Energy Performance Tune-up

Tips for Arkansas builders on building better performing new homes

June 2001

Arkansas Energy Office
Arkansas Department of Economic Development

Author: Evan C. Brown
Consultant
Arkansas Energy Office of the
Arkansas Department of Economic
Development

Technical Advisors:

Susan Recken, Arkansas Energy Office of the Arkansas Department of Economic Development
Royce Lewis, Comfort Diagnostics and Solutions

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For more copies of this publication or to provide comments or suggestions contact:

Susan Recken
Arkansas Energy Office of the
Arkansas Department of Economic Development
One Capitol Mall
Little Rock, AR 72201
Phone: (501) 682-7334
1-800-ARKANSAS
srecken@1800ARKANSAS.com

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Introduction

The purpose of this Tune-up is to promote energy-efficient construction in Arkansas. It is hoped that this information will:

- **improve the overall energy performance of homes**
- **increase the quality and marketability of new homes**
- **lengthen the lifetime of the home**
- **enhance the safety and healthfulness of homeowners**
- **improve the value of the home by reducing operating costs and increasing comfort**

This Tune-up assumes that a contractor/homebuilder already knows how to build a home. It does not cover the basics of construction practices or provide extensive detailed information on all aspects of construction. This Tune-up is the result of a 1998-1999 survey of 100 new homes that were built in Arkansas. A close evaluation of the construction process, from bottom to top, from beginning to end, indicated that there were several areas where small changes or improvements could be made that would enhance energy performance, lengthen a building's lifetime, reduce call-backs, increase comfort levels, add to the value of the homebuilder's product, and reduce the cost of construction.

The Arkansas Energy Code establishes a set of minimum guidelines that focus on the insulation level of the exterior shell or envelope. The Energy Code is a good place to start. This Tune-up, however, goes beyond these minimums by focusing on the details that improve the performance of the whole building and its associated equipment. Looking at the building as a "whole system," instead of just a collection of parts, enables builders to make cost-effective trade-offs that enhance overall performance while maintaining comfort, economy and safety.

Findings in recent survey of new homes

The results of the 1998 – 1999 survey of 100 new homes built in central and northwest Arkansas indicated that:

- Only about half of new homes surveyed passed the Arkansas Energy Code (the Code) requirements. Many of the homes that failed came close to passing.
- The selection of solid aluminum frame windows (no thermal break) kept many homes from passing the Code.
- Many ceilings were under-or inconsistently insulated. Insulation certificates were found in only a few homes.
- Knee walls were poorly insulated with exposed batts.
- Slab insulation was applied well in two out of 81 homes.
- Homes are being built tighter now than in the past. Air leakage tests by Energy Rated Homes of Arkansas indicated that as few as five years ago the average air leakage for new construction in Arkansas was about 0.5 natural air changes per hour (NACH). This average has been reduced to about 0.35 NACH, a level below which odors and moisture might be a problem.
- Fireplaces caused additional air leakage ranging from 5 percent to almost 20 percent of the total air leakage of the house.
- Unvented gas fireplaces were found in seven homes with air leakage rates below 0.35 NACH – considered by the American Gas Association to be "extremely tight" and needing "additional mechanical ventilation."
- Heating and cooling systems were oversized, and most ducts were sealed with temporary (duct) tape, not mastic.
- Homemade return ducts caused excessive duct leakage.
- Oversized cooling systems cost builders an average of $600 in unnecessary expenditures for excess capacity.
- When a gas furnace was located inside, usually in a hallway closet, it was typically not air-sealed and insulated from the conditioned space.

Selling performance

Following these guidelines will help you to build homes that are more energy-efficient, healthier to live in, and longer lasting with fewer callbacks. The higher quality and attention to detail can enhance your reputation as a quality builder.

Many energy-efficiency and performance-enhancing details are hidden from view after all of the finish work is done. On the surface, a poorly performing home can look just like a home that is performing very well. It's below the surface and many times those not-too-beautiful details that make all the difference. Homebuyers are becoming more aware of energy in their buying decisions. Since homebuyers are not always aware of these "hidden benefits," it is a good idea to point them out. One suggestion is to copy selected pages from this Tune-up and staple them together with a short cover letter that explains how "the following details were used in the construction of this home in order to make it perform to the best of its abilities." This will help to document how this home was carefully constructed, highlighting details only visible during construction, and will explain why this is a higher quality home.

About this Tune-up

A "tune-up" is typically associated with a used car. If a vehicle is new, tuning it up usually means that it is not yet ready for sale and something is wrong. The title of this publication, "Performance Tune-up," is meant to suggest that new construction is almost but not quite at a level of good performance – a little work still needs to be done. Homes are now being built with insulation and air leakage levels that have been greatly improved over past decades. However, the survey found several areas where improvements can be made

– some at very little expense – that will help homes perform to the best of their abilities (get the best mileage) and reduce callbacks (trips to the garage). In the recent past, increased levels of efficiency meant higher costs. Now, developments in technology and materials, as well as improved building techniques, allow builders to build a better home while containing costs.

The homebuyer's perception of cost effectiveness includes the utility-operating costs whereas the homebuilder's perception of that same economic decision focuses only on initial cost. No builder wants to price a home out of reach; however, there are economic trade-offs that can be made that will improve the comfort level and reduce the homebuyer's operating costs while maintaining a competitive total price. For instance, the survey found that an average of $600 was unnecessarily spent on oversized cooling systems. Had systems been properly sized and installed, these savings could have been re-invested in improved energy performance and product quality.

These homes are approximately the same price. One home passed the Energy Code (it was 10 percent above the Code) and the other one failed (it was 22 percent below Code). Can you tell which one is which? Find the answer and more on www.1-800-ARKANSAS.com/energy.

1. Slab insulation – Heat lost at the edge

Survey results of slab insulation

Only two out of 81 homes had effective slab insulation. Many homes in the northwest part of the state had foam installed under the slab; however, this placement did little to reduce the heat loss from the edge.

Slab insulation is cost-effective compared to other options. An uninsulated slab can account for one-fifth to almost one-half of a home's heat loss – the smaller the home the larger the fraction. Slab insulation can cut this loss from 25 percent to 40 percent.

Infrared picture of slab heat loss with insulation under slab.

The problems with slab insulation

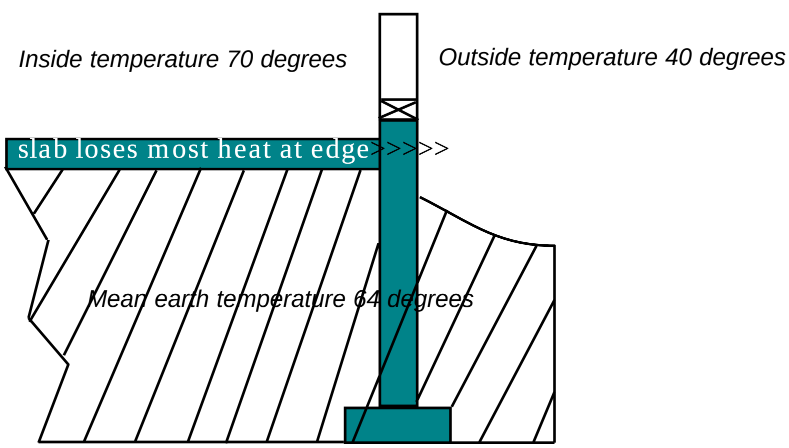
There are several challenges to effective slab insulation:

- Arkansas is in a "medium" termite infestation zone which means that slab insulation is not required. To compensate for no slab insulation, improvements need to be made by adding more insulation or specifying better windows.
- When placed under the slab, the insulation does little good.
- When placed on the exterior, the foam needs to be covered and protected from the sun and abrasion. For termite protection, the foam should not contact the bottom plate.
- When placed on the inside of a solid "L" block, the foam could interfere with the rug-nailing operation.

Slab insulation solutions

It is possible, and not too difficult, to install slab insulation correctly so that all concerns and issues are addressed:

- **The concrete company**: When the foam runs vertically from the top and down the inside of the foundation, it is completely out of the way of the foundation crew.
- **The pest control company**: By installing the foam within the slab, there is no access to the outside and therefore a reduced possibility of infestation. For added protection, foam insulation products are available and approved by the SBCCI that are impregnated with a termite-resistant chemical.
- **The framers**: If there are some foundation bolts to secure the wall, the framers will not even know that the slab is insulated.
- **The carpet installers:** The foam insulation is covered with wallboard and molding that allows the rug installer to securely nail the tack strip directly to the concrete.



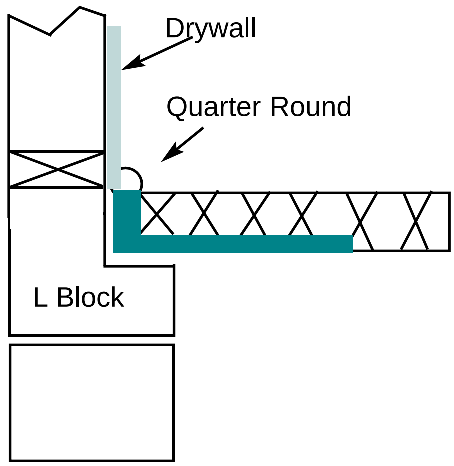
This graphic indicates where the majority of the heat flows through an uninsulated slab.

Slab insulation details

Not all slab construction techniques allow for easy inclusion of insulation. Hollow "L" blocks and monolithic slabs pose their own problems. Following is how one builder used solid "L" blocks to insulate the slab successfully and securely.

The critical top 4 inch piece of foam is placed against or nailed with 2 inch concrete nails to the solid "L" blocks.

The remaining 20 inch piece is pressed against it on the ground that is covered with plastic sheeting. Over this is placed the welded wire mesh. Note also that the placement of the foam around the edge acts to absorb slab expansion and contraction.



The exposed foam is covered with the edge of the drywall and baseboard molding. See Appendix E for other slab insulation options.

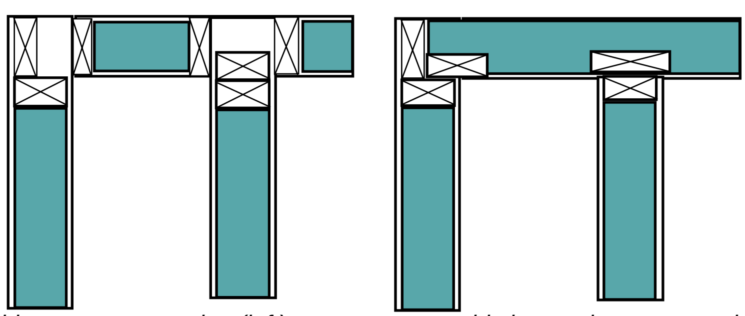
Suggestion: Keep the foam slightly below the surface of the slab at the thresholds to prevent the problem of having to dig out a little of the foam and patch the surface in preparation for the threshold.

2. Construction techniques – Walls: using less wood Ceiling: raising the rafters

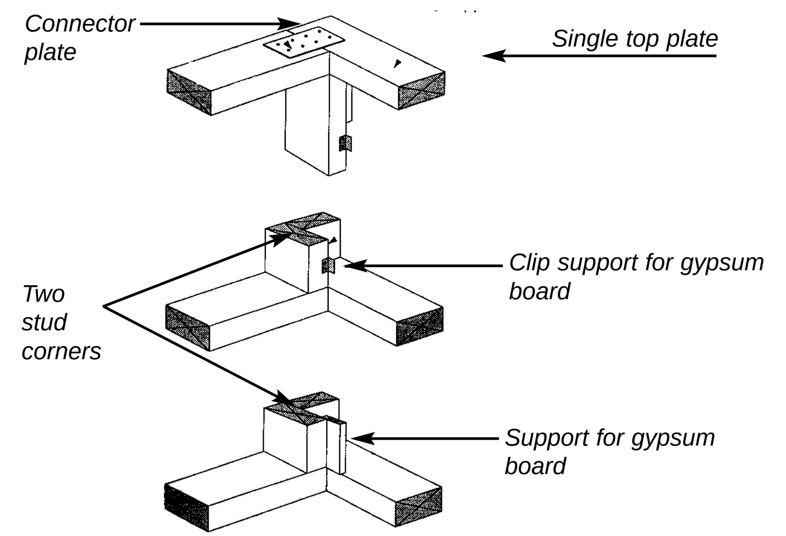
Framing techniques to reduce wood

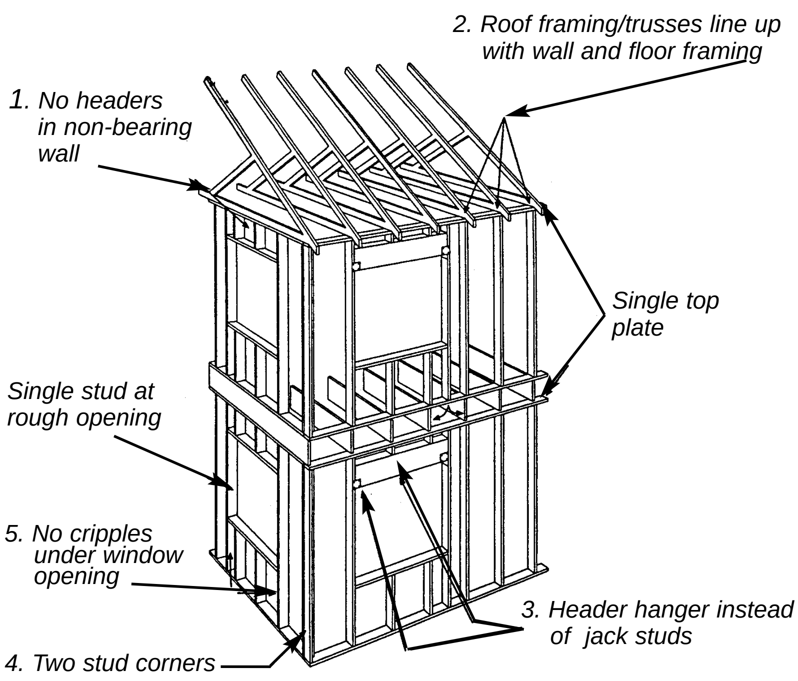
Almost one-fourth of a typical 2x4 wall is filled with wood, not insulation (Source: *Super Good Cents Builder's Field Guide)*. There are varieties of framing techniques that reduce the amount of wood in a wall. Wood transfers heat almost four times as fast as insulation; reducing the unnecessary wood in a wall allows for more insulation and reduces construction costs.

1. Headers are not necessary in non-load bearing interior and exterior walls – just make sure that there is absolutely no load being transferred to the header area.
2. When roof framing lines up with wall and floor framing, double headers are not necessary. Check first with your local building official.
3. Rigid foam should be used to insulate behind or between exterior headers.
4. Three stud corners are not necessary to support wall-board.
5. Windows are typically hung; therefore, cripples under window framing are not structurally necessary.
6. 2 x 6 construction at 24 inches on center reduces wood.



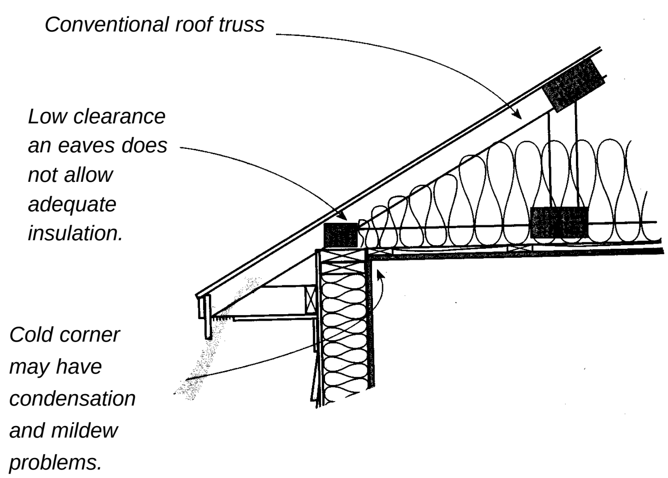
Old corner construction (left) creates many voids in exterior corner and partition walls. This can also cause moisture and mildew to develop. The right detail uses less lumber, is easier to frame and allows for more insulation.


Connector plate
Single top plate
Two stud corners
Clip support for gypsum board
Support for gypsum board


2. Roof framing/trusses line up with wall and floor framing
1. No headers in non-bearing wall
Single top plate
Single stud at rough opening
5. No cripples under window opening
3. Header hanger instead of jack studs
4. Two stud corners

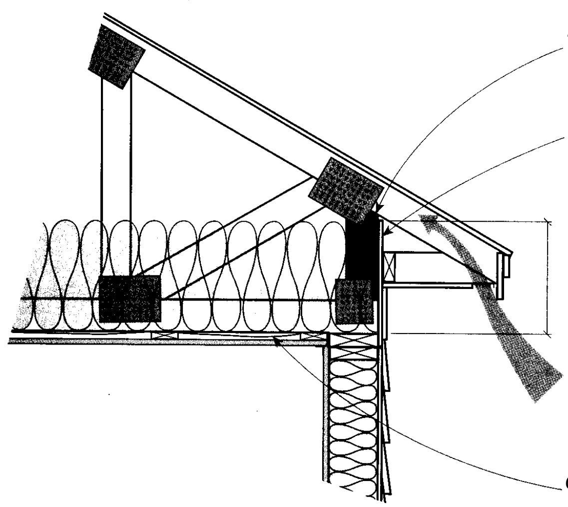
Roof truss framing techniques

Getting full insulation coverage over the entire ceiling is difficult when ceiling trusses are not designed to allow the insulation to maintain its desired thickness all the way to the wall. Note that all of these examples have soffit vents. What is not shown here is the continuous ridge vent that allows the attic air to gently escape.



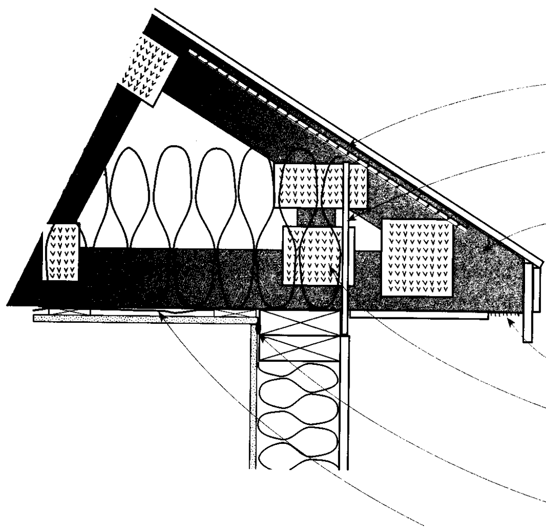
Ceiling insulation level is reduced by as much as 7 percent, and the air passing through the soffit vents is restricted.

With the "raised-heel truss" or "energy truss," the ceiling's insulation can maintain its full thickness all the way to the wall.

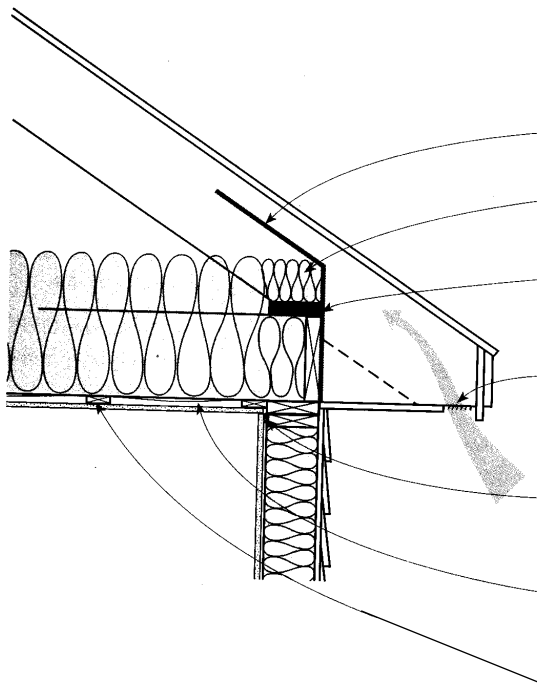


At one time, this truss design used to be a part of what was called "The Arkansas Story." It is still a good idea.

Here are two more examples of trusses that allow full insulation coverage.



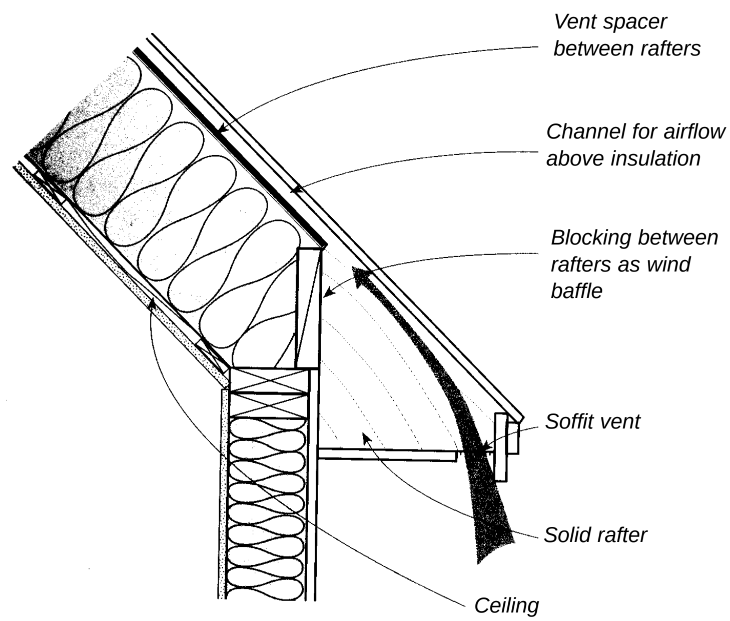
This cantilevered, oversized truss provides full-thickness of insulation plus 2 inches for ventilation.



This is a raised rafter plate. Rafter "bird-mouths" can sometimes be set on a raised rafter plate that is on top of the ceiling joists, instead of on the top plate of the wall.

Cathedral ceilings

Insulating and venting cathedral ceilings is a challenge. If the insulation thickness is less than the thickness of the rafters, the space above the insulation forms an air channel for ventilation. Higher density insulation can be used, such as an R-30 batt that is only 8 inches thick. However, if the fibrous insulation is thicker than the rafters, it is important to install continuous vent spacers under the roof sheathing.



The survey found one truss construction that was raised a little – just not far enough. The 2x4 (above) that is on its side, on top of the bottom member of the truss, raises the edge level for attic insulation only 1 1/2 inches. The truss should be raised enough to allow the insulation to maintain full thickness out to the exterior walls.

3. Windows – Frames, coatings, orientation and overhangs

Survey results of windows

Today's builders are all selecting double-pane windows. In most cases the survey found that the selection of solid aluminum-frame windows, which have no thermal break, was the reason that homes failed to meet the Energy Code (**See Appendix B**). Vinyl-frame windows are becoming cost-effective and provide a greater level of comfort because the frames are close to the inside temperature. Solid aluminum frames transfer the outside temperature inside.

There are several important considerations in the design and product selection of windows:

- **Window area** – A larger window area decreases the wall area and reduces the overall efficiency of the wall. About one-quarter of homes in the survey had window areas equal to or greater than 15 percent of the gross wall area.
- **Window frame type** – Thermal-break and vinyl windows are better at reducing heat transfer. Their frames also reduce window condensation and sweating. They feel more comfortable because of their higher radiant temperature.
- **Glass** – Special coating films (low-e and "summer low-e"), inert gas fillings, and the width of the gap between the panes all contribute to a window's efficiency. See **Appendix D** for descriptions of window technologies.
- **Window orientation** – Attention to orientation, combined with a good overhang, can reduce summer overheating and lower winter heating costs. **See page 27**.
- **Overhangs** – Properly sized overhangs reduce summer sunshine through south-facing windows. **Pages 28 and 29** give instruction on sizing overhangs in Arkansas.

This house shows an example of poor window orientation and a good overhang.

- The front of the home faces west, and there are several windows on the second floor that allow the summer sun to overheat the top floor. The selection of "summer low-e" windows would have reduced the overheating.
- The overhang above the entry shades the bottom floor's windows from the harsh summer sun.

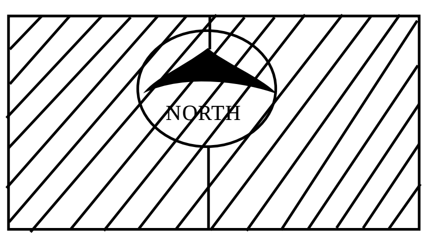
Suggested window options for Arkansas

- To compensate for a large window area, use higher efficiency windows. Look for the National Forestration Rating Council label and try to get a U-Value of 0.56 or lower. If no NFRC label is present, use the default U-Values in Appendix D. Higher efficiency, more expensive windows have inert gas fillings; however, the extra expense for these might not be justifiable in our mild winter climate.
- Select vinyl-frame windows. Thermal-break, aluminum windows are better than solid aluminum frames, but vinyl-frame windows are now cost competitive and are much better at reducing heat loss.
- If possible, design the window areas based on orientation. Reduce the east-facing and especially the west-facing window areas as much as possible to cut down on summer overheating. Maximize the south-facing window area to reduce winter heating costs and build an overhang above these windows to reduce summertime overheating.
- Unobstructed east-facing and especially west-facing windows allow the sun to overheat a home. Windows that reduce the solar heat gain (summer low-e or "spectrally selective") reduce the air conditioning load. Look for the NFRC label and check that the Solar Heat Gain Coefficient (SHGC) is 0.55 or less.
- Use regular (winter) low-e on north- and south-facing windows for increased levels of wintertime performance.
- Skylights add both heating and cooling costs. Their construction typically increases the area of the ceiling with hard-to-insulate vertical areas, and they provide opportunities for air and water leakage.

Designing window areas to reduce energy use

The survey found that the average window area was about 15 percent of the gross wall area or 12 percent of the floor area. Many homes failed Code due to a larger than average window area **(see Appendix B)**. When designing a building, do a quick calculation of the percentage of window in the gross wall. If this number is 15 percent or greater, and no reduction in window area is possible, then either extra insulation or higher quality windows will be needed to reduce the impact of the excessive window area. A small window area does not guarantee an overall good energy performance, but it makes it easier.

To calculate the percentage of window area in the wall:
1) Gross wall area = perimeter length x wall height
2) Percent window = total window area ÷ gross wall area
For example, if the perimeter length is 180 feet and the wall height is 9 feet, the gross wall area is 180 x 9 = 1620 square feet.
If the total window area is 240 square feet, the percent of window in the gross wall is 240 ÷ 1620 = 0.148 or 15 percent.



Window orientation is critical to comfort and operating cost.

Overhangs on south-facing windows

In the winter, south-facing windows reduce heating costs. If these windows have even a small overhang to reduce summertime overheating, they can admit the low-angled winter sun to reduce heating costs and then shade the high-angled summer sun to reduce the load on the air conditioner. The shading of the sun is based not only on the overhang length (see graphic on right) but the distance of the overhang to the bottom of the window (height).

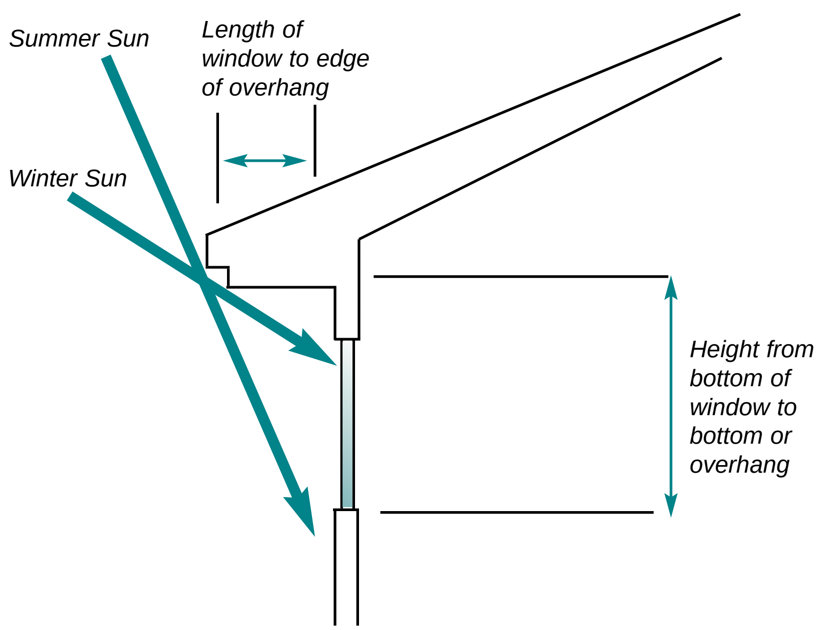
The graphic to the right gives the information needed to design an overhang that will reduce the summertime sunlight and allow the entry of the beneficial wintertime sun. There is an easy-to-follow rule for overhangs: **Length = Height ÷ F** where "F" is a factor based on our north latitude. There are two options presented here: the first provides full shade in the middle of summer (**F-mid summer is June 21**), and the second provides full shade for the full summer (**F-full summer is from May 5 to August 1**).

Here's an example of how this works. If a home is being built in Fayetteville and it was desirable to shade the window the entire summer season, use the "F-full summer" for the north Arkansas region, which is 3.0. If the height from the bottom of the window to the bottom of the overhang is 72 inches, the length of the overhang is Length = 72 ÷ 3.0 = 24 inches.

Latitude	Arkansas Region	Cities	F-mid Summer	F-full Summer
33°	South	Texarkana El Dorado	5.85	3.75
34°	Central	Little Rock Pine Bluff	5.40	3.50
35°	North Central	Ft. Smith Conway	4.95	3.25
36°	North	Fayetteville Jonesboro	4.50	3.00

Length = Height / "F"

Source: Edward Mazria, *The Solar Home Book*



4. Air leakage – The many small gaps and cracks

Air-leakage rates found in survey

All homes leak air through tiny or large holes and cracks. In the past, this accidental leakage was a way to remove stale air and allow the entry of fresh air. Current best building practice is to "build it tight and ventilate right." Reducing air leakage is more important in our hot, humid climate than it is in drier climates.

Home air leakage is commonly referred to as the number of times a home's air is completely replaced in an hour. A blower door was used to measure air-leakage rates that ranged from 0.2 to 0.6 Natural Air Changes per Hour (NACH). An evaluation of homes tested by Energy Rated Homes of Arkansas indicated that, in the not too distant past, new Arkansas homes were experiencing an average of 0.5 NACH. This recent evaluation of Arkansas' homes indicated that the average is getting lower and homes are now getting close to 0.35 NACH. This is quite good and should not be a source of alarm. It takes extra work to go below this level when odors and moisture might become a problem if there is inadequate ventilation. Above this level, homeowners will feel less comfortable and their utility bills will increase.

The "blower door" tries to pull all of the air out of a home, forcing the house to suck in air through all the leaks in the house and ductwork. These leaks can then be located and sealed.

Sealing bypasses

A "bypass" is any small or large hole that is not always obvious. These leakage sites should be sealed before they are insulated. In fact, the insulation and air sealing should be done on the same surface. In other words, avoid air sealing on one surface and then insulating on a nearby but separate surface. Here are several areas that contribute to air leakage:

- Around fireplaces – whether on an exterior wall or inside the building, define the area surrounding the fireplace as either inside the conditioned area or outside, then seal and insulate accordingly.
- Behind bathtubs – air seal and insulate before installing

Caulk or foam and seal the following locations:

- Edges of floor trusses that connect to the attic or outside
- Around flues for furnaces
- Around chases for plumbing and utilities
- Around headers above windows and doors
- Around and behind dropped soffits for cabinets
- Around dropped ceilings in closets
- Around the attic access hatch or pull-down stairs
- Around rim joists in homes that have more than one story
- Where recessed lights attach to the ceiling
- At every wire, pipe or vent penetration
- Around complex walls, wall-ceiling junctions, dormers, etc.

Air-leakage sources and solutions

Air will enter and exit through the smallest of cracks and it will take unexpected pathways. During the construction process there are many opportunities to reduce unwanted air leakage:

- **The bottom plate** – Where a wooden bottom plate meets a concrete slab floor is a major leakage area. The slab and the wood shift during the curing and aging process. For this reason, products commonly referred to as "nail in a tube" do not do a permanent job of sealing the bottom plate. This product is an adhesive compound and not a permanent air seal because it does not flex with movement of the wall and slab. Running a bead of caulk between the bottom plate and the floor seals this intersection for a while; however, when the concrete expands and contracts this seal could be broken and air leakage can increase.

  A special sill-sealing product that is made for this purpose can be used where the wall meets any type of floor. The easiest installation technique is to place the sill seal around the perimeter and push it over the wall's foundation bolts. Then, when the wall is placed over the bolts, it smashes the sill-sealing product, and the bottom plate is sealed.
- **The top plate** – All holes that are made in the top plate (electrical, plumbing, etc.) should be caulked or foamed. This not only reduces the air leakage, it keeps unwanted pests from entering.

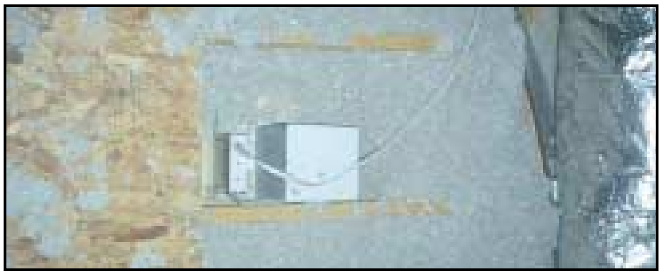
- **Interior walls** – Not only exterior walls need attention but inside walls as well. It is important to treat the top plates of interior walls the same as exterior walls and to caulk or foam all holes. Plumbing is especially suited for interior walls because it reduces the freezing problem. Caulk the gap between the sheetrock and subfloor prior to installing the quarter round – the quarter round by itself does not seal air leakage.

Seal areas between wood and concrete with foam sill seal.

Foam all penetrations in the top plates.

Evidence of a leaky interior wall.

- **Recessed lights –** Newer recessed lights are air-tight (AT) and have the ability to be in contact with the insulation ("IC" = Insulation Contact). Caulk the junction between the light and the ceiling's drywall.
- **Heating and cooling system –** Seal all HVAC penetrations such as refrigerant lines. Also seal all supply and return grill penetrations and thermostat wire holes.
- **Plumbing –** Before the drywall is applied, caulk or foam all plumbing penetrations. The drains and water inlet pipes under sinks are typical leakage locations. After the wallboard has been installed, fill the gap between the drain or pipe and the wallboard with caulk or foam.
- **Dryer exhaust, gas pipe and refrigerator water –** All penetrations are potential air leakage areas. The trim plate for the refrigerator water line needs to be caulked around its edges and firmly set in place to be airtight.
- **Fireplaces –** **See page 36 and 37.**
- **Windows and doors –** Most new windows and doors are reasonably air tight. Look carefully at field-installed weather-stripping and thresholds for light that comes through the cracks; where there's light, there's air leakage. Use non- or minimum-expanding foam to seal around windows and doors without doing any damage to these sensitive areas.
- **Outlets –** Electrical outlets and switch plates all leak a little; however, the air that passes through these comes from openings such as the top plate and other exterior wall penetrations. Take care of the basic air sealing, and outlet gaskets will not be needed.
- **Floor joists –** Cantilevered floors, as well as the joist cavities between floors, can let outside or attic air enter. Place pieces of exterior sheathing between these joists and seal with caulk. **See Page 45**.



These recessed lights were IC rated but the insulation contractor was not notified.

This is an excellent example of a finished dryer vent and water shut-off valve.

Before the ceiling is insulated, caulk around all holes that that were made through the sheetrock.

Fireplaces and air leakage

Of the 100 homes surveyed, 33 had no fireplace of any type. Of the 57 with a fireplace, 54 were vented gas, 11 were unvented gas and two burned wood. About one-third of the vented fireplaces were somewhat tight: they measured less than 5 percent of the home's total air leakage. Some fireplaces contributed as much as 20 percent of the home's total air leakage.

The flu damper was shut before this fireplace was covered for the air leakage test. Note the effects of the blower door's pressure on this cover from the outside air that is leaking through the damper.

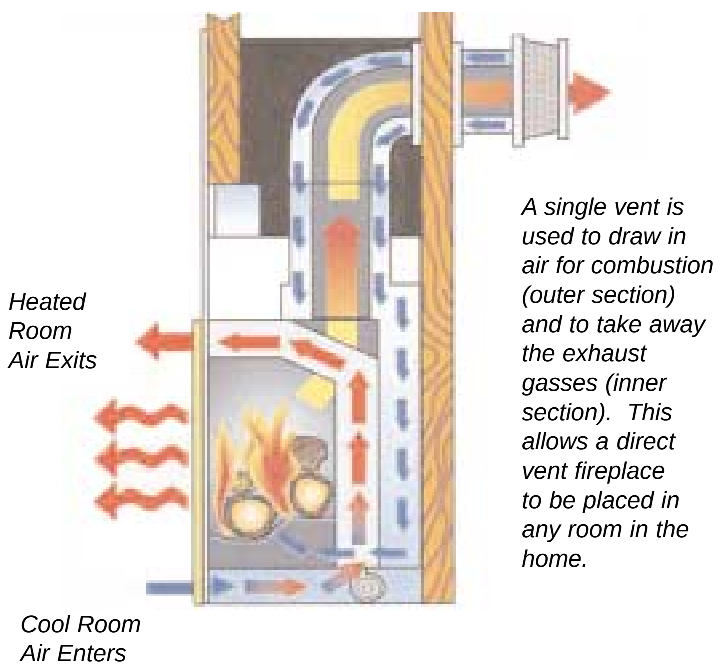
Selection of fireplace covers to reduce air leakage

Work with the homebuyer to purchase and install a glass fireplace cover that prevents unwanted air leakage. A vented fireplace burning gas or wood is essentially a hole in the ceiling through which a damper slows down, but does not seal off, the escape of conditioned air. Glass covers are typically designed to prevent sparks from jumping out of the fire. These covers do little to reduce the conditioned air that is always escaping up the stack. Builders are encouraged to work with the homebuyer to select and install an effective fireplace cover that fits their decor and reduces air leakage.

Sealed combustion fireplaces

When typical "open combustion" fireplaces are installed in a tight home, there could be a drafting problem, especially when kitchen and bathroom exhaust fans are in operation. Also fireplaces that have "outside air for combustion" have dampers that are not air-tight. These allow outside air to enter and inside air to exit when the fireplace is not in operation.

The benefits of a sealed combustion fireplace pay back whether the fireplace is burning or not. When in operation, only outside air is used for combustion. When not in operation, the unit does not leak conditioned air up the flue.



5a. Ceiling insulation – Is it all there? I paid for it!

Survey results of ceiling insulation

The majority of ceilings were insulated as per specifications. There were a few problems noted: the insulation certification was not present in almost all homes, and 17 percent of ceilings were under-insulated. Also many "complicated" ceilings with vertical and steeply sloped areas were under-insulated. Going above the minimum for ceiling insulation in your climate zone (use Arkansas Energy Code Simplified Zonal Options) is hard to justify on a cost-effective basis; however, it is important to check that the insulation level is measured and is consistent throughout the ceiling.

Steps to a better-performing ceiling

1. Air seal before insulating. Ceiling insulation does not seal air leaks. Seal around all holes made for lights, boots, etc. For recessed lights use AT/IC (**see page 34**).
2. Ask the insulation company for the expected minimum thickness for their product at your requested R-Value. Place markers, such as reflective tape, on strategic locations at that thickness level to assist with installation and inspection.

   About 17 percent of the ceilings in the study were under-insulated – the majority of these measured only R-26. Many attics had an uneven distribution with a decreasing thickness at the extremes. See typical insulation values on **page 93** and "Insulation certification" on **page 41**.
3. Check the work for consistency (same minimum thickness throughout), missing spots, holes, blocked soffit vents, and accidental insulation blown into vent ducts.

Sealed with caulk

An unsealed light wiring box

Uneven distribution

Measuring marker

Hole in ceiling exposes many walls to attic temperature.

Missing knee wall insulation. Check the work.

Batt insulation with exposed joists

Few ceilings are insulated with batts because this is a more expensive option. When batts are used, it is important to pay attention to the exposed joists that transfer heat three to six times as fast as the insulation. Suggestion: Use two sets of R-19 batts. The first R-19 batt goes between the joists; the second R-19 covers the joists by being placed perpendicular to them. In our hot-humid climate, unfaced insulation (not faced with a vapor diffusion retarder) is recommended for the attic.

Attic-framing techniques

There are a variety of energy-efficient ceiling and roof framing techniques that allow for the full thickness of ceiling insulation to go all the way to the walls while allowing for soffit ventilation. **See pages 18-22** for several examples of truss designs for regular ceilings and one example of a cathedral ceiling framing technique.

Soffit-vent baffles

When soffit vents are installed, baffles should be placed around the perimeter to prevent the insulation from blocking the soffit vents and to prevent the wind from blowing on the insulation.

Insulation certification

The Federal Trade Commission (FTC Rule 460) requires that insulation contractors sign and prominently place an insulation certificate in the attic that documents what material was used, the name of the insulation company, and the minimum thickness, R-Value and density of the applied product. This certificate is typically printed on a piece of 8 inch x 11 inch card stock and should be stapled in the attic in such a way that is easily visible from the attic hatch. This certificate was only found in about three out of 100 homes. Do not accept a "bag count," a copy of the bag's specifications or a home-made "certificate." The "bag count" is only a rough "rule of thumb" to help the installer load up the truck for a particular job. This is not any guarantee of adequate and consistent minimum thickness.

Attic ventilation

Attics without a ceiling vapor barrier should be ventilated with 1 square foot of net free vent area for each 150 square feet of ceiling. **See page 46** for estimating net free areas of various screens and louvers.

- **Gable vents** – 1 square foot of gable vent for each 150 square feet of ceiling. Half of the total gable vent area is installed in each gable end. Gable vents rely on cross winds as the driving force, and in the summer, the wind is not always blowing.
- **Continuous ridge vent and soffit vents** – One-half square foot of ridge vent and one-half square foot of soffit vent for each 150 square feet of ceiling. This combination is more effective than gable vents because the naturally rising hot air is the force that draws in cooler air, and it does not rely on the wind. The best ridge vents have external baffles that prevent the wind from interfering with the escape of hot air. When soffit vents are installed, baffles should be placed around the perimeter to prevent the insulation from blocking the soffit vents and to prevent the wind from blowing on the insulation.
- **Turbine vents** – When enough replacement air is provided through soffit vents, turbines can allow hot attic air to escape even though the summer wind is not blowing. Gable vents should not be combined with turbine vents because this combination does not allow enough circulation.
- **Power vents** – These devices are not recommended because because they consume more energy than they save. They can remove conditioned air from the home through ceiling leaks and bypasses, pull pollutants from the crawlspace into a home, and cause exhaust gases from fireplaces and combustion appliances to enter a home. (Source: U. S. Department of Energy)

*Use information on **page 46** to estimate the net free area of various soffit vent products.*

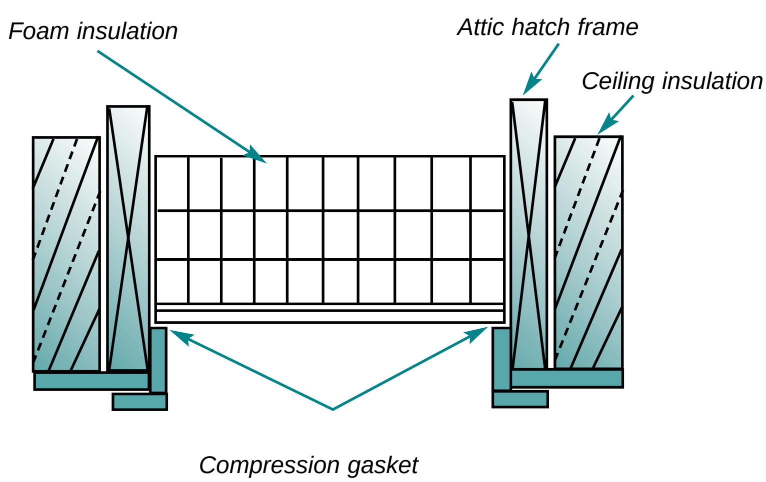
A continuous ridge vent should be matched with continuous soffit vents.

A turbine vent waits for the wind to blow during the hot summer

Attic hatch

The survey found that when an attic hatch was located inside the home, it was not insulated or sealed. It doesn't take much to reduce the overall ceiling R-Value. For instance, if a 2,000 square foot R-30 ceiling has an uninsulated 6 square foot attic hatch, then the overall R-Value is reduced about 8 percent to R-27.6 for that 0.3 percent uninsulated hatch area.

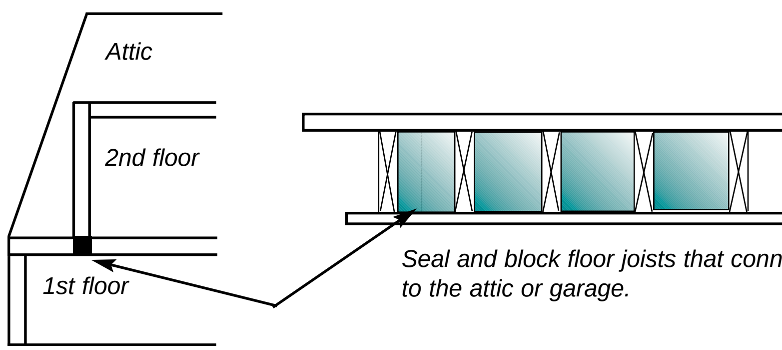
The attic hatch should also be carefully weather-stripped to reduce air leakage and to prevent dust and ceiling insulation from entering the conditioned space. An insulated and air-sealed attic hatch can be built in about 15 minutes using scrap plywood, weather-stripping, a 6-inch thick block of Styrofoam, and some wood veneer. Build a channel for the attic hatch with some wood framing that will prevent the ceiling insulation from falling into the living space. Glue the Styrofoam to the hatch cover, and then attach a good compression gasket (weather-stripped to the wood veneer. (Source: *Energy Design Update*, June 2001)



Block exposed floor joists

When the ceiling of the first floor of a 1 1/2 story home is also the floor of the room above it, the ceiling's joists are typically connected to the attic area. Keep the attic air from this floor/ceiling area by blocking off and air-sealing these joists with some insulated sheathing. Then the attic insulation can be installed against the blocking.

A similar problem occurs when a room is directly above a garage. The ceiling of the garage is the floor of the room above it; however, the joists between these two rooms are typically connected to the attic, and the insulation is typically found resting on the garage's ceiling. These joists also need to be blocked, air-sealed and insulated.



Seal and block floor joists that connect to the attic or garage.

Joist cavity is blocked and sealed to prevent attic or outside air from entering between floors.

Calculating net free area

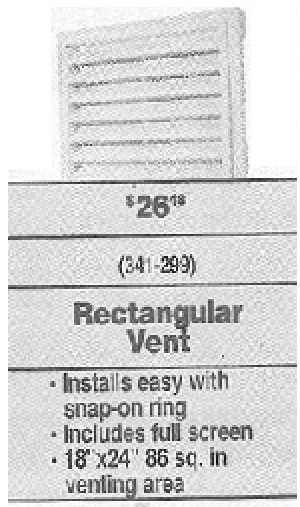
Ventilation area is defined as a "net free area." This is the unobstructed area through which air can freely pass. Here is how to determine if enough net free area is being considered for adequate ventilation:

> Example: Say a roof area is 1,000 square feet, and louvered and screened attic vents are being used to ventilate the attic. One square foot of net free vent area is needed for each 150 square feet of roof. Therefore, 1,000 ÷ 150 = 6.67 square feet of net free vent area is needed. Using the formula below for louvered and screened attic vents, 6.67 ÷ 0.44 = 15 square feet of this vent type is needed to deliver 6.67 square feet of net free area.

Louvered & screened attic vents: NFA ÷ 0.44 = Area
Roof ventilators: NFA ÷ 0.66 = diameter
Soffit louvers: NFA ÷ 0.37 = Area
Continuous soffit strips:

- Parallel slots: NFA ÷ 0.25 = Area
- Closely punched holes: NFA ÷ 0.3 = Area
- 1/4" hardware cloth & louvers: NFA ÷ 0.5 = Area
- 1/8" mesh screen: NFA ÷ 0.8 = Area
- 1/8" mesh plus louvers: NFA ÷ 0.44 = Area
- 1/16" mesh screen: NFA ÷ 0.5 = Area
- 1/16" mesh screen plus louvers: NFA ÷ 0.33 = Area

Two gable vents are probably not enough



Example: An advertisement for gable vents indicates that one particular model has 86 square inches of venting area for each vent (the size of the vent itself is 18 inches by 24 inches). In that same 1,000 square foot attic example, 6.67 square feet of venting area is needed, which is 6.67 x 144 = 960 square inches of venting area. 960 square inches ÷ 86 square inches per vent = 11 vents. Therefore, a total of 10 to 12 of these vents (5 or 6 on each side) would be needed to adequately ventilate the attic with only gable vents.

If, however, gable vents are used in combination with continuous soffit vents, half of that area (six gable vents) could work if an equal net free area is installed for the soffit vents. Attic ventilation works by taking advantage of the hot air that is rising in the attic. An inadequate ventilation area easily restricts this low-pressure force.

5b. Wall insulation – Seal it, pack it and wrap it

Survey results of walls

The survey found that all cavities in exterior walls were insulated; however, the types of insulation ranged from glass fiber to cellulose to a special foam. The performance of any product is mostly a function of careful installation. Even though insulation is not typically credited with reducing air leakage, half of the homes insulated with glass fiber products had air-change rates higher than the highest air-change rate found in the homes insulated with cellulose.

Steps to a better-performing wall

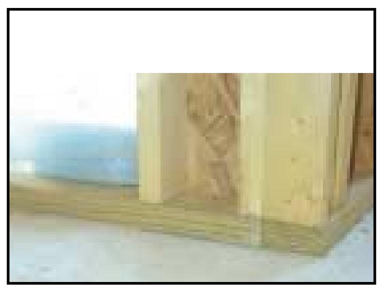
Since the wall is typically the largest element in a home, attention to the details of construction will help to make the walls energy-efficient, water-resistant, and long-lasting.

1. Use framing techniques that reduce the amount of wood in the wall. Wood is a poor insulator and it displaces the insulation in the wall.
2. Air seal before insulating. Insulation, unless it is an expensive foam product, does not air seal. It is important to seal all holes made through the exterior sheathing, the top plate, and any other hole that allows outside or attic air to enter the wall's cavity.
3. Install the insulation carefully. To be effective, insulation must be installed so that the movement of air will not reduce its effectiveness.
4. Use a good housewrap product (one without visible holes) and install it in such a way that it sheds water, prevents wind from blowing in and allows water vapor to exit.

Framing the wall

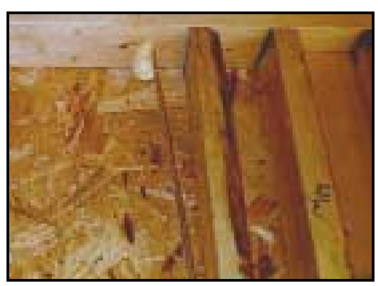
Exposed foam will be covered with drywall and molding

A leaking bottom plate



Sealing bottom plate with foam sill-sealing product

Wiring penetration in top plate is open to attic.



Penetration is sealed with foam caulk.

Installing insulation carefully

Step 1: Air seal all wall penetrations. Step 2: Insulate by completely filling all voids – edge to edge and top to bottom.

Faced insulation has a vapor barrier "face" attached to the insulation. Tabs on either side of the facing are used to staple the insulation in place. To allow the insulation to expand to its proper thickness, these tabs should be stapled to the outer "face" and not on the inner sides (inset) of the studs. Even though the manufacturers say that if properly installed, both face and inset stapling methods are "acceptable," research has shown and many professionals recommend face stapling because it allows a full expansion of the insulation and reduces the air currents that carry away the heat. Some drywall contractors have not had experience with this technique, but if faced batts are to be used, this is the best way to install them.

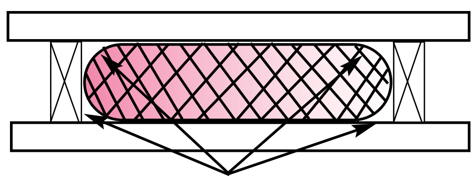
Stapling the tabs on the inside of the studs reduces the effectiveness of the insulation for two reasons: 1) it compresses the insulation, which reduces its R-Value; and 2) it allows air to easily move, thus actively transferring the heat.

The combined effect of compressed insulation and air circulation can reduce the effective insulating value of an R-13 batt to a value below R-10.

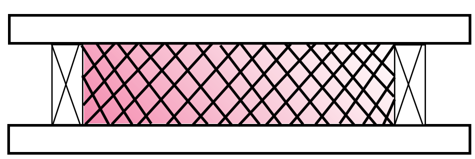
Because some drywall contractors have difficulties with face stapling, there are two alternatives that can be used:

1. Inset staple not only the sides but also the top and bottom. Cut the insulation 2 inches longer than the stud space, then fold back 1 inch at the top and bottom, and staple as flanges. The air in the pocket that is created with this inset is now trapped, and the insulation value of the dead air pocket almost offsets the compression of the insulation.
2. Use unfaced insulation. These wider batts rely on friction-fit for support. Since they are not stapled, they can often be installed in less time. Also, it is easier to cut unfaced batts to fit around wiring, plumbing and other obstructions in the walls

Neither unfaced insulation batts nor loose-fill products provide a vapor retarder. Use a vapor retarder drywall primer and sealer with a perm rating lower than one to reduce moisture diffusion through the interior finish materials.



Air Pockets
Inset stapling can create many air pockets



Unfaced batts can more easily fill the cavity

Wrapping insulation around boxes and wiring

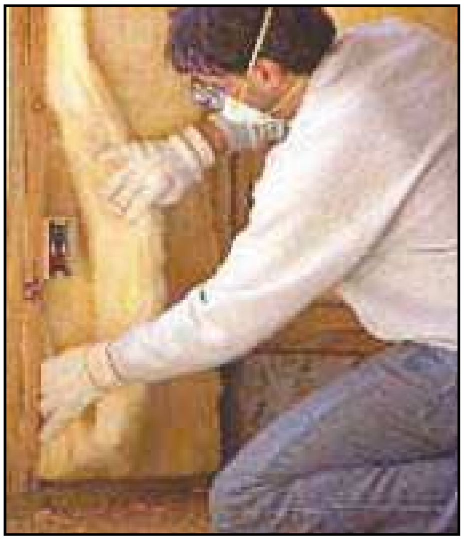
Install fibrous insulation around pipes and electrical outlets and panels. Fill all of the space with insulation. Rip the insulation apart to allow some to go behind and some in front of the obstacles. Cut out the insulation around plumbing and electrical outlets, and stuff the insulation behind if any space is available.

Drying before closure

It is important that the framing of a building has dried out as much as possible before the insulation and finishing are done. A propane heater releases excess moisture that interferes with the drying process. Suggestion: hook up a temporary heating system that will really dry out the house. Do not use the home's new heating system because this will introduce dust and construction debris into the ducts and permanently damage the heat exchanger or coils.

If wet-blown cellulose has been installed in the walls, it needs to dry to manufacturer's specifications prior to closure. Typical drying times are 24 to 48 hours depending on the weather. If the temperature is 40°F or below, it may be necessary to use supplemental heat until the moisture content is 25 percent or less. (Source: Cellulose Insulation Manufacturers Association) Cellulose dries to about the same water content as kiln-dried wood – 10 to 15 percent moisture. If it feels dry to the touch, it is ready for the dry-wall. Any remaining moisture will dry to the outside.

Compressed insulation not only loses its R-Value, but it also creates an open void where circulating air can further reduce the thermal effectiveness of the wall.



Pull the insulation apart and place some behind switch boxes and cut openings for outlet boxes. Note the use of unfaced batts. Note also protective mask, goggles, gloves and long sleeves help to protect worker during installation.

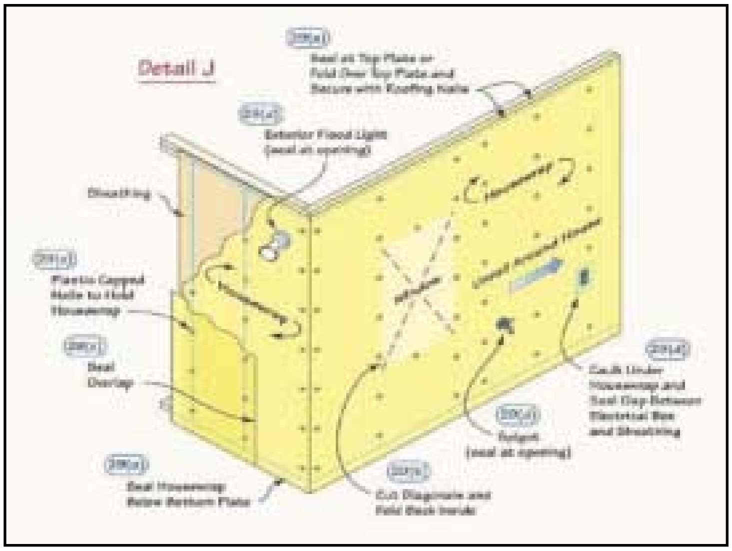
Housewrap installation

The survey found that almost all homes had a housewrap product on the exterior walls; however, the installation was poorly done in every case. There are three reasons for using a good exterior housewrap: 1) to direct the flow of any surface water on the housewrap to the outside; 2) to reduce incoming air from leaking into the house; and 3) to allow interior water vapor to pass through the walls.

Not all housewraps are the same. The best is made with microscopic pores that are large enough for water vapor to pass through, yet small enough to resist air and liquid water penetration. Products that look like housewrap but attempt to do these same functions with many small pinholes do not do a good job of reducing air leakage, and liquid water is also allowed to pass through. Hold a piece of housewrap up to the light; if many small pinholes are visible, the material will not do a good job protecting the wall.

Improper housewrap installation allows the entry of water into the wall. Many vinyl-sided homes have experienced water leakage, and improperly installed housewrap is usually the culprit. (Source: Spiderman's & ITA Systems, a Florida company that conducts building water leakage investigations) Install housewrap over exterior sheathing and under foam board. Think of housewrap as flashing or shingles – start at the lowest level and overlap the layers above it. Tape all holes, tears and punctures. Use large head or, for optimum protection, plastic washer-head nails. If staples are used, make sure that they are wide with a 1-inch minimum crown to prevent the housewrap from tearing away from a smaller staple head.

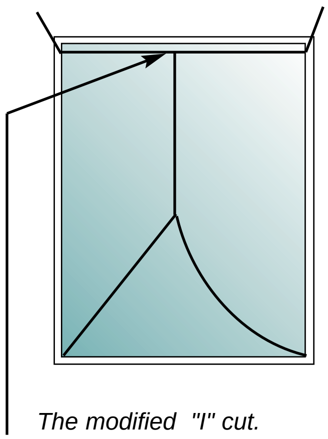
The detail shown at top right (source: U. S. Department of Energy) shows information about the many areas where housewrap needs to be overlapped, caulked and sealed.



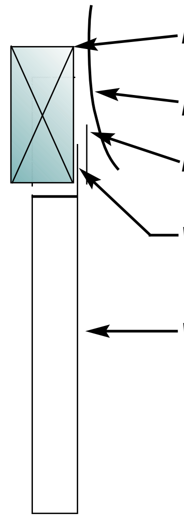
Note that this has the commonly used "X" cut for window installation. Cutting an "X" in the wrap and placing the window over the wrap (below) can direct water into the back side of the window assembly and into the wall. It is important to put the window flange and head flashing under the housewrap. This directs any water coming down the face of the wrap over the window instead of under the flashing and into the wall.

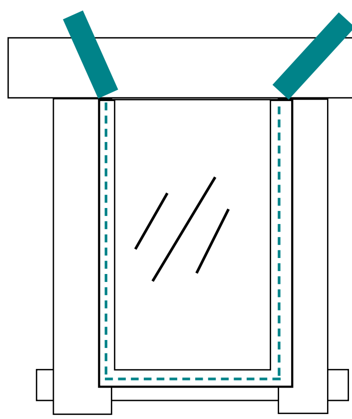
DuPont has a comprehensive Weatherization System. These are their latest installation instructions:

1. Unroll housewrap starting at corner leaving a 6-inch to12-inch overlap. Line up printed stud marks with first stud.
2. Start at bottom and check for plumb. Edge of bottom roll should extend over sill plate at least 2 to 3 inches. For best air leakage reduction, seal wrap with caulk or tape.
3. Secure housewrap every 12 to 18 inches on vertical stud line with large head or plastic washer head nails. Wide staples with 1-inch minimum crown can also be used. When attaching wrap to masonry, use adhesives with polyurethane, elastomeric or latex base.
4. Unroll directly over windows and doors. Overlap upper rolls 6 inches over bottom rolls. Attach housewrap up to and covering the top plate.
5. Create a continuous membrane by overlapping and taping all seams, as well as band joists and headers. Tape overlaps with 2- or 3-inch DuPont contractor tape or equivalent. Tape accidental tears or damage.
6. Make a modified "I" cut (right) in housewrap.
7. Fold flaps inside around openings of windows and doors. Fasten every 6 inches and trim excess.
8. Tack up bottom sill flashing overlapping rough sill by 4 to 5 inches. Best practice: make two vertical corner cuts in the flashing and fold flashing inside over rough sill.
9. Tack up side flashings overlapping bottom sill flashing. Install window or door, according to manufacturer's instructions, over side and bottom flashing. Make sure that the top window flange is attached under the house wrap.
10. Cut two 45-degree angles upward from each top window corner. Install head flashing UNDER top flap of house wrap and OVER window flange. Head flashing should extend out over side flashings by 3 to 4 inches. Fold top flap of housewrap OVER head flashing. Tape both diagonal cuts.



The modified "I" cut. Top cut is at rough opening.





This detail shows the two taped-over 45-degree cuts in the housewrap, as well as the top flashing that is extended over the side flashings. The top flap of the housewrap is lifted for the window flange and flashing and then folded over and taped on top of them

Drywall as part of the air sealing package

Air sealing is not a vapor barrier – they are two different issues. The best and most economical approach to building a tight home is to use the drywall as a part of the air-sealing package. The prevailing wisdom is to "build it tight and ventilate right." Junctions or connections in a wall are the most critical locations for air leakage:

- Where the wall meets the windows and doors
- Where the wall meets the roof
- Where the wall meets the floor or foundation
- Where the wall or ceiling meets the supply and return vents
- Where there are penetrations for dryer vents, refrigerator water, plumbing, electrical and gas lines.

Polyethylene vapor retarders

Polyethylene vapor retarders can be a serious problem in Arkansas' humid climate as homes become tighter and ventilation is inadequate. In northern, cold climates, the "warm side of the wall" is always on the inside, and a vapor barrier on the inside of the wall helps to reduce the flow of moisture laden air which can condense as it reaches the cold exterior. In Arkansas, both sides of the wall are the "warm side" depending on which season it is. During the summer it is important that the moist outside air does not have a chance to condense on the cool surfaces inside a wall. By maintaining a slight, positive air pressure inside the house (see page 67), any leakage will be directed to the outside.

Gaps in the drywall can be air leakage sites.

The attic access door should be treated as an exterior door with good weather-stripping, a threshold and a secure latch. Best practice would also include adding some rigid insulation to the backside of the door

Knee walls are really "vertical ceilings"

An exterior wall insulates the inside from the outside temperatures. A "knee wall" functions as a vertical ceiling because it insulates the inside from the attic temperatures that are frequently much hotter than the outdoor air temperatures in the summer. Because a knee wall is framed with 2x4's it does not mean that it can hold only R-13 insulation. Many new homes have experienced difficulties conditioning upstairs areas because the knee wall was insulated with R-13 insulation and these batts were left exposed to the attic temperatures.

The best approach to fixing this problem is to cover the exposed batts with foil-faced insulated sheathing. This will not only add at least an R-3 but will also help the insulation work better by trapping the air within the cavity and reflecting the attic's radiant heat.

Many homes have more complicated ceilings with several vertical elements. These should also be treated as vertical ceilings with the insulation enclosed using some solid material.

Batts of wall insulation that are left exposed to attic temperatures have little insulating value because they allow air to circulate

Ceiling insulation should be placed directly against vertical ceiling elements, otherwise, convection will transfer attic temperatures to ceiling.

Trap the air in the insulation by sealing the knee walls with reflective foam insulation. Note that seams are taped for better sealing.

5c. Wood floor insulation – Fighting gravity while keeping dry

Survey results of wood floors

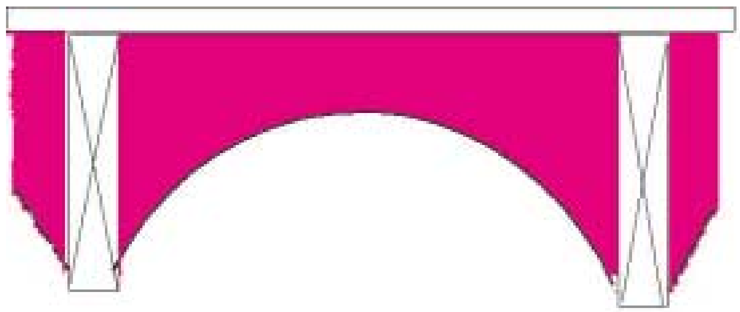
Seventeen percent of the floors surveyed were wood – the majority were in central Arkansas. The insulation for these floors ranged from R-11 to R-19. Although more costly to construct, homes built on wood floors can more easily meet the minimum Energy Code requirements.

Insulating wood floors

There are three basic types of wood floors: exposed, cantilevered and enclosed over a crawlspace. The Energy Code suggests that an exposed floor be insulated to the same level as the ceiling. This suggestion is not necessary because the exposed floor is experiencing much different temperatures than attic insulation. The insulation level for the exposed, cantilevered wood floor should be at least R-19. The underside of the exposed floor is then enclosed with an exterior material.

A wood floor over a crawlspace is "enclosed" by that crawlspace and since the weather is not directly blowing across the floor, the insulation level can be reduced (R-19 is typically used). Installing the insulation to its maximum benefit has been a problem because gravity pulls the insulation away from the floor – the insulation should be in contact with the surface it is insulating.

The insulation should be placed with the facing towards the living (warm) side. Short wires are commonly used to hold the insulation in place, but these compress the insulation and lower its R-Value.



Sharpened metal wires are used to keep floor insulation from falling. The wires compress the insulation, and between the wires the insulation sags away from the floor. Both of these factors contribute to the loss of some insulation value.

Chicken wire works well to keep insulation in place without compressing it. It is important that the insulation be in contact with the floor above it.

Crawlspace ground cover

The survey found very few ground covers under insulated wood floors. A ground cover significantly helps to keep relative humidity at a low level and should always be used for moisture control. Without a ground cover, moisture can collect on the wood structure causing decay and can be a source of mold and excess humidity.

Six-mil polyethylene or other approved material should cover the entire ground area. It should be overlapped 12 inches at all joints, turned up 12 inches at the foundation wall and turned up and taped to pillars. This produces a continuous barrier with "no gaps at the edges." Also, if possible, the crawlspace should be level with or a little higher than the outside ground.

A common misperception is that termite companies require 20 percent of the crawlspace to be uncovered. This practice applies to existing homes with wood floors that have been experiencing long-term water problems in the crawlspace. A good job of installing the ground cover changes the moisture level in the wood floors, which can cause the wood to shrink and crack. This practice does not apply to new construction.

Crawlspace access

If an HVAC system and ducts are in the crawlspace, make sure that there is enough height for ductwork installers to do their work. A cramped crawlspace not only makes this work hard, it sets up the ducts for future, unintentional damage. Also, if hot and cold water pipes are in the crawlspace, they should be insulated. The access door should be large enough to permit removal of the largest piece of the appliance. If equipment is present the minimum is 22"x 36." If there is no equipment, then 18"x 24."

Crawlspace ground cover

Crawlspace access

6. Ventilation and indoor air quality – Fresh air – no longer an accident

Accidental leakage vs. controlled ventilation

Not too long ago, homes were built with little attention to air sealing – accidental air leakage allowed entrance of fresh air and exiting of stale air. The art of homebuilding and the technologies available today are producing homes that are much tighter than in the past. What this means is that ventilation cannot be ignored and left to chance in today's new homes.

Ventilation basics for bathrooms and kitchen

There are two important criteria to consider when selecting a ventilation fan: 1) how many cubic feet per minute (cfm) can the fan push? 2) how noisy (rated in "sones") is the fan? For quiet operation, look for fans with a maximum 1.5 sone rating.

Stoves with built-in fans are inefficient at removing moisture and too efficient at removing conditioned air. Since homes are now being built much tighter, it is important that vent fans not be oversized. Being a little undersized is better than oversized and reduces the opportunity for dangerous back drafting.

A slightly outdated rule-of-thumb for sizing fans is to estimate the cfm by adding 10 percent to the floor area of the space. For instance, if a bathroom is 80 square feet, 80 + 8 (10% of 80) = 88 cfm. Since fans do not come in all available cfm's, select the next largest available size. The Arkansas Mechanical Code (503.3.2) says that the exhaust air can be a minimum of 1 cu ft. per minute per sq. ft of floor area."

Cost vs. benefit of good ventilation

Why should a builder make the extra effort to build it tight, and then have to spend more money to ventilate it right? Many builders now understand that a few hundred dollars invested in mechanical ventilation can pay a large return in the durability of the building, the health of its occupants, and reduced callbacks.

An option that is acceptable for a climate with less humidity is to use just the kitchen and exhaust fans for ventilation. The problem with this option in our climate is that in the summer, the humid make-up air is coming through cracks and openings wherever it can.

A preferable approach is to put the house under a slight positive pressure by ducting the fresh air directly into the return side of the furnace and installing a control timer. The advantage of a positive pressure is that any leakage will be pushed out of the house. The problem with this option is the same: an introduction of humid air in the summertime.

Note: re-circulating range hoods do not remove kitchen moisture and odors; these devices are essentially just grease traps. A hood over the stove with a good exhaust vent will remove moisture and cooking odors and keep them from contaminating the home.

The most comprehensive ventilation strategy is to install a stand-alone, air filtration and dehumidification system. This is not inexpensive; however, it is the best solution to indoor air quality and moisture removal for our climate.

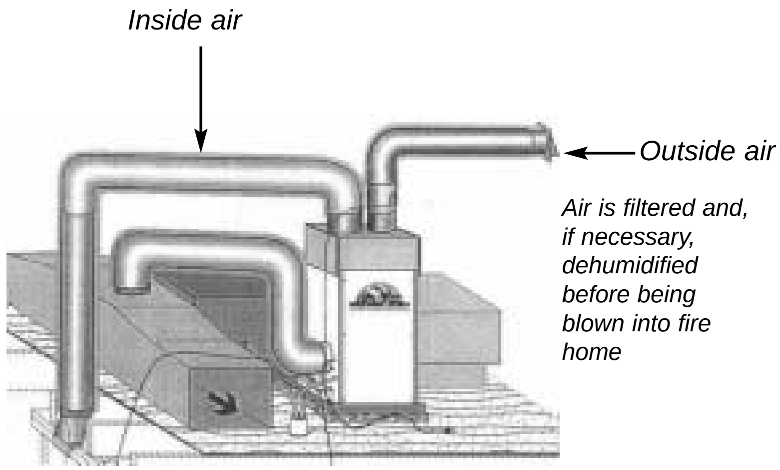
Filtration and ventilation

All homes have some level of pollutants in them. As homes become more airtight with improved building techniques, attention to ventilation becomes more important. While most houses in Arkansas currently are not built tightly enough to need supplemental ventilation, controlled mechanical ventilation is a good way to improve air quality. Such systems not only offer the homeowner control of the air they breathe but also the opportunity to dehumidify, filter and clean the air inside the home and the air that is introduced from the outside.

Unvented gas fireplaces – a note of caution

The by-product of gas combustion is a tremendous amount of water vapor that, in a fairly tight house, can quickly accumulate and condense on windows and other cool surfaces. The homeowner must open a window, usually in the middle of winter, to provide fresh air for combustion and breathing, and to remove moisture and other gasses. It is important to stress that homeowners read the instructions that come with a non-vented combustion fireplace to ensure that they carefully and appropriately operate it. The American Gas Association says, "If a home is below 0.35 air exchanges per hour (extremely tight construction), additional mechanical ventilation should be added before installing a vent-free gas heating appliance." This recent survey indicates that about half of Arkansas' new homes are in this "extremely tight construction" category.

In a very tight home, a sealed combustion fireplace, although more expensive, would be the best choice. **See page 37**.



An air filtration, ventilation and dehumidification system

An unvented fireplace

7. Heating and air conditioning systems

7a. Proper sizing – Bigger is not better

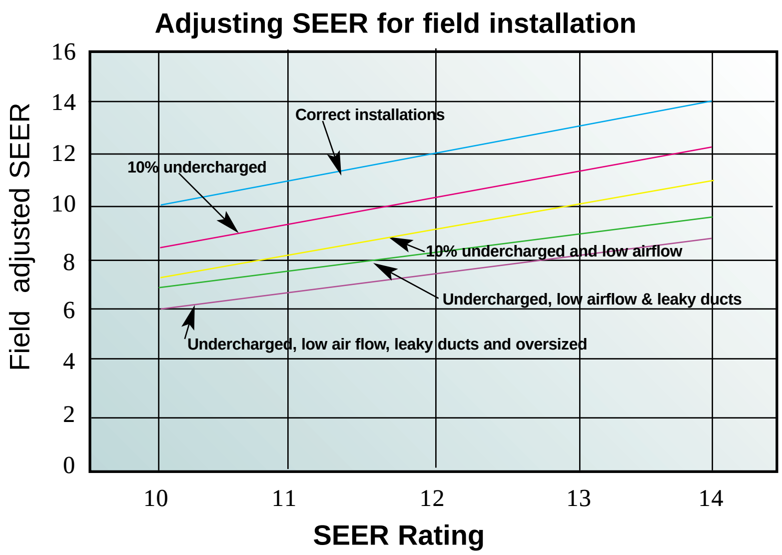
Oversizing found in survey and effects of oversizing

The survey found that oversizing of heating and especially cooling systems is a consistent problem. When houses used to be under-insulated and leaky, a commonly used industry formula was "One ton of cooling for each 500 square feet of floor area." The study found that this outdated formula is no longer appropriate. A correctly sized system delivers more comfort at less initial cost.

An oversized A/C will quickly cycle off and on in short bursts. Since it is oversized, it will rapidly deliver cool air to the space, and the thermostat will think that a level of comfort has quickly been reached. Unfortunately, most thermostats do not measure humidity, and removing moisture is one of the main functions of an air conditioner. An oversized system is not only more expensive, it is shorter lived, noisier and more prone to maintenance problems. A properly sized A/C that operates for a prolonged period of time during the hottest days of summer is actually more efficient and less costly than a rapidly cycling, oversized system.

Builders pay the price for oversized systems. The survey found that the excess sizes of cooling systems ranged from 1/2 to 3 tons. The unnecessary extra expense for this over-sizing ranged from $200 to $1,700 with an average of about $600 – and that was just for the cooling system.

Oversizing a furnace by more than 1.4 times can lead to loss in seasonal efficiency, higher equipment cost, comfort sacrifices due to short cycling, and premature degradation of the furnace and/or vent system. Source: **See page 84** under HVAC.



Air conditioner efficiency (SEER is the Seasonal Energy Efficiency Ratio) is measured in the laboratory, not in the field. With correct installation, a system will deliver close to its measured efficiency (top line this graph). When the system is undercharged and oversized with low air flow (often caused by a restrictive return duct) and leaky ducts, a 14 SEER might actually only deliver the efficiency of a 9 SEER. Careful sizing and installation will help deliver the expected efficiency.

Source: *National Energy Savings Potential from Addressing Residential HVAC Installation Problems* by Chris Neme, John Proctor and Steve Nadel

Balancing the air flow

After the boots have been sealed and supply and return grills have been installed (and after almost all but the final finishing touches have been done), ask the HVAC company to balance the flow of air to all rooms. This final installation step will ensure an even distribution of conditioned air and prevent unnecessary callbacks.

Request a Manual-J analysis

Manual-J is an industry-wide standard that is used to size heating and cooling systems. Local weather conditions and information on insulation, window orientation and efficiency, and duct leakage are processed to recommend peak summer and winter cooling and heating loads. These loads are used to select appropriate equipment to meet these peak conditions.

The Air Conditioning Contractors of America developed Manual-J to size heating and cooling systems. By supplying the builder with the results of a Manual-J analysis, the HVAC contractor can validate the selection of units and avoid potential callback problems.

Going beyond the minimum

If a custom home is being built, encourage the future homeowner to explore the operating costs of HVAC equipment with efficiencies that are higher than the minimum. For a gas heater, 80 percent AFUE (Annual Fuel Utilization Efficiency) is hard to beat for being cost-effective; however, a 12 SEER (or even higher) air conditioner, when properly sized and installed, is usually quite cost-effective and should be seriously considered. Any heat and air system will deliver expected results only if it is carefully assembled and installed.
See page 71 – Adjusting SEER for field installation.

Protect the HVAC equipment during construction

Keep grills, boots, and especially floor boots taped and covered during the building process to keep dust and construction materials from getting into the duct system. The area in the return should be clean and free of debris. Keep the home's breathing passages clean.

Rent temporary conditioning equipment *– do not use the new HVAC system for temporary conditioning*. The use of the home's heating or cooling system during construction permanently contaminates the entire system with dust, paint and other building materials. A recent revision to the Arkansas Mechanical Code (Section 601.5) indicates that the "air distribution system, including equipment shall be protected during construction to be maintained free of debris or other foreign material." Suggestion: Require subcontractors to provide their own safe, auxiliary conditioning equipment.

One-inch thick filters catch some dust, but much of the fine dust passes through. Even with a filter in place, the new heat exchanger coil on the left is clogged with drywall and sawdust construction debris. On the right, the HVAC technician uses an acid/water wash that will dislodge most of the baked-on material. The ductwork, blower motor and all the other hard-to-clean components will continue to blow construction dust back into the house long after this emergency work is done.

7b. Tighter ducts – Delivering all of the air and none of the dust

Work with the HVAC company to design the return duct

The HVAC contractor and builder should consult and review plans prior to construction so that the HVAC contractor can design and install the best and most efficient return duct, as well as an efficient overall system. The return should be short, large enough, well-insulated, well-filtered, and air-tight. Return ducts have caused more problems and callbacks than almost any other HVAC area. A properly sized (1.5 to 2 square feet of return grill area per ton of cooling) and sealed return will reduce overall duct leakage as it delivers more comfort for the dollar. In addition, this reduces several problems such as dust, transmission of ceiling insulation materials, noise, intake of unexpected air through building channels, and mold.

Best practice is to allow the HVAC company to build the return out of metal and not 2x4's and sheetrock as has been done here.

The HVAC company is responsible for handling the air from the filter in the return to the diffuser in the supply boot. The builder should be aware of the location and size of the return duct, which is typically installed prior to any sheetrock. A return should be sized so that the area of the filter grill is from 1 1/2 to 2 square feet per ton of cooling.

This return was finished with particle board and sealed with mastic. Careful sealing prevents any unwanted air, dust and insulation from entering the air stream.

Duct sealing materials

Duct mastic and mastic tapes are the best duct sealants available. If "duct tape" is used, insist on UL or equivalent tested and approved "duct sealant" tape.

7c. Where the HVAC meets the home

Seal it, duct it and secure it

Seal the gap around the supply boots

Many small problems arise between the junction of a heating/cooling system and the building's envelope. These can add up to a large problem. Supply ducts bring conditioned air to a "boot" into which a diffuser grill is placed. It is important that the gap between the boot and the surface through which it delivers conditioned air is caulked and sealed to deliver all of the conditioned air to the space and reduce the home's air leakage.

Return duct vs. a framed-in cavity

The builder and HVAC contractor should consult and review plans prior to construction so that the HVAC contractor can design and install the best and most efficient return duct as well as an efficient overall system. The return duct is the responsibility of the HVAC contractor. The builder can frame around a metal return air duct that will allow the air to flow quietly and reduce duct leakage.

Also, it is important that the area of the return vent be large enough for the size of the system. A good rule-of-thumb is 1 1/2 to 2 square feet per ton of cooling.

A supply boot is caulked to the floor to reduce leakage.

A home-made return air "duct." Note the unsealed electrical penetrations at the top that can pull down attic air into the return

When possible, keep the ducts in the conditioned part of the house

When designing a small, uncomplicated home, it is possible to install the ducts to be directly connected to the conditioned space. Larger, more complicated homes create more challenges and fewer opportunities for the ducts to be in the conditioned space. Even though the ducts are "in the home," they still need to be insulated and vapor tight.

If ducts are in a crawl space, it is important that this space be high enough for visits by technicians, pest control businesses and others. If the space is restricted, the ducts are vulnerable to damage.

If the ducts are in the attic, they are exposed to very high temperatures in the summer and low temperatures in the winter. Consider running metal ducts, attached with mastic, covered with duct insulation and vapor-sealed, 1 or 2 inches above the ceiling's joists. The metal ducts, connected with sheet metal screws and sealed with mastic, create a duct system that is rigid and self-supporting.

When the attic gets insulated, extra insulation can be placed against the sides of the ducts to increase the relatively thin duct insulation. Leave the tops of the ducts exposed or mark their locations to prevent damage. Check with local code officials prior to this option. The Arkansas Mechanical Code states that ducts must be "securely supported." There is not a good reason to suspend them and a much better reason to increase the modest level of duct insulation.

Suspended flex ducts droop between supports. The supports can restrict the air flow.

Suspended ducts are vulnerable to attic temperatures.

Metal ducts, sealed with mastic, are placed 2 inches above the rafters.

Insulation is piled up against the ducts to provide extra protection from the attic's temperatures.

Seal, weather-strip and secure indoor furnace doors

When a gas furnace or other combustion appliance is located inside the home (as opposed to the garage), it is important to isolate it from the conditioned space. The closet walls should be insulated. The door to the furnace closet not only needs to be securely shut, but also should be carefully weather-stripped all around, with a tight threshold on the bottom of the door. These measures will prevent the hot, humid summer air from being drawn down those combustion air pipes and into the house, and the home's conditioned air will not be burned in the furnace in the winter.

Secure this door with a good doorknob and latch so that the weather-stripping will be effectively compressed and the door will not open as freely as a kitchen cabinet door.

The furnace door should be securely sealed and weather-stripped and the walls of the furnace closet should be insulated. The arrow points to 1-inch gap where hot, humid summer air can be pulled into the return. In the winter, conditioned air is drawn through the same gap to feed air to the furnace.

8. Appliances

Bulbs, fixtures and water heaters

The homebuyer makes many appliance selections after purchasing the home. The builder, however, typically makes many appliance decisions that impact the home's energy use:

- **Lighting fixtures and bulbs** – New models of compact fluorescent bulbs produce more light for less cost, last for several years, can be ordered to produce a variety of colors, and fit most fixtures. Use these in areas that are not frequently switched on and off or in difficult places to reach.
- **Recessed lights** – There are several models on the market that are airtight (AT) and can have insulation contact (IC). Many times, these fixtures are good candidates for the new models of compact fluorescent bulbs.
- **Hot water heater** – Water heating can cost from $200 to $400 a year; therefore, improving water heating efficiency is important and the costs are minimal:
  - The higher the Energy Factor (EF) the better. Look for a gas EF above .56 and an electric EF above .88.
  - The First-Hour Rating the FHR is also listed on the Energy Guide label. This is a measure of how much hot water will be delivered during a busy hour. A larger tank doesn't necessarily mean a higher FHR.
  - Only a few water heaters come equipped with R-24 insulation. If the water heater is in an unconditioned space and the manufacturer does not prohibit it, wrap it with an additional R-11 insulation. Follow the manufacturer's instructions and keep the insulation away from the thermostat. For a gas water heater, wrap the sides except for the thermostat, and keep the jacket away from the burners and from the flue at the top.

- Insulate hot water pipes (and cold water feed pipes) wherever accessible, especially within 3 feet of the water heater. For gas water heaters, keep the pipe insulation at least 6 inches from the flue.
- If an electric water heater is on a slab, insulate the underside with a bottom board of rigid insulation.
- Anti-convection valves and loops are "heat traps" that prevent hot water from rising into the pipes when no water is being drawn. A $5 pair of these simple devices can save from $8 to $28 a year. Even less expensive is plumbing that creates a 1 or 2 inch high point in the hot and cold water pipes connected to the heater that will prevent the water from convecting up the pipes.
- Special, high-efficiency gas water heaters have sealed combustion and are typically power-vented allowing them to be easily placed in the home without needing a special closet. The supply and combustion air pass through plastic pipes that can go through the wall.
- Small or large tankless or demand water heaters, especially gas-fired ones, can be considered when the distance to the conventional water heater is long or when the use is infrequent.

Other household appliances

When builders or homebuyers check for an Energy Star label on any of the following consumer devices, they are assured that a good energy efficient decision has been made:

- Refrigerator
- Stove
- Water Heater
- Dishwasher
- Clothes washer and dryer
- Microwave

Sources of information

Following are several sources of valuable information on energy efficiency, including Web sites and publications:

Reference materials:

Here are two excellent and comprehensive builder's guides that are currently in print:

Builder's Guide – Mixed-Humid Climates. This is a very comprehensive "systems approach to designing and building healthy, comfortable, durable, energy efficient and environmentally responsible homes." It is available from the Energy Efficient Building Association, 2950 Metro Drive, Suite 108, Minneapolis, MN 55425. Their Web site is www.eeba.org or e-mail: EEBANews@aol.com.

Builder's Guide to Energy Efficient Homes in Georgia. Available from GEFA, Division of Energy Resources, 100 Peachtree Street, Suite 2090, Atlanta, GA.

HVAC: The best and most comprehensive source of information on residential HVAC systems is "Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems" by the Consortium for Energy Efficiency. There is a wealth of information from this organization, including this entire report that can be downloaded from the Web at: **www.ceeformt.org.**

Information sources:

Southface Energy Institute. This organization has done a tremendous amount of work on furthering the understanding of energy efficiency in the hot, humid South. They have a newsletter and many pre-printed brochures on almost all aspects of energy use. Many of their recommendations are built into their office structure in Atlanta. They also give many local and regional seminars and local tours. Address: 241 Pine Street, Atlanta, GA 30308. Phone: (404) 872-3549

Energy Design Update. This "Monthly Newsletter on Energy-Efficient Housing" is read from cover to cover by many energy professionals. Since it is expensive, you might want to ask your professional organization to subscribe or check your local library. Visit their Web site at www.cutter.com/energy.

Home Energy. This is a bimonthly publication of Energy Auditor and Retrofitter Incorporated. This magazine is more affordable because it carries advertisers; however, in many cases, the advertisements are almost as interesting as the articles. This magazine contains information on all aspects of energy use in the home. Address: 2124 Kittredge St. No. 95, Berkeley, CA 94704

Internet sources:

Energy Star -- http://www.epa.gov/energystar is a good site for Energy Star products, manufacturers, retailers, purchasing, frequently asked questions and recent news about Energy Star appliances.

American Council for an Energy Efficient Economy (ACEEE) is a good source for a variety of energy efficiency information. See their top-rated energy efficient appliances: **www.aceee.org/consumerguide/index**

Energy Efficient Builders Association has many good publications available for the building professional. *The Builder's Guide for Mixed Climates* can be ordered through their Web site: www.eeba.org

The **U. S. Department of Energy** has conducted extensive research and development on energy technologies. This site is useful for keeping up with the latest information: **www.eren.doe.gov/buildings**

The Arkansas Energy Office has created a clearinghouse of information on its Web site. The ARKcheck™ program and much more information is available on the Web site of the Arkansas Department of Economic Development: **www.1-800-ARKANSAS.com/energy**

Notes for your additional information sources.

Appendix A
Builder component specification sheets

	Builder	Framing Contractor	Insulation Contractor	HVAC Contractor	Plumber	Electrician	Drywall Contractor
Seal bottom plate to floor	❑	❑	❑				❑
Seal top, bottom plate holes	❑		❑		❑	❑	❑
Seal plumbing penetrations	❑		❑		❑		❑
Seal supply boots	❑		❑	❑			
Seal recessed lights	❑		❑			❑	
Seal cantilevers and joist cavities	❑		❑				
Seal fireplace enclosure	❑	❑	❑				
Provide ventilation	❑			❑		❑	

Appendix A

A prototype of a builder's specification sheet that identifies the problem areas – typically those places where one profession meets another – with areas of responsibility. It is not intended to be an exhaustive list of the problems or potentially responsible parties, but a starting point of discussion between builders and their subcontractors. It shows tasks the builder has to do or make sure are done, with clear assignments to specific contractors.

Appendix B
The Arkansas Energy Code

Any energy code can go only so far to prescribe levels of efficiency that are easy to understand and follow as well as to confirm. Currently the Arkansas Energy Code looks at the exterior components of the building: ceiling, wall, floor, window and door. The Code establishes minimums for these components in the four climate zones that have been identified in Arkansas.

Most builders are using insulation levels that satisfy the Code minimums for ceiling, wall and wood floor insulation. Most of the problems with compliance have been the result of the selection of windows and the lack of effective slab insulation.

Windows

Energy Code compliance becomes more difficult with excessive window area and highly conductive window frames. Windows with solid aluminum frames conduct heat and cold from the outside to the inside. Selecting windows with a thermal break, or even better, vinyl frames, improves the thermal properties of windows, allows for easier Code compliance, and provides greater levels of comfort.

The Code looks at walls as a combination of the solid wall plus the windows and doors. Wall area is reduced when window area is increased, making Code compliance more difficult. Try to keep the window area under 15 percent of the gross wall area. If the home has more than 15 percent window area, use the ARKcheck™ program, an easy-to-operate program available free from the Arkansas Energy Office Team to evaluate trade-offs for compliance.

Slabs

Most homes in Arkansas are built on a slab. Proper insulation of the slab allows for easier Code compliance. **See Slab insulation details pages 14-15.**

Trade-offs

The ARKcheck™ program allows one component to be traded off for another so that the entire home can comply even though, an individual item might be less than the minimum or a window area might be larger than average. Trade-offs can also be used when heating and/or cooling systems are above minimums.

The Arkansas Energy Code is a place to start. If a home has met the minimums, there is a good chance it will be comfortable and economical to operate. The other "tips" in this publication will help to bring a house from this minimum to a higher level of performance where homeowners will feel more comfortable, utility bills will be more reasonable, and homeowners will have fewer reasons to call back with problems. With some attention to a few details, builders can contain costs while improving performance and reliability.

Appendix C
Insulation basics

Insulation works by trapping air or a gas such as Argon that is used in high-efficiency windows. The fibers or foam hold onto small pockets of air and, because air is such a poor conductor, the flow of heat is slowed down but not stopped. The R-Value is the resistance to heat flow. The R-Value only affects the conduction of heat, it does not represent heat transfer from radiation (infrared rays) or convection (air movement).

The R-Value of the insulation is based on its thickness and density. A 5–inch thick R-19 batt that is stuffed into a 2x4 wall cavity will deliver only about an R-13 because the compression of the batt has squeezed the air out. In fact, tightly rolled batts should be fluffed up to their full thickness before being placed in wall cavities.

Even though air is an insulator, the movement of the air should be restricted. When air is trapped, it has an R-Value of about R-1 per inch. If the air is circulating (convection) in a cavity, it is actively transferring heat from one surface to another. It is important to seal all leakage areas prior to insulating and to install insulation so that convection cannot occur.

Issues with insulation

Insulation comes in a variety of colors and types. There are pros and cons for every type of insulation, and there are important differences that distinguish one insulation type from another.

Here are a few insulation facts:

- Batt and loose-fill ceiling insulation do not air seal.
- Batt insulation, if done very carefully, can work. The issue is that proper and careful installation is required in combination with good air sealing.
- Foam insulation not only air seals but also vapor seals.
- R-Values for different products are slightly different. Even products from the same manufacturer with the same thickness have a different density and R-Value.
- Dry cellulose (ceiling) settles; however, wet-blown (typically applied to walls) does not settle.

Suppliers or manufacturers typically state the R-Value of their products. If not available, use the default values below.

R-Values for Ceiling, Wall, Floor or Slab

Insulating values of typical insulating products	R-Value
3-1/2" low density Fiberglass batts	11
3-1/2" med. density Fiberglass batts	13
5-1/2" low density Fiberglass batts	19
5-1/2" med. density Fiberglass batts	21
8" med. density Fiberglass batts	30
9-1/4" low density Fiberglass batts	30
10" med. density Fiberglass batts	38
12" low density Fiberglass batts	38
3-1/2" Cellulose	13
5-1/2" Cellulose	20.4
8" Cellulose	30
10" Cellulose	37
12" Cellulose	44.4
14" blown glass (pink or yellow)	30
14" blown glass (white)	33
3/8" R-Board tm	2.7
1/2" R-Board tm	3.6
3/4" R-Board tm	5.4
1" R-Board tm	7.2
1/2" Fiberboard (blackboard)	1.3
1" Polystyrene foam (blue or pink)	5
1" Styrofoam tm (beadboard)	4

Appendix D
Window basics

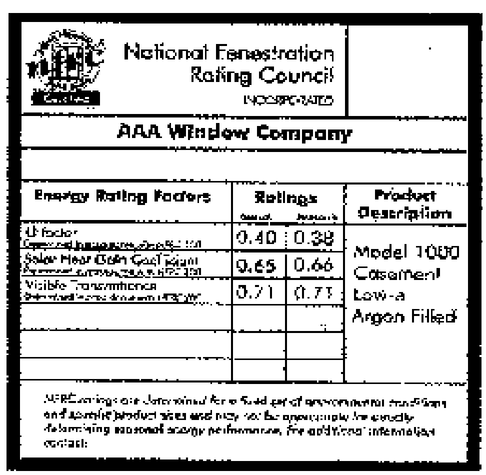
Window technology continues to develop. There are several things to consider when selecting a particular window type. These include not only the heat loss/gain of the window, but also the amount of sunlight that passes through and the impact of that light on both energy use and bleaching of furniture and flooring.

U-Values – The flow of heat is defined as a U-Value. The lower the U-Value, the more efficient the window. Solid aluminum frame windows have a high U-Value (0.87) and vinyl windows have a low U-Value (0.56). Aluminum is a very good conductor of heat, and a solid aluminum frame is like a radiator that quickly transfers heat between the outside and inside.

The **National Fenestration Rating Council (NFRC)** has developed a window energy rating system based on the performance of the whole window including the frame and sash, not just the center of the glass. More and more window manufacturers are investing in these rigorous testing procedures to label their window products. Once tested, these windows can then affix an official NFRC sticker, a third-party validation of the quality of their products.

If an NFRC sticker is not found on a window, use this default table to select the appropriate U-Value.

Frame/Glazing Features	U-Value
Single-paned, aluminum without thermal break	1.30
Single-paned, aluminum with thermal break	1.07
Singled-paned, wood or vinyl frame	0.94
Double-paned, aluminum without thermal break	0.87
Double-paned, aluminum with thermal break	0.67
Double-paned, wood or vinyl frame	0.56
Double-paned, wood or vinyl frame with low-e	0.46
Double-paned, wood or vinyl frame with low-e, inert gas fill	0.41
Triple-paned, wood or vinyl frame	0.39
Triple-paned, wood or vinyl frame with low-e	0.36
Triple-paned, wood or vinyl frame with low-e, inert gas fill	0.35
Glass block	0.60



Thermal break – This is a non-conductive material such as rubber that is sandwiched between the outer and inner pieces of an aluminum frame to provide a break in the transfer of heat from the inside to the outside. It makes window frames more efficient than solid aluminum frames but not as efficient as vinyl or wood.

Low emissivity coatings – There are two types of low-e (low emissivity) windows that have special transparent coatings: "low-e" and "summer low-e." The "summer low-e" windows are the most appropriate for east and west windows in this climate because they reduce the radiant solar heat as well as the bleaching effect of ultraviolet radiation, and therefore reduce the load on the air conditioner. Most windows that are advertised as "low-e" are actually "winter low-e," which are suitable for south and north facing windows. Both types of low-e windows reflect heat back into the living space.

Solar heat gain co-efficient – A low SHGC reduces the amount of sunlight that can pass through a window. A high SHGC allows more sunlight to pass through the window. The SHGC ranges from zero to one. In our mixed climate, select a window with a SHGC of 0.55 or less. The "summer low-e" window coating produces a SHGC of about 0.5, which reduces the air conditioning load on windows with solar exposure.

The gap – The space between the double-glazing should not be too narrow (below 3/8 inch conduction reduces the efficiency) or too wide (above 5/8 inch convection reduces efficiency). Regardless of frame type, low-e coating or inert gas filling, the optimum air space ranges from 7/16 inch to 5/8 inch. Therefore a 1/2–inch gap is just right.

Shading co-efficient – This is similar to the SHGC; however, it is a number that is relative to double-pane, clear glass. The shading co-efficient of double pane, clear glass is set at 1.0 whereas the SHGC for the same window type is 0.84. Therefore, you can calculate the shading co-efficient by dividing the SHGC for a given product by 0.84.

Inert gas fillings – Very high efficiency windows replace the air between the panes with a special gas that further reduces the transfer of heat. These windows bring the U-Value down to around 0.40 or less.

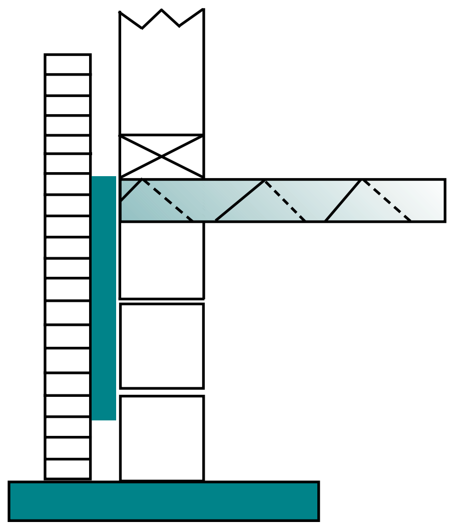
Visible light transmittance – A window with a VT (visible light transmittance) above 0.70 is desirable to maximize day-light and view.

Air leakage – The major problem with windows is typically poor installation. Various window designs have different leakage characteristics: casement windows clamp shut and seal the best; vertical sliders are better than horizontal sliders that allow more air leakage than other window types.

Internal grids – These are designer features that attempt to convert a single window area into what looks like a multiple pane window. Some manufacturers placed these grids in contact with the inside and outside panes providing a bridge to transfer heat. The grids should not contact the glass.

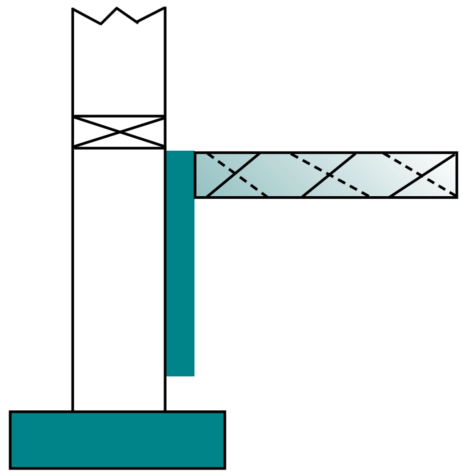
Appendix E
Alternative methods of slab insulation

Note that many construction details have been omitted in these simplified drawings. These slab insulation techniques demonstrate acceptable practice.



Insulation can be placed on the exterior of homes that are finished with brick veneer. Note that the top of the insulation is at the top of the slab.

This same technique can be used on a monolithic slab. Because the insulation is more vulnerable to termites in this application, termite resistant foam should be used.



This technique is similar to the "L" block option but requires less work. As with the "L"block, the exposed foam is covered with the edge of the drywall and baseboard molding.

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B

C

D

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