a special one designed for heat pumps. Because it must deal with Iowa temperatures ranging from -20 degrees in the winter to 100 degrees in the summer, it tends to have a shorter life and can often have higher maintenance costs than a gas furnace.

Water Source Heat Pump: The water source heat pump extracts heat from water instead of air. Access to the water is usually gained in one of two ways; it can be drawn out of the ground and returned to the ground, or circulated in a closed loop pipe either trenched-in and laid horizontally or drilled-in and run vertically. Because the water source heat pump uses water that is essentially the same temperature year around, its life is longer than the air source heat pump. The operating cost is usually lower than other heating systems, but for the IDEAL home with its low heating demand, the initial high cost of the water source heat pump makes its installation hard to justify for a house that requires very little heating and cooling.

Gas Heating System Options

(See Figure 11)

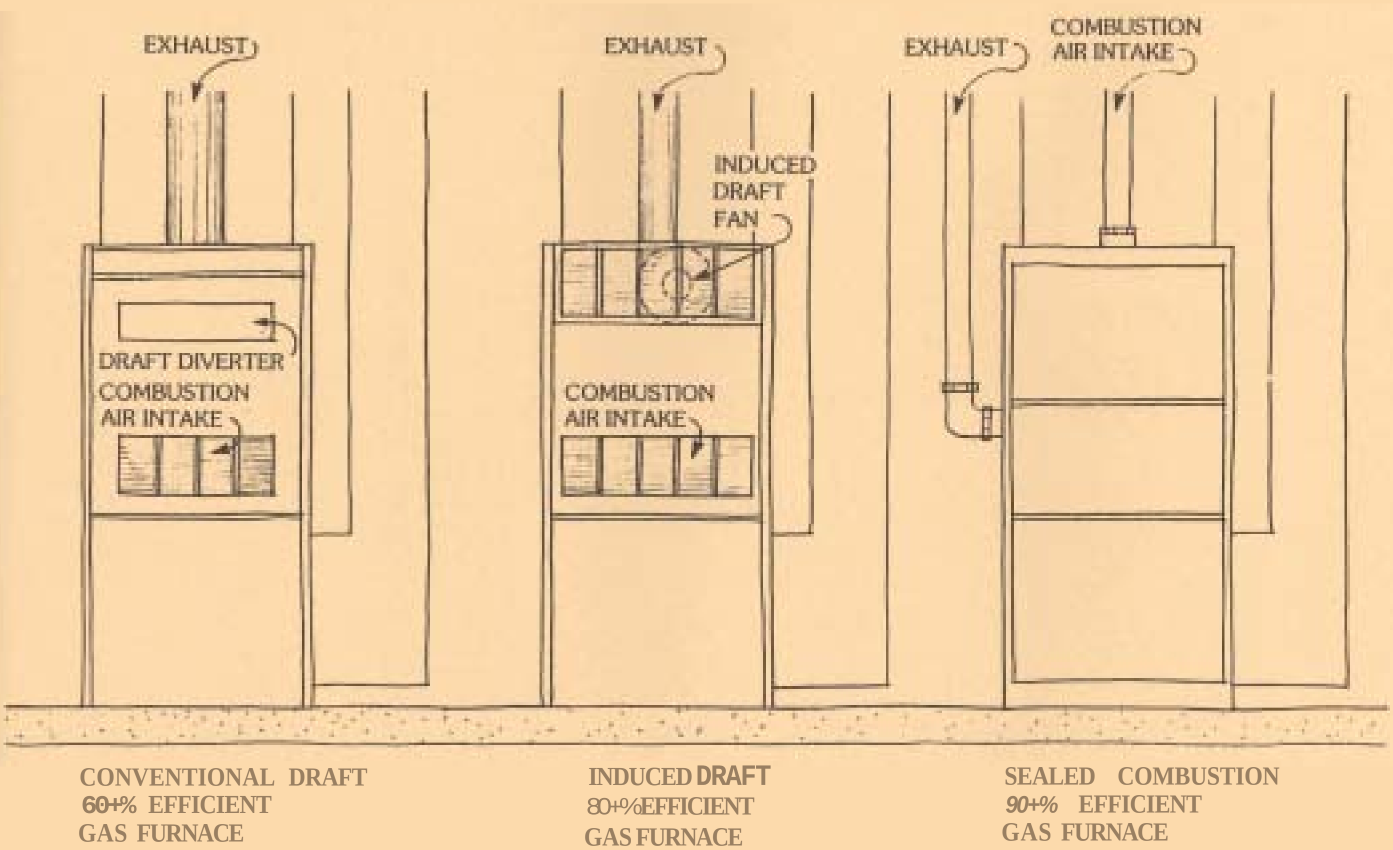
Conventional Forced-Air: A conventional gas furnace should not be used in an IDEAL home. The controlled ventilation system puts the home under a slight negative pressure which could cause flue gases to come back down the chimney endangering the occupants.

Moderate Efficiency Forced-Air: These furnaces have Annual Fuel Utilization Efficiency (AFUE) ratings of 80-87%. Most of these units have an induced draft fan on the exhaust to insure that the flue gases are carried out of the house. Keep the vent of an induced draft furnace as short as possible, venting it out the side of the house instead of up the chimney, if possible. An induced draft furnace that has no source of outside air should not be installed in a home without the recommended controlled ventilation system.

Some medium efficiency furnaces funnel outside air directly to a special sealed combustion chamber and out the exhaust vent without using any inside air. This eliminates the possibility of combustion products entering the house. When using gas, sealed combustion systems are preferred.

High Efficiency Forced-Air: These furnaces have AFUE's over 90%. Most vent out the side of the house rather than up a chimney. Some have sealed combustion chambers and all are induced draft. High efficiency furnaces are usually more expensive than other furnaces. This makes it harder to justify their higher cost for an IDEAL home.

Figure 11 Gas Furnaces



Integrated Heating Systems

New heating systems are being developed every day. Heating systems will eventually combine heating, air conditioning, water heating and controlled ventilation. Some new systems use a small boiler to heat the house and the water with an add-on cooling coil for air conditioning. Another may use a heat pump water heater which heats, cools and dehumidifies. Other systems use a conventional air-to-air heat exchanger with an add-on fan coil for heating the house using the water heater and an add-on air conditioning coil for cooling the house. Watch for new developments.

Water Heater/Fan Coil System: One system that seems to be getting more popular uses the water heater to heat the house. Hotwater circulates from the water heater to a fan coil located in a forced-air plenum chamber. *See* Figure 12. Central air can easily be added to this system. The water heater can be gas-fired or electric. The cost of heating water with gas is usually less than half what heating water with electricity costs, but a conventional gas water heater should not be used. If gas is the choice, use one of the new direct vent sealed combustion models, induced draft models, or add an induced draft attachment to a conventional water heater. Some of these new models need to be placed close to an outside wall because of their next design. If gas is not available, an electric water heater can also be used. The set up is the same.

Heating your home with a water heater allows the later addition of a solar water heating system when it may prove to be cost effective. The solar system can supplement both the domestic hot water system and the space heating system.

Heating With Wood

Because the heating load in an energy efficient home is so small, heating with wood can be a problem. Overheating can easily occur. Try to purchase as small a unit as you can find. If you must have a fireplace or woodstove, install a unit that is designed to use outside air for combustion. □

Figure 12 Water Heater to Fan Coil Heating System

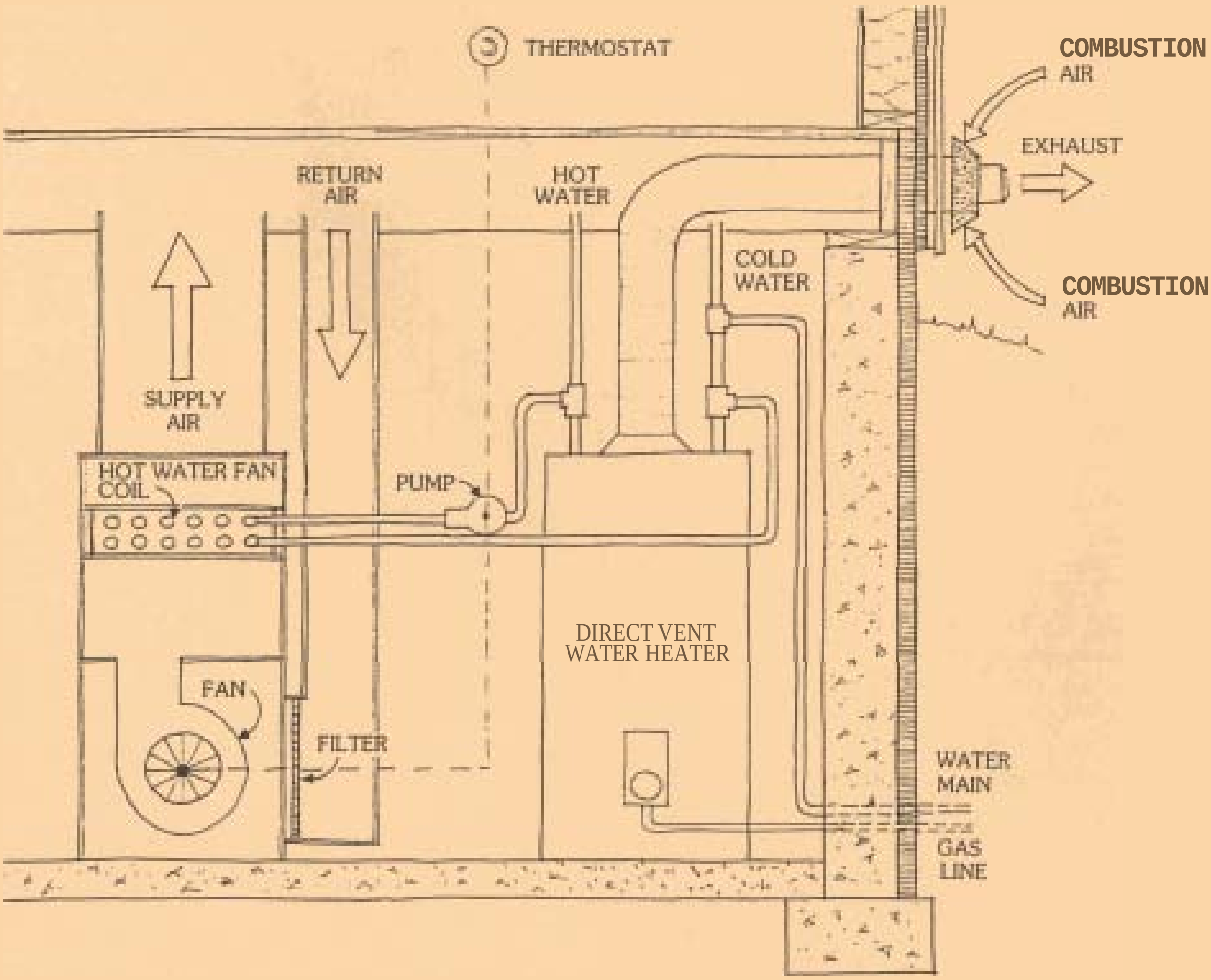
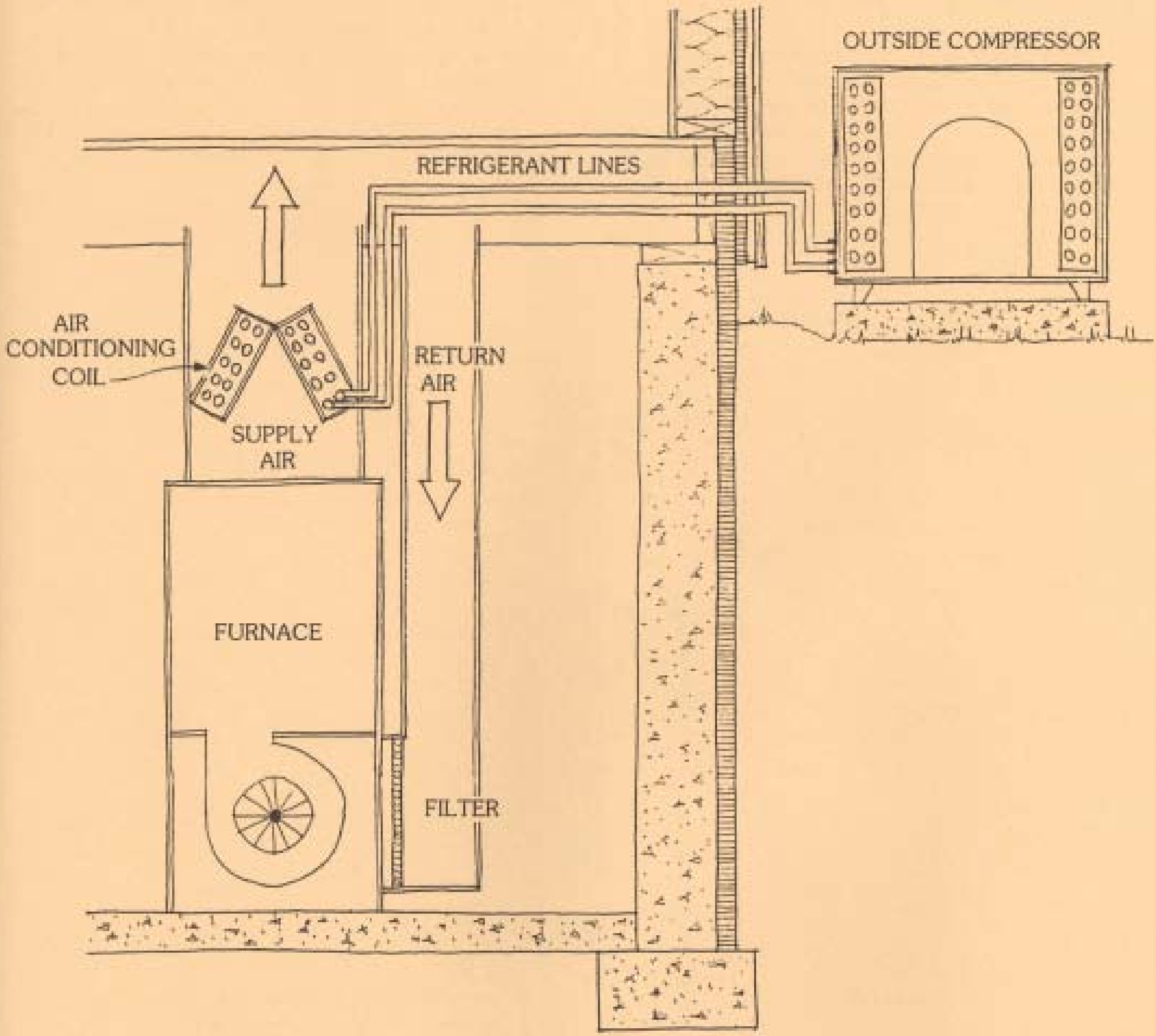


Figure 13 Central Air Conditioner



COOLING SYSTEM

The type of heating system you've chosen will dictate the type of cooling systems available to you.

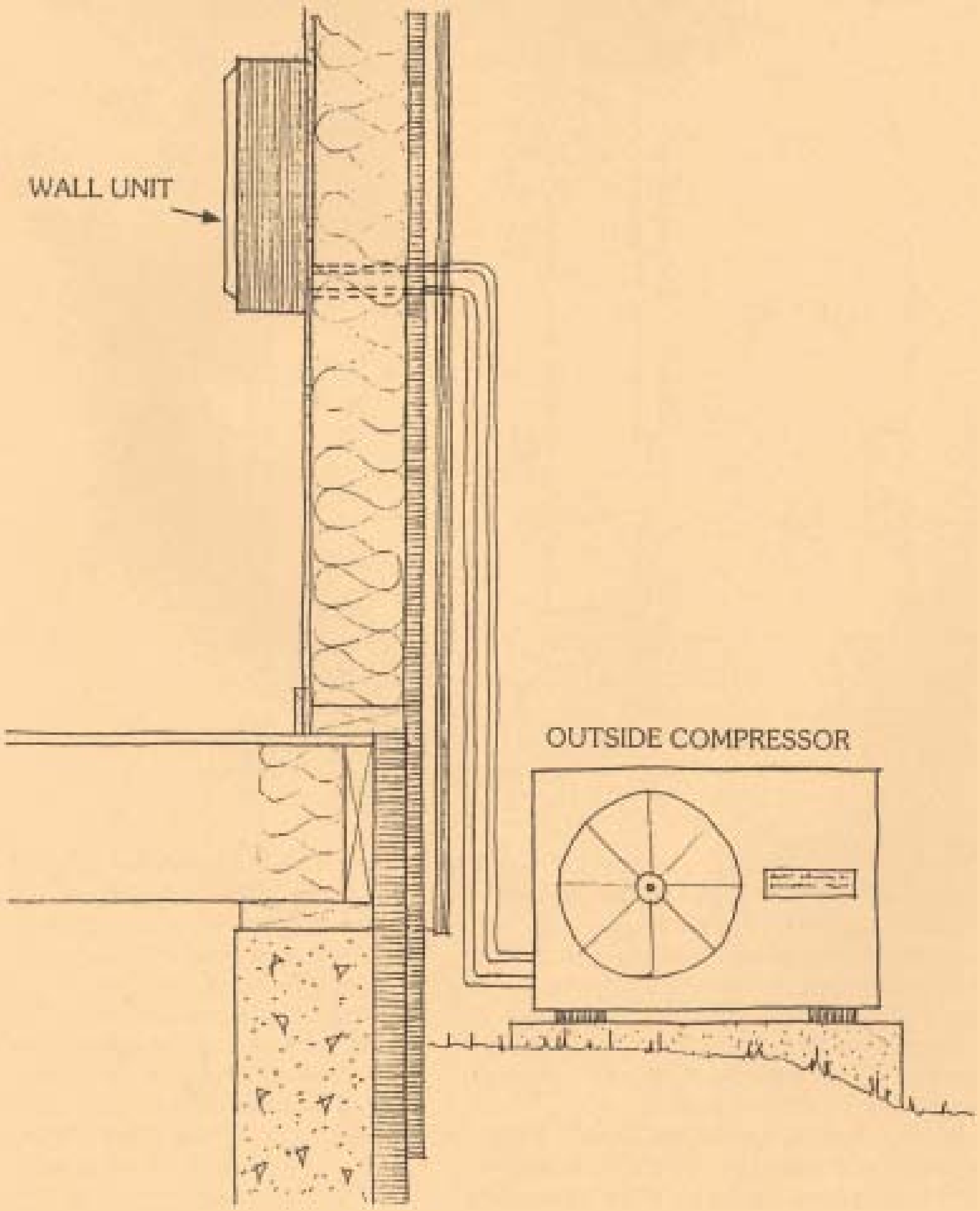
If a conventional central air conditioning system is desired, a forced-air heating system would be the logical choice. The ductwork would then be dual purpose. A central air conditioner has a compressor sitting outside the home and an " A coil in the ductwork with refrigerant lines connecting the two. See Figure 13.

If you choose a heating system that doesn't require ductwork, adding a conventional duct system may be a lot of additional expense for Iowa's moderate cooling season. A horizontal flow fan and an "A coil can be mounted on the underside of the floor system. Flexible ducts can then be used to distribute the cooled air.

Another alternative is to use a wall-mounted, split system room air conditioner as shown in Figure 14. Avoid using a conventional window or through-the-wall unit because it is difficult to seal around. In a tight, well-insulated home, a stationary room air conditioner, sized to meet the heat gain of the structure, may be able to cool a whole floor adequately. If the doors are open to the rooms at the other end of the house, the difference in temperature between the two areas is usually within a few degrees. If the home you design has more than one floor or a finished basement, you may need more than one unit to do an adequate job.

Homes constructed with an IDEAL approach will probably only need two tons or less of air conditioning. The major need in an IDEAL home in the summer is not necessarily cooling, but dehumidification. Air conditioning efficiency is measured in terms of the Seasonal Energy Efficiency Ratio (SEER); the higher the number the more efficient the unit. The normal SEER range is 6.0 to 15.0. If you choose a high efficiency air conditioner (one over 10.0), it may be wise to undersize it so it runs longer, keeping the coil colder and dehumidifying better. Higher efficiency units tend to have warmer coil temperatures and consequently dehumidify less. If you oversize an air conditioner for an energy efficient home, your home may be cool, but it will also be more humid. □

Figure 14 Wall-Mounted, Split-System Air Conditioner



WATER HEATING

The choice of the water heating fuel is usually determined by the choice of heating fuels. Here are some options for water heaters, operational tips, and new ideas for plumbing systems.

Gas Water Heaters: If you choose a gas heating system, it is logical to go with a gas water heating system. Because the house will be under a slight negative pressure due to the controlled ventilation system, only an induced draft water heater or a sealed combustion water heater should be used to prevent flue gases from coming back into the house. Induced draft attachments which can be added to conventional gas water heaters are available, but they are relatively new and their long term effects are unknown. Figure 15 illustrates these three gas water heater options.

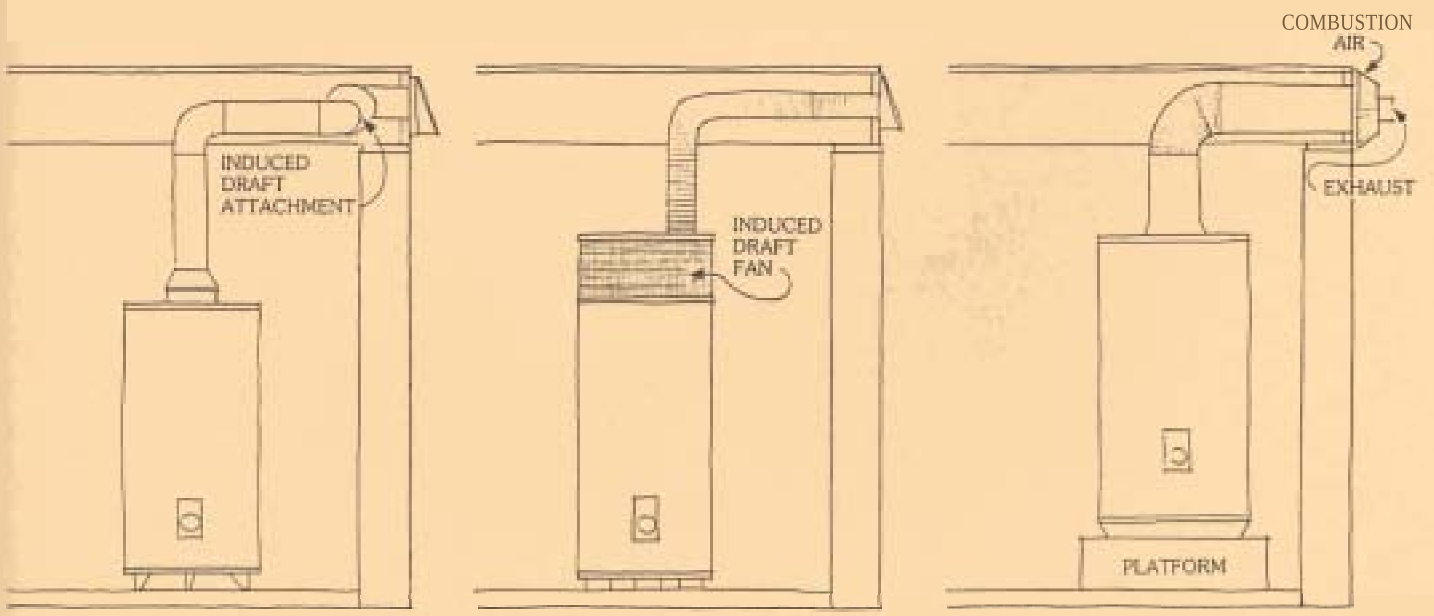
Electric Water Heaters: If your heating fuel choice is electric, a standard electric water heater is an option you might choose. Because there is usually no insulation on the bottom of an electric water heater, it should be placed on at least 2 inches of extruded polystyrene insulation.

Heat Pump Water Heater: Another option, if you choose electric fuel, is a heat pump water heater. It can be twice as efficient as a standard electric water heater, but usually costs 2-3 times as much. There are two types of heat pump water heaters. One is attached to a storage tank. The other is a separate unit that can be added to any water heater. Both extract heat from the surrounding air to heat the water, a desirable advantage in the summer because they cool as well as dehumidify. On the other hand, in the winter, this cooling effect could make a living space located next to the unit uncomfortable. However, the relatively short heating season in an IDEAL home tends to alleviate this problem. Although the initial cost of a heat pump water heater is considerably more than a standard electric water heater, it may be cost effective for a larger family.

Tankless Water Heaters: Tankless water heaters, both gas and electric, have been used in Europe for many years. There are small units meant to heat water for just one tap, and there are whole house models. The electric models generally cannot deliver sufficient flow and temperature rise to completely replace a conventional water heating system. The cost of having a small heater for each hot water outlet would be cost prohibitive. However, they can be used as booster heaters.

As the name implies, the tankless water heater has no storage tank. It heats water as needed, avoiding the normal heat losses from the tank. Theoretically, this is where it saves you money. However, reported energy savings appear to be exaggerated. If you follow the tips listed at the end of this section, standby losses on a conventional water heater will be minimal. Also, unlike a conventional gas water heater where the pilot light helps heat the tank, the energy from the pilot of a gas tankless unit is lost up the chimney.

Figure 15 Gas Water Heating Options



CONVENTIONAL GAS WATER HEATER w/INDUCED DRAFT ATTACHMENT

INDUCED DRAFT WATER HEATER

DIRECT VENT GAS WATER HEATER

Tankless water heaters may never run out of hot water, but neither do they deliver as much hot water as a conventional water heater. The conventional water heater can deliver water as fast as your plumbing can handle it, but the largest whole house tankless unit can deliver just over 3 gals/minute at a 60 degree temperature rise. This means you couldn't take a shower and wash clothes at the same time. Because of high initial costs, whole house tankless units are hard to justify economically. And, some people may find the low output objectionable. Also, induced draft or sealed combustion models are not currently available.

Solar Water Heaters: There are two types of solar water heaters: active and passive. (See Figure 16). Active solar water heaters use a pump to circulate fluid through solar collectors mounted on the roof. These collectors collect solar energy and use it to heat your domestic hot water. A properly sized active solar water heater can supply up to 70% of your hot water, but at today's prices would be hard to justify economically unless you used an extremely large amount of hot water.

A passive water heater is a less expensive option, but can only be used in the warm months. It generally consists of a black tank in a box, with a glass cover facing south. The sun shines through the glass and heats up the water in the tank. All the cold water entering your water heater is preheated as it passes through the passive solar water heater. This option appeals more to the do-it-yourselfer.

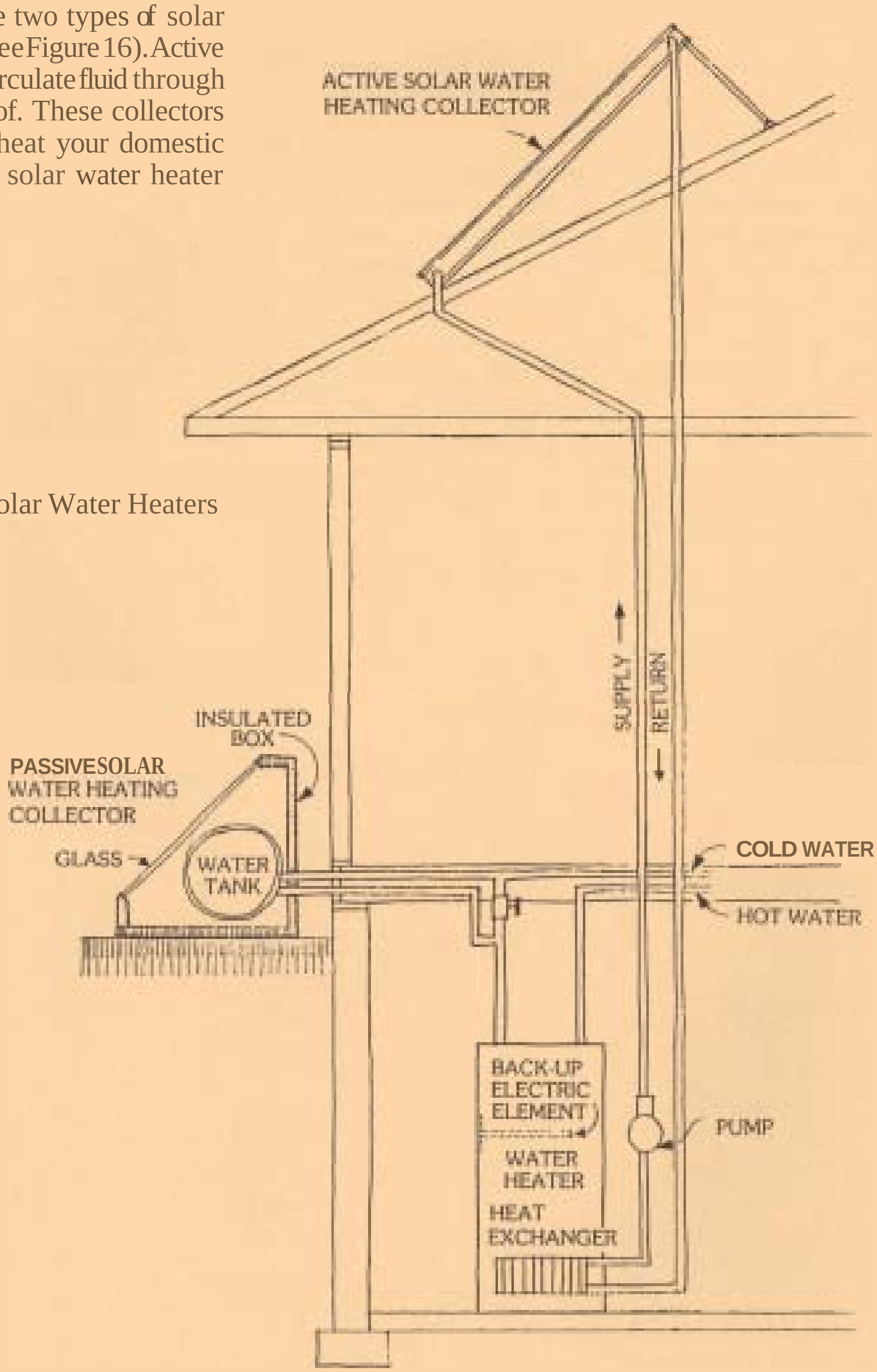


Figure 16 Active & Passive Solar Water Heaters

Water Heating Tips: The two main ways to save on water heating costs are to reduce standby losses and reduce the amount of hot water used. Methods for reducing standby losses are illustrated in Figure 17. Either special check valves or heat traps should be installed on the hot and cold water lines. An insulation jacket should be installed on a new water heater even if it is advertised as an energy efficient model. And, the first 10 feet of bath hot and cold water lines should be insulated to slow heat loss due to conduction through the copper pipes.

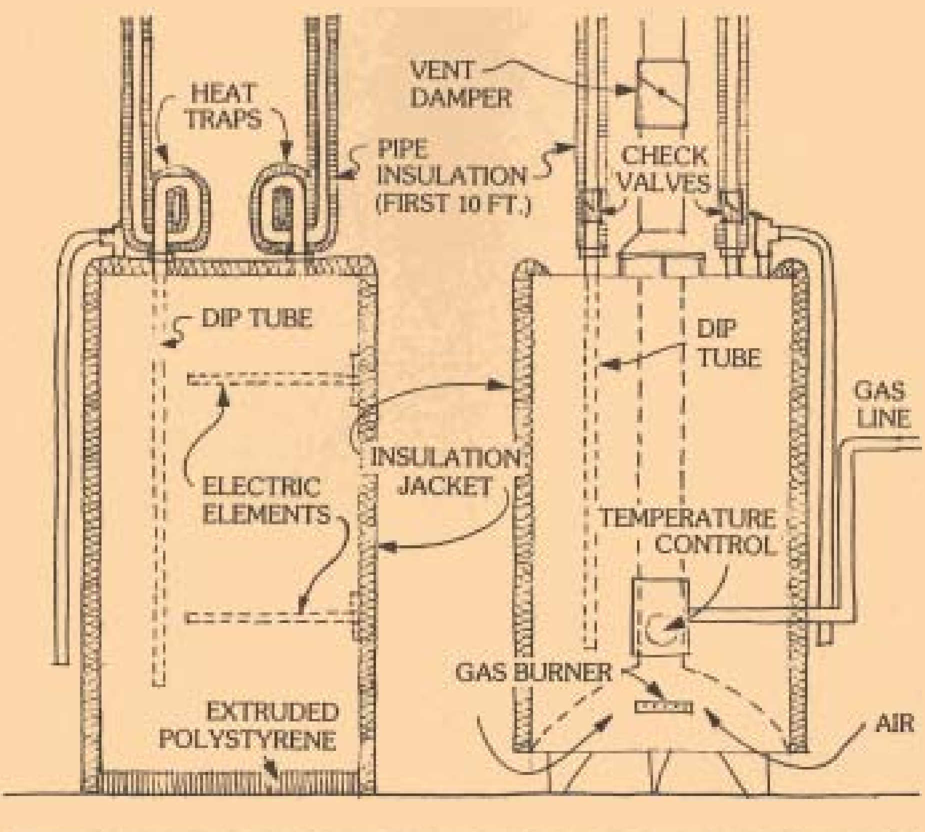
To reduce hot water consumption, install low flow shower heads in showers and aerators on faucets. Always use cold water to rinse clothes and dishes Choose a dishwasher that has a booster heater so you can set your water heater temperature at 120 degrees.

New Ideas: Some new innovations in plumbing systems can be energy savers. One system uses small diameter flexible polybutylene tubii with one tube running to each fixture. Push button panels at each point of use allow the user to select the temperature and flow rate desired. Small diameter lines mean you don't have to wait very long for hot water to arrive. Being able to set your own flow rate allows maximum water conservation. And, according to the manufacturers, the system costs little more than a conventional copper plumbing system. One drawback is there are more little things to go wrong.

Another approach would be to use the polybutylene pipe but install the plumbing in the normal fashion. This saves energy and labor time, but check your local codes first. Some city plumbing codes may not allow the polybutylene pipe.

Another new device saves energy by using cold water to gush the hot water left in the supply lines back to the water heater. A combination of a cylinder, a piston and a check valve accomplishes this. The savings average 15-20% of hot water consumption. However, if you shut the hot water off for a moment, you may have to wait for the hot water to return. Another potential problem is the damage to the seals that extremely hard water could cause. □

Figure 17 Reducing Water Heater Standby Losses



ELECTRIC WATER HEATER GAS WATER HEATER

OTHER CONSIDERATIONS

SELECTING THE SITE

If you have a choice of lots, choose a south sloping lot with good solar access surrounded by a windbreak of trees as shown in Figure 18. If the back of the house faces south, it allows you to have a walkout basement with the potential of solar gain to both the upper and lower levels of the house. However, south sloping lots with trees are not always available, especially in urban areas. An IDEAL home achieves efficient energy performance by relying on airtight construction and high levels of insulation instead of strictly passive solar. Solar energy should be used when possible, but an IDEAL home can be oriented in directions other than south with only a small loss in energy performance. □

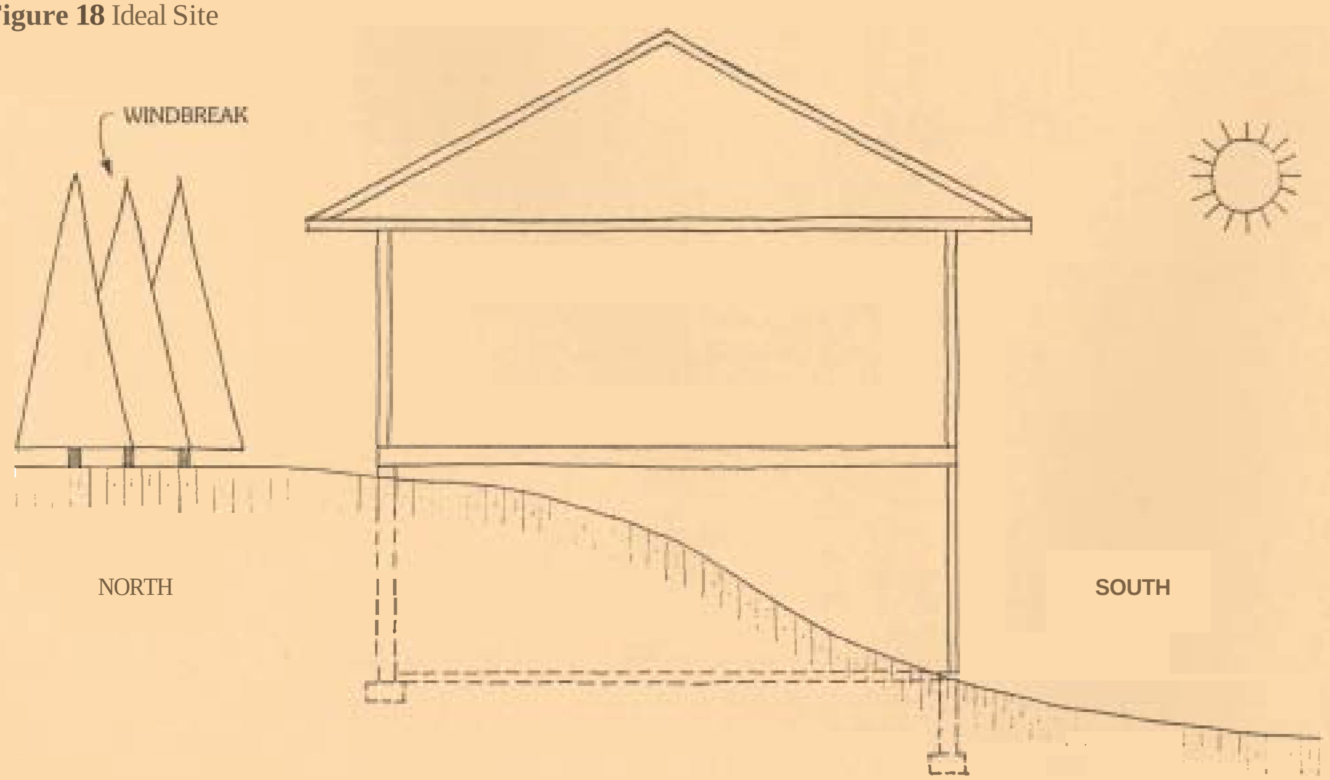
LAYING OUT THE FLOOR PLAN

An IDEAL home can be adapted to virtually any architectural style, but try to design with as few corners as possible. Each corner increases the wall area exposed to the outdoors and adds to the construction cost. The simplest and most efficient design, though probably not the most architecturally appealing, is a rectangular plan with one of the long sides facing south.

Two story homes are generally cheaper to build than single story homes of the same size due to less foundation and roof area. A two story home has one-third more exterior wall area which historically has been poorly insulated; a single story house has more exposed foundation. This means both types of homes are fairly equal on energy efficiency. Since the walls and foundations of an IDEAL home are better insulated those in conventionally constructed homes, the two story house will remain fairly equal to the single story home on energy efficiency.

The following tips can be used to layout an IDEAL home. The garage is best located on the northwest corner of the house where it can buffer the winter winds and protect the entry. Living areas that will be used primarily in the evening should be located in the southwest part of the house to use natural evening light as long as possible. Bedrooms, contrary to tradition, are best suited for the lower level where it is cooler and where there is protection from the tornadoes we frequently have in Iowa. However, this is not always practical if you are planning a two story house. Bathrooms, laundry areas, mechanical rooms, and other rooms needing only small windows or no windows at all should be located along the north wall of a house where they will not take up valuable south exposure. The closer you can locate bathrooms to kitchens, the cheaper and more efficient the plumbing system. Although many of these tips seem to contradict each other, a good designer will be able to incorporate them into an appropriate design to meet your needs. □

Figure 18 Ideal Site



WINDOWS AND DOORS

Windows are important to an energy efficient home for many reasons. They provide natural light and a view to the outdoors. They improve the exterior and interior aesthetics, provide solar heat gain in the winter, allow for natural ventilation, and are an optional exit in case of fire. On the negative side, windows increase heat losses in the winter, heat gains in the summer and increase air infiltrating the building envelope. For these reasons, the following factors should be evaluated when selecting an efficient window system: type of window, type of glazing system, location, and shading.

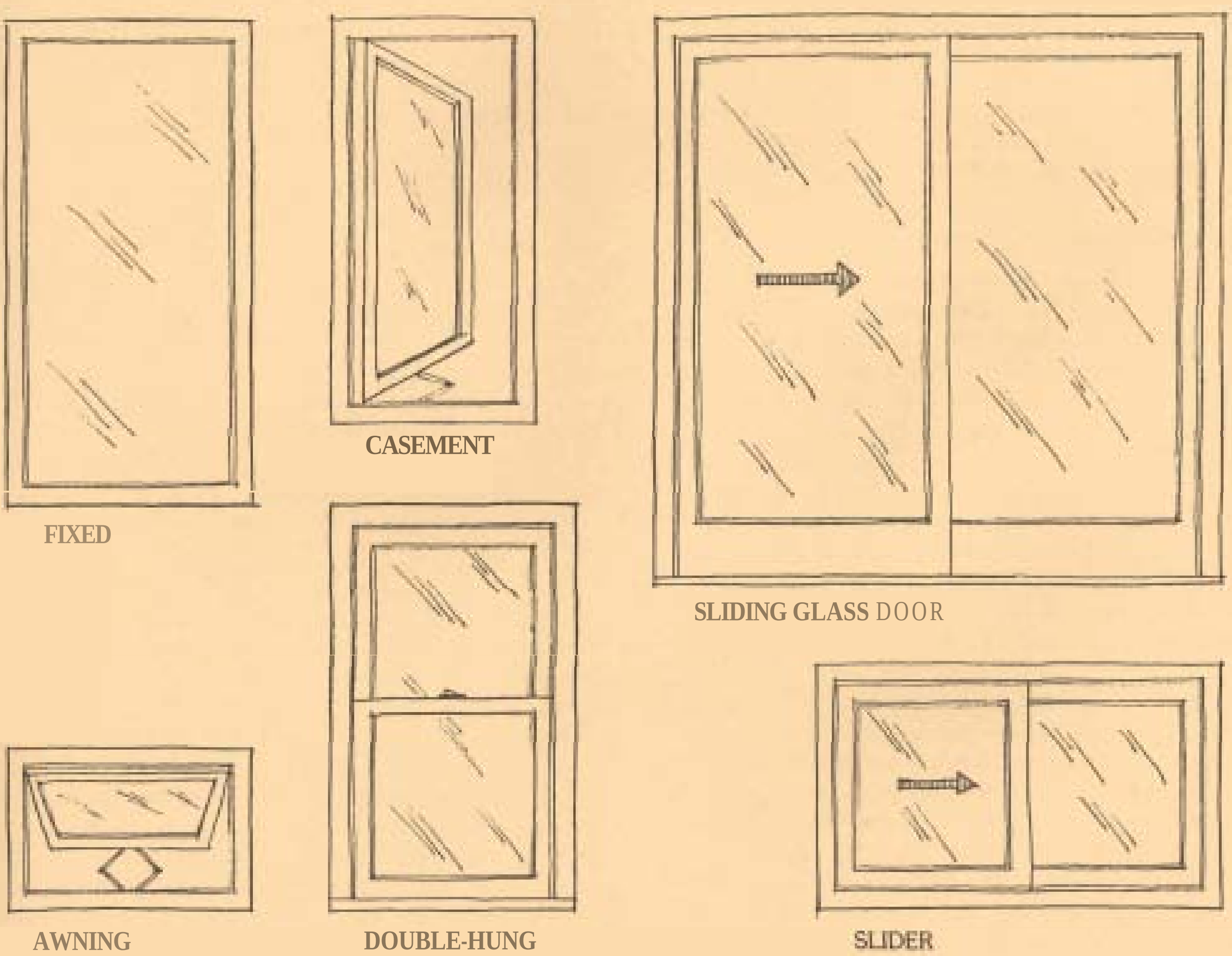
Type of Window

Figure 19 shows the six common types of windows, The main difference between them is the amount of air leakage they allow around the sash. Generally, fixed windows are the tightest, followed by awnings and casements, double-hungs, sliders and sliding glass doors.

All manufacturers of windows have data available on air infiltration. This data is measured in cubic feet of air leakage per minute per lineal foot of crack between the sash and frame (cfm/ft). The industry standard is .50 cfm/ft, but most good windows are below .20 cfm/ft with some down below .02 cfm/ft. This information is useful for comparison purposes, but when the window gets installed in an actual house, the numbers may be entirely different. The way a window is manufactured, how it is crated and transported, and how it is installed, affects its final performance. Even the best window, if treated roughly and installed in a skewed rough opening, could leak a considerable amount of air. The best defense against a leaky window is to seal the fixed joints on the window with a clear caulk after it is installed.

Fixed windows should **be** used anywhere that an operable window is not needed for ventilation or emergency escape. Although fixed units should have

Figure 19 Window Types



no air leakage, they are not always factory sealed and should be sealed on the site. Sliding glass door replacement glass can be used for inexpensive site-built fixed windows. Fixed units can also be ordered in combination with operable windows.

Casements, the most popular operable windows, are similar to awning windows in that they open like a door and seal fairly tight. When you order casement combinations, not all the windows have to open. For larger window areas, awning windows can be placed under fixed units to provide the largest window area with the smallest operable area.

Double-hung windows, like sliding windows and doors, have to be loose enough to allow the windows to slide. Thii is why they normally have **2-3** times the air leakage rate as casements and awnings. If the look of a double-hung window is desired, two awning windows of equal size can be stacked on top of each other. The top half can be made non-operable for more energy savings. Also, an in-swinging patio door will provide a much tighter seal than a sliding glass door.

Wood is the most common type of window frame material and is a fairly good insulator. If maintenance is a concern, the wood can be covered with exterior cladding such as aluminum or vinyl. Aluminum frames should only be used if they contain an adequate thermal break between the inside aluminum and the outside aluminum. Enclosed air spaces increase the insulation value in polyvinyl chloride (**PVC**) and vinyl frames.

Type of Glazing System

Glazing refers to a layer of glass. **A** double-glazed window consists of two layers of glass separated by an air space. Although double-glazed systems remain the most popular option in window glass, a variety of glazing systems have been designed to meet the recommended R-3 insulation rating which ordinary double-glazing cannot achieve. Table 7 compares different types of glazing systems. The higher the **R**-value, the warmer the interior surface temperature and the less chance of condensation problems. Table 8 lists the indoor relative humidity at which condensation will occur at a given outdoor temperature. The warmer surface of the **R-3** windows also makes the home more comfortable.

A new development is the low emissivity (low-E) coating. This transparent metal oxide coating, when applied to a double-glazed window, reflects radiant heat back into the room. The result is a double-glazed window with the R-value of a triple-glazed window. Another method being used to achieve the insulation value of a triple-glazed window is the suspension of a clear film between double glazing, creating dead air spaces without the weight of the third glazing. This film can also have a low-E coating applied to it achieving an R-4 rating.

Still another option requires suspending a mini-blind between the glass. The window is a double-glazed window when the blind is open during the day, but performs similar to a triple-glazed window at night when the blind is closed. Thii blind can also be used to keep out unwanted solar gain.

Table 7 Window Glazing Comparisons

Glazing Type		*R-Value*[1]	*UV Trans*	*Solar Trans*[2]	Winter Energy Gain Btu/sq ft[3] *South*	*E/W*	*North*
Single Glazed	:	*0.9*	*78%*	*87%*	*10500*	*-58400*	*-106600*
Double Glazed	:	*2.0*	*64%*	*77%*	*73300*	*12300*	*-32200*
w/ Low-E	:	*3.1*	*29%*	*61%*	*67800*	*19400*	*-15800*
w/ 1 Film	:	*2.8*	*6%*	*74%*	*86700*	*28100*	*-14600*
w/ 2 Films	:	*3.8*	*2%*	*71%*	*93700*	*37500*	*-3500*
w/ Low-E Film	:	*4.0*	*43%*	*61%*	*77400*	*29000*	*-6200*
Triple Glazed	:	*3.2*	*51%*	*70%*	*85400*	*29900*	*-10500*

1R-values are taken from the 1981 Ashrae Handbook of Fundamentals and from product literature. R-values will vary according to amount of air space between glazings or films, and the emissivity of the low-E coating.

2Solar Transmission = shading coefficient x.87, or usable solar heat transmitted through the glass. This may vary with manufacturer.

The estimated winter energy gain is the net gain (solar gain-heat loss) based on the average solar radiation and heating degree **days** for central Iowa from Nov. - Apr. These figures are for comparative purposes only, and should not be used in actual calculations. The amount shown assumes that all the solar heat that penetrates the window is usable.

Table 8 Window Condensation Chart

Window Type		*Single Glazed*	*Double Glazed*	*Double Low-E*	*Double Film*	*Double 2Films*	*Double Low-E Film*	*Triple Glazed*
R-value:		*0.9*	*2.0*	*3.1*	*2.8*	*3.8*	*4.0*	*3.2*
Outside Temp	:	*Percent Relative Humidity at Which Condensation Will Occur Inside Temperature = 70F*						
40F	:	44%	70%	80%	78%	83%	84%	80%
30F	:	30%	62%	74%	71%	79%	79%	74%
20F	:	25%	55%	69%	66%	71%	71%	69%
10F	:	—	48%	63%	60%	69%	70%	65%
0F	:	—	42%	58%	55%	65%	67%	59%
-10F	:	—	37%	53%	50%	60%	62%	55%
-20F	:	—	32%	49%	46%	57%	59%	50%

Location

A rule of thumb on window placement is to have 10-15% of your floor area in glass with 40% on the south, 30% on the east, 20% on the west, and 10% on the north. North windows are always a net heat loser, but they are useful for cross ventilation. West windows add significantly to the cooling load in the late afternoon during the summer unless adequately shaded.

Shading

Overhangs are a common means of shading windows, but only work effectively on south windows. (See Roof Systems under the Construction Details section for sizing information on overhangs.) Overhangs aren't effective for east and west windows because the sun comes in under the overhang in the afternoon. Just one hundred square feet of east or west glass will require more than a ton of additional air conditioning capacity. Options for cutting summer solar gain through east and west windows include reflective films, solar screens, appropriately placed landscaping, bamboo shades, and awnings.

Window Treatments

The main problem with using movable night insulation on windows is it usually requires occupant involvement. The homeowner either has to put an insulated panel in at night or pull down an insulated shade. Often homeowners will use the night insulation for the first couple years, but then lose interest. People want something simple. It is generally better to install an R-3 window that requires no occupant involvement than to install a double-glazed window and rely on the use of movable insulation. If the movable insulation doubles as the window covering, it is more likely to be used. Most people close their curtains at night.

Window treatments do increase the comfort of a home by eliminating the few cold surfaces that do remain, but are seldom cost effective for an IDEAL home based on energy savings alone,

Doors

An R-15 insulation rating is recommended for all exterior doors. A metal insulated door with a thermal break between the interior and exterior metal surfaces with a tight seal is the most desirable option. Although a storm door may not be cost effective based on energy savings, you may still want to install one for summer ventilation or security reasons. A vestibule entry is generally not cost effective for an IDEAL home. The home is already tight enough to prevent cold air from rushing in; the minor energy savings that would result from the vestibule is not justified by the valuable space it occupies. It would, however, reduce drafts and increase comfort near a heavily traveled door. Most houses can be designed to use the garage as a vestibule for family members. □

LIGHTING SYSTEM

The primary goal in designing an energy efficient lighting system is to minimize the number of light fixtures needed. One way to accomplish this is to plan window locations in areas used often during daylight hours to take advantage of natural light. Also, decorating with light colors makes a home seem brighter.

One of the first considerations in an energy efficient lighting system is where you place the lights. Provide low-level general illumination for the whole room using task lighting to brighten specific reading or working areas. Try to avoid ceiling fixtures; mounting fixtures on interior walls avoids penetrating the air barrier and

Table 9 Lighting Efficiency Comparisons

Bulb	Light Output (lumens)	Efficacy (lumens/watt)	Lifetime (hours)
Incandescent			
200 W	3910	19.6	750
150 W	2790	18.6	750
135 W **miser**	2580	19.1	750
100 W	1750	17.0	750
100 W **long-life**	1500	15.0	2500
95 W **miser**	1710	18.0	750
90 W **miser plus**	1360	15.1	2500
75 W	1190	15.9	750
70 W **miser**	1170	16.7	750
60W	855	15.0	lo00
55 W **miser**	855	15.5	1000
52 W **miser plus**	700	13.5	2500
40 W	470	11.8	1500
25 W	190	7.6	2500
15 W	120	8.0	2500
3-way incandescent			
150W	2220	14.8	1150
100W	1640	16.4	1200
50 W	580	11.6	1500
Fluorescent			
40 W 4 ft **tube1**	2200	47.8	20,000
34 W 4 ft **tube1**	2800	71.6	20,000
40 W 16" **circular1**	2500	**54.3**	12,000
32 W 12" **circular1**	1800	48.9	12,000
22 W 8" **circular'**	1050	41.5	12,000
20 W 6" **circular'**	*800*	34.8	12,000
44 W **screw-in circular2**	1750	39.8	7,500
18 W **compact screw-in2**	1100	61.1	7,500
13 W **compact screw-in**[2]	900	69.2	10,000
9 W **compact screw-in2**	*600*	66.7	10,000
Other			
55 W GE **Miser Maxi-light (base down)**	2250	40.9	5000

1 An additional wattage of 15% was added to cover ballast consumption.

2 Includes ballast comsumption.

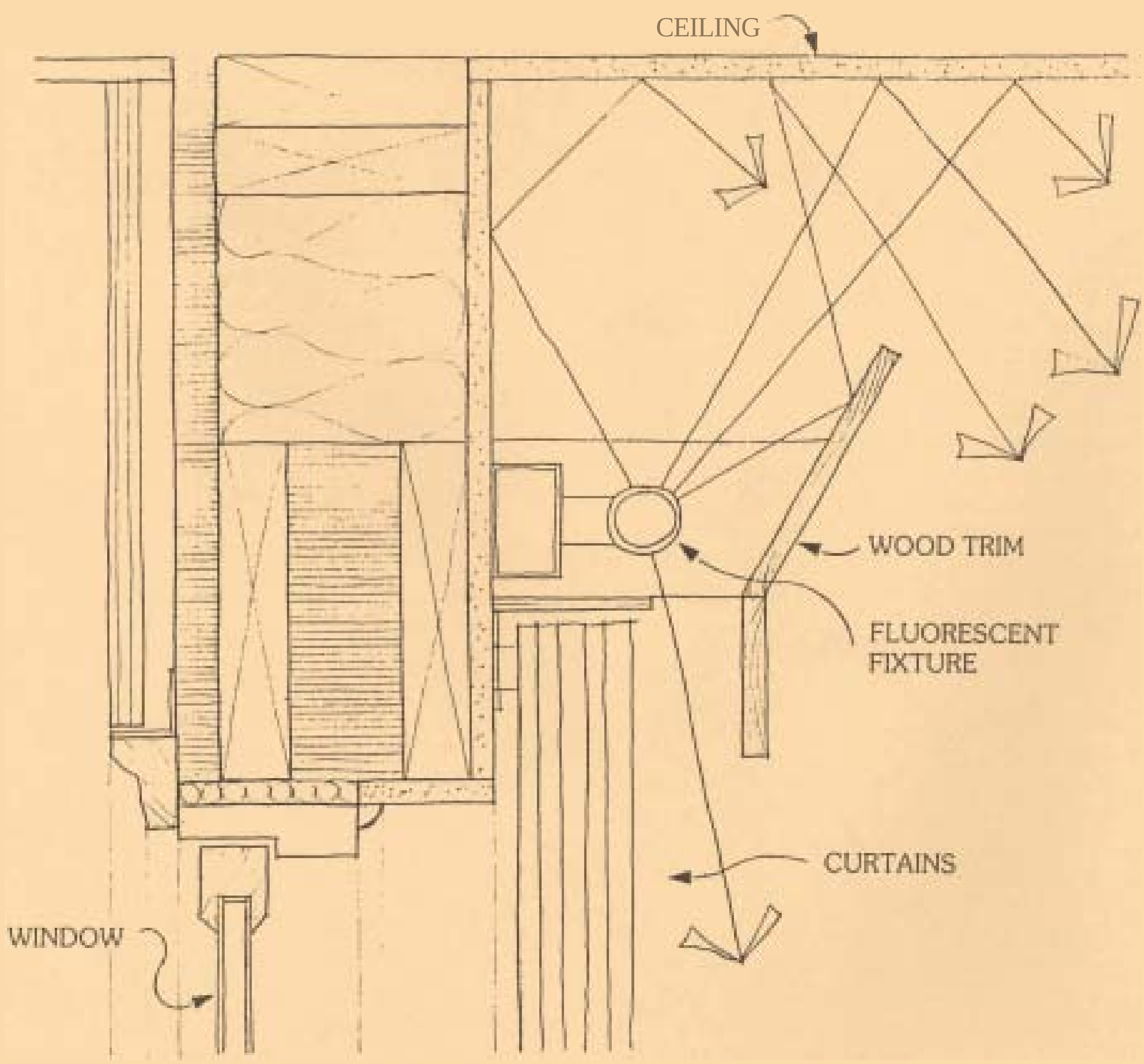
cuts down on infiltration. When possible, use track lights instead of recessed lights. Recessed lights are best used between two heated spaces, such as on the basement ceiling.

Efficiency is another important consideration. Multi-bulb fixtures are poor choices. Larger wattage bulbs are more efficient than several smaller wattage bulbs. The main way to compare lighting efficiencies is by their "efficacy" (lumens/watt). The higher the number, the more efficient the bulb. For example, a 100 watt bulb gives off more light than two 60 watt bulbs.

Table 9 compares the efficacies of the types of lighting common to residential construction. As you can see from the chart, fluorescent lights use **1/3** to 1/4 the amount of energy incandescent bulbs use to provide the same amount of light. The fixtures and bulbs cost more, but last ten times as long. Consider fluorescent lights for the kitchen, baths, basement recreation room, laundry room, and utility room. They can also be used for indirect lighting in hallways, living rooms, and bedrooms. Figure 20 illustrates how to use fluorescents for indirect lighting.

New types of bulbs and systems are being developed all the time. One new development features a low voltage lighting system which allows you to have as many switches per light as you desire. **The** lights can be controlled from one central control panel and can be set to turn on and off at certain times. This system is probably chosen more for convenience than for energy savings. □

Figure 20 Indirect Fluorescent Lighting



APPLIANCES

In an energy efficient home, lights and appliances can account for over half of your energy bills, Figure 21 shows how your appliance energy dollar is divided. When purchasing new appliances, compare "EnergyGuide" labels and buy the highest efficiency you can afford. Less efficient appliances add considerable heat to the home during the summer months. This increases the cooling load. Tips for cutting down energy costs on specific appliances follow:

Refrigerator/Freezer: Don't buy a larger refrigerator than you need. A large refrigerator takes more energy to keep the same amount of food cold. Be sure the unit has an energy saver switch which shuts off the electric elements that keep condensation from forming on the surface of the refrigerator. You will probably only need to turn the switch on during hot humid days. Finally, keep the refrigerator away from heat sources and out of direct sunlight which can make it work harder to keep food cool.

Freezer: A chest unit is more energy efficient than an upright model; it doesn't lose as much cold air when you open the door. Compare "EnergyGuide" labels.

Range: An electric range is recommended for an energy efficient home. A gas range can be a source of indoor air pollutants. Install a recirculating range hood to remove grease and odors. Glass top units are less efficient than surface elements. Since a self-cleaning oven has more insulation than standard models, it's also more energy efficient. A window in the door can reduce the amount of energy lost from opening the door to check on food.

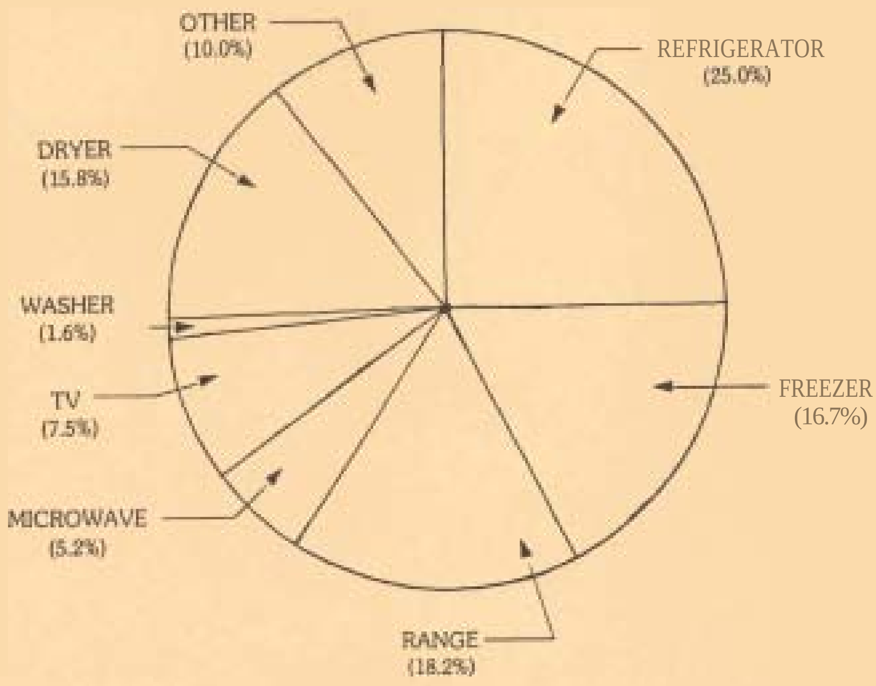
Dishwasher: Select a dishwasher with a booster heater, an air dry option, and a short cycle selector. Compare the "EnergyGuide" labels and water usage when shopping for a dishwasher.

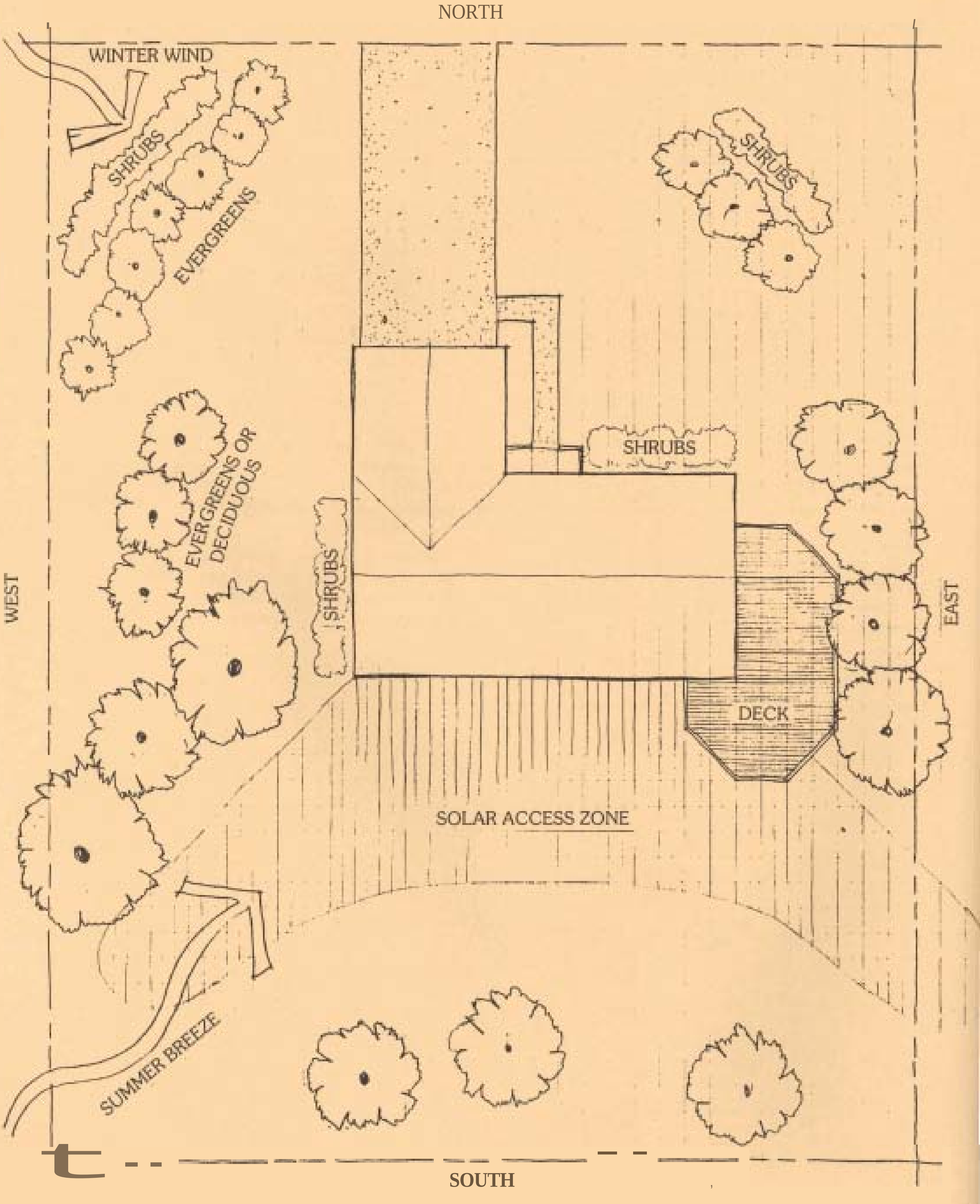
Washer: Select a washing machine with a variety of settings for water level and temperature as well as a cold rinse option. A suds saver tank, which allows you to wash several lightly soiled loads with the same water, is a nice option but it is seen in few models. Compare "EnergyGuide" labels and water usage.

Dryer: Since the dryer is vented directly out of the house, you can select either a gas or electric model. This will probably be determined by the choice of heating and water heating fuels. If gas is chosen, make sure the unit has an intermittent ignition. Gas dryers cost considerably less to operate than electric. Select a dryer with a variety of settings for different fabrics, an easy to reach lint filter that should be cleaned after every load, and a moisture sensor to shut the dryer off when the clothes are dry.

Waterbed: Insulate under and around the mattress with at least 3/4 inch extruded polystyrene. This can cut the operating cost by 30-50%. Use a mattress pad and keep the bed covered when not in use. □

Figure 21 Appliance Energy Consumption




NORTH
WINTER WIND
SHRUBS
EVERGREENS
SHRUBS
EVERGREENS OR DECIDUOUS
SHRUBS
SHRUBS
WEST
EAST
DECK
SOLAR ACCESS ZONE
SUMMER BREEZE
SOUTH

LANDSCAPING

In new homes you have many landscaping options with few limitations. Your options range from siting the house using already existing trees, to planting new trees and shrubs. With all houses, landscaping can be divided into four areas: south, east, west, and north. The south side will receive the most solar gain in the winter and is best kept clear of large trees. Even deciduous trees (those that lose their leaves in winter) can still block up to 60% of the sun's solar radiation. Trees on the south should be at least twice as far away from the house as the trees' mature height will be. Shading for south walls is best accomplished with fixed or movable overhangs or awnings, shade screens or other similar devices.

East and west windows receive only minimal solar gain in winter, but are a major cause of summer overheating. They actually receive over 50% more solar radiation in the summer than south windows do. So when landscaping your home, summer shading takes precedence over winter heating. Trees on the east and west should have low branches to shade the windm and walls from the low early morning and late afternoon sun. Slightly taller trees can go on the southeast and southwest corners of the house, located at a distance of five times their mature height away from the house, to avoid winter shading.

The winter wind in Iowa usually comes out of the northwest, so the primary concern for the north side of the house is to give it protection. This can be done by placing windbreaks and low shrubs against the foundation. Evergreens never lose their leaves and make an excellent winter windbreak for the north and west sides. Windbreak density must be maintained from the ground up with no gaps between trees or pruning of lower branches. A combination of low shrubs, fences and trees of various heights makes an ideal windbreak. Locate the windbreak one to three times its height away from the house in order to deflect the wind over the house.

Ground cover can also have an impact on summer comfort. Concrete or asphalt patios, sidewalks and driveways can absorb heat and raise the temperature of the air around your home that you use for ventilation. They can also reflect sunlight into your house, raising the inside temperature. To avoid these problems, either shade these hard surface areas or substitute gravel, wood decking or a new method called grasscrete. Grasscrete uses a specially patterned form which allows grass to grow through the concrete. Grass covered surfaces can be 25 degrees cooler than asphalt surfaces. The object is to minimize paved surfaces, shade them where possible, substitute cooler materials, and cover bare ground with grass or other natural ground covers. Any combination of these will make your surroundings more comfortable and cool the air you use for ventilation.

Most urban lots do not allow much room for landscaping, but if you have room to properly landscape your IDEAL home, Figure 22 shows an option. □

Figure 22 Landscaping For Energy Efficiency

SOURCES OF INFORMATION

If you have questions concerning this book or other energy related topics, call the Energy Hotline at 1-800-532-1114 from anywhere within the state of Iowa. In Des Moines the number is 281-7017. The Energy Hotline is a service provided by the state of Iowa to help answer questions on all aspects of energy. Many publications on a wide variety of topics are available free of charge.

The Energy Hotline has additional information on the following topics that deal with energy efficient construction:

Basement Insulation	Solar Radiation in Iowa
Blower Doors	Sunspaces
Heating Degree Days	Window Developments
Home Heating Index	Window Treatments
Passive Solar	Wood Burning Stoves & Fireplaces

The following are other sources of information on energy efficient construction:

Books:

The Airtight House, *James K. Lischoff and Joseph Lstiburek, Iowa State University Research Foundation, EES Building, Habor Road, Iowa State University, Ames, IA 50011. 515-294-8815, 95 pages.*

The Superinsulated Home Book, *J.D. Ned Nisson & Gautam Dutt, John Wiley & Sons, Inc., 605 Third Ave., N.Y., NY 10158. 1985, 316 pgs.*

A New Approach to Affordable Low Energy House Construction, *Joseph W. Lstiburek & James K. Lischkoff, Alberta Dept. of Housing, 10050-112 Street, Edmonton, Alberta, Canada T5K ZJ1. 1984, 100 pgs.*

Practical Building Science—Affordable Problem Free Construction, *Joseph W. Lstiburek, Building Engineering Corp., 157 Richard Clark Drive, Downsview, Ontario, Canada, M3M IY6, 416-926-8910. 1986, 300 pgs.*

Energy Efficient Home Construction - Basic Superinsulation Techniques, *National Center for Appropriate Technology, P.O. Box 3838, Butte, Mt 59702-3838, 406-494-4572. 1984.*

Magazines:

Energy Design Update, *Energy Design Update, 1100 Massachusetts Ave., Arlington, MA 02174. 617-648-8700. Monthly.*

Practical Homeowner, *Rodale Press, 33 E. Minor St., Emmaus, PA 18049. 9 issues/yr.*

Progressive Builder, *Solar Vision, Inc., P.O. Box 470 Petersborough, NH 03458-0470. 603-827-3347. Monthly.*

Publications & Reports:

Energy Efficient Housing—A Prairie Approach, *Energy Research Development Group, Univ. of Saskatchewan. Available from: Saskatchewan Power Corp., 2025 Victoria Ave., Regina, Saskatchewan, Canada S4P 0S1. 306-566-3190. 1982. 34 pgs.*

Maine Audubon Society Guide to Superinsulated Construction, *Maine Audubon Society, Energy Dept., 118 U.S. Route One, Falmouth, ME 04105. 207-781-2330. 1983. 36 pgs.*

Air-Vapor Barriers, *D. Eyre & D. Jennings, Energy Mines & Resources, Conservation & Oil Substitution Branch, 580 Booth St., Ottawa, Ontario, Canada K1A 0E4. 1983. 101 pgs.*

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