WALL INSULATION

For more information, contact:
Energy Efficiency and Renewable Energy Clearinghouse (ERECE)
1-800-DOE-3732
www.eren.doe.gov

Or visit the BTG Web site at www.eren.doe.gov/btg

Or refer to the Builder's Guide Energy Efficient Building Association, Inc..
651-268-7585
www.eeaa.org

Written and prepared for the U.S. Department of Energy by:
Southface Energy Institute
404-872-3549
www.southface.org

U.S. Department of Energy's Oak Ridge National Laboratory
Buildings Technology Center
425-574-5178
www.ornl.gov/ORNL/BTC

The Model Energy Code can be obtained from the International Code Council by calling 703-931-4533
MECcheck, a companion compliance software package, can be ordered from DOE by calling
1-800-CODE or downloaded directly from the Web at

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STEPs for effective wall construction and insulation

1. Review the plans and specifications and identify all walls (including bandstands) between conditioned (heated and cooled) spaces and unconditioned spaces (exterior, attics, crawl spaces, garages, and mechanical rooms). Use advanced framing techniques to increase insulation levels and reduce lumen use.

2. Use diagonal corner bracing (let-in bracing) on exterior walls to substitute for corner plywood sheathing and allow continuous insulated sheathing.

3. Use foam sheathing for insulating headers to reduce framing heat loss.

4. Seal all air leaks through walls before insulating, including under the bottom plate, band joint areas between floors, electrical boxes, and all electrical, plumbing, and HVAC penetrations.

5. Use caulk and backer rod or non-expanding spray foam, not insulation, to seal around window and door jambs.

6. If fixtures such as stairs or shower/tub enclosures cover exterior walls and do not allow easy installation of insulation after the sheathing is attached, insulate behind these components in advance using R-13 or R-19 batts and cover with a weatherproof barrier (1/2-inch drywall, plastic, or other sheet material).

7. Select insulation levels based on the MEC and the DOE Insulation Fact Sheet.

8. Face-staple batts because side stapling creates channels for air flow and compresses the insulation, thus reducing the R-value. If face stapling is not an option, use unfaced batts or carefully side staple within 1/4 inch of the stud face.

9. Obtain full coverage of batt or blown wall insulation. Cut batt insulation to fit snugly into non-standard stud spaces and to completely fill cavity.

10. Silt batt insulation to fit around the back and front side of electrical wiring and plumbing without compressing or tearing the batts.

11. Notch out batt insulation around electrical boxes and use scraps to insulate behind the box.

12. Once the interior drywall is in place, seal all penetrations with durable caulking.

Fiberglass Batt Insulation Characteristics

<table>
<thead>
<tr>
<th>Thickness</th>
<th>R-value</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3½</td>
<td>14</td>
<td>$0.50/sq ft</td>
</tr>
<tr>
<td>4½</td>
<td>14</td>
<td>$0.50/sq ft</td>
</tr>
<tr>
<td>3½</td>
<td>15 (high density)</td>
<td>$0.40/sq ft</td>
</tr>
<tr>
<td>4½</td>
<td>15</td>
<td>$0.40/sq ft</td>
</tr>
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Buildings for the 21st Century

Buildings that are more energy efficient, comfortable, and affordable...that’s the goal of DOE’s Office of Building Technology, State and Community Programs (BTG).

To accelerate the development and wide application of energy efficiency measures, BTG:

• Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances.

• Promotes money-saving opportunities to both builders and buyers of homes and commercial buildings.

• Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use.

• Provides support and grants to states and communities for deployment of energy-efficient technologies and practices.

WALL INSULATION

Provide Moisture Control and Insulation in Wall Systems

Effective Wall Insulation

Properly sealed, moisture-protected, and insulated walls help increase comfort, reduce noise, and save on energy costs.

However, wall assemblies are the most complex component of the building envelope to insulate, air seal, and control moisture. The keys to an effective wall are:

• Airtight construction—all air leaks sealed in the wall during construction and prior to insulation installation.

• Moisture control—exterior rain drainage system, continuous air barrier, and vapor barrier located on the appropriate side of the wall.

• Complete insulation coverage—advanced framing to maximize insulation coverage and reduce thermal bridging, no gaps or compressed insulation, and continuous insulated sheathing.

Air Sealing

Air sealing reduces heat flow from air movement (convection) and prevents water vapor in the air from entering the wall. In a 100-square-foot wall, one cup of water can diffuse through drywall without a vapor barrier in a year, but 50 cups can enter through a 1/4-inch, round hole. In fact, sealing air leaks is 10 to 100 times as important as installing a vapor barrier.

Control moisture in walls

All climates require these steps:

• Install a polyethylene ground cover on the earth floor of houses with crawl spaces and slope the ground away from the foundations of all houses.

• Install a continuous vapor barrier that has a Perm rating of less than one (see page 3).

• Place a termite shield, sill gaskets, or other vapor-impermeable membrane on the top of the foundation wall. This action will prevent moisture from wicking into the framed wall from the concrete foundation wall by capillary action.

Prevent rain penetration

Causes of rain leaks through exterior walls include improper installation of siding materials; poor-quality flashing; weatherstripping, or caulking around joints in the building exterior (such as windows, doors, and bottom plates); and wind-driven rain that penetrates the exterior finish. To enhance protection against rain penetration, create a drainage plane within the wall system of the home.

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WALL FRAMING WITH ADVANCED FRAMING TECHNIQUES

Building experts have performed considerable research on ways to reduce the amount of lumber in our homes while maintaining structural integrity. The U.S. Forestry Products Association and other organizations have devised an “optimum value engineering” (OVE) framing system that reduces unnecessary lumber use and improves the whole-wall R-value by reducing thermal bridging and maximizing the wall area that is insulated. Selected OVE practices include:

- Design the house to use materials efficiently by employing simpler shapes and volumes, compact designs, and designs based on a 2-foot module.
- Frame at 24-inch rather than 16-inch centers.
- Design headers for loading conditions and use insulated headers.
- Locate window and door openings in-n-wall with established framing and size windows to fit within existing stud spacing.
- Eliminate unnecessary framing at intersections using two-stud rather than three-stud corners and ladder blocking where interior partitions intersect exterior walls.
- Use let-in bracing to allow the use of insulated sheathing in corners.
- Eliminate curtailed studs (cripples) under windows.
- Align roof, wall, and floor framing members (studs and joists) vertically throughout the structure so that a single top plate can be used.

2X6 WALL CONSTRUCTION

In most code jurisdictions, 2x6’s can be spaced on 24-inch centers, rather than 16-inch centers used for 2x4’s. The advantages of using 2x6 studs on 24-inch centers are:

- The thicker wall cavity provides room for R-19 or R-21 wall insulation.
- Overall, thermal bridging through studs is reduced due to the higher R-value of 2x6’s and less stud area in the wall.
- Less framing reduces labor costs.
- There is more space for insulating around piping, wiring, and ductwork.

The economics of 2x6 wall construction is favorable primarily in areas with significant winters and homes in which windows and doors occupy 10 percent or less of the total wall area. Walls with substantial window and door area may require almost as much framing as 2x4 walls because each opening can add extra studs. Additionally, the window and door jambs must be wider, requiring the purchase of a jamb extender that increases costs by $12 to $15 per opening.

Thicker insulated sheathing may be a less expensive way to increase overall R-value than 2x6 construction, especially in homes with more window and door area. Another factor to consider is that the interior finish or exterior siding may bow slightly between studs when using 24-inch centers.

WALL INSULATION

- Foam-in-place insulation can be blown into walls and reduces air leakage. Some types use carbon dioxide in the manufacturing process rather than more environmentally harmful gases such as pentane or hydrochlorofluorocarbons.

WALL SHEATHINGS

Some builders use 1½-inch wood sheathing (R-0.8) or asphalt-impregnated sheathing, usually called blackboard (R-1.3), to cover the exterior framing before installing siding. Instead, consider using ½-inch foam insulated sheathing (R-2 to R-3.5). Sheathing thicker than ½ inch will yield even higher R-values. Foam sheathing has these advantages:

- The continuous layer of insulation reduces thermal bridging through wood studs, saving energy and improving comfort.
- It is easier to cut and install than heavier weight sheathing products.
- It protects against condensation on the inside wall by keeping the interior of the wall warmer.
- It usually costs less than plywood or oriented strand board (OSB).

Ensure that the sheathing completely covers, and is sealed to, the top plate and band joist at the floor. Most sheathing products come in 8-, 9-, or 10-foot lengths to allow complete coverage of the wall. Once it is installed, patch all holes, penetrations, and seams with caulk or housewrap tape.

Because of its insulation advantages over plywood and OSB, foam sheathing is best when used continuously in combination with let-in bracing, which provides structural support similar to that offered by plywood or OSB. Some builders use two layers of sheathing—plywood or OSB for structural support and a seam-staggered layer of rigid foam for insulation. When the total depth of the sheathing material exceeds ½ inch, make certain the window and door jambs are adjusted for the total wall thickness. Some flanged windows are readily adaptable to this approach.

2. 1½" / 3½" = 2½" stud (R-11) + 1½" = 3½" stud
3. 1½" / 3½" = 2½" stud (R-11) + 1½" = 3½" stud

INSULATED HEADERS AND LET-IN BRACING

<table>
<thead>
<tr>
<th>Insulated headers</th>
<th>Let-in bracing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double top plate</td>
<td>Metal T-bracing nailed to studs around the extra layer of OSB (R-2.5)</td>
</tr>
<tr>
<td>Metal T-bracing nailed to studs around the extra layer of OSB (R-2.5)</td>
<td>2x4 or 2x6 stud</td>
</tr>
<tr>
<td>1½&quot; metal sheathing or fiberglass felt</td>
<td>1½&quot; metal sheathing or fiberglass felt</td>
</tr>
<tr>
<td>1½&quot; metal sheathing or fiberglass felt</td>
<td>Metal T-bracing nailed to studs around the extra layer of OSB (R-2.5)</td>
</tr>
</tbody>
</table>

Wall DOE 772 MS.p6510/30/00, 11:10 AM 2
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Thicker insulated sheathing may be a less expensive way to increase overall R-value than 2x6 construction, especially in homes with more window and door area. Another factor to consider is that the interior finish or exterior siding may bow slightly between studs when using 24-inch centers.

WALL INSULATION
Some builders use 1½-inch wood sheathing (R-0.6) or asphalt-impregnated sheathing, usually called blackboard (R-1.3), to cover the exterior framing before installing siding. Instead, consider using ½-inch foam insulated sheathing (R-2 to R-3.5). Sheathing thicker than 1/4 inch will yield even higher R-values.

Vapor sheathing has these advantages:

- The continuous layer of insulation reduces thermal bridging through wood studs, saving energy and improving comfort.
- It is easier to cut and install than heavier weight sheathing products.
- It protects against condensation on the inside wall by keeping the interior of the wall warmer.
- It usually costs less than plywood or oriented strand board (OSB).

Ensure that the sheathing completely covers, and is sealed to, the top plate and band joint at the floor. Most sheathing products come in 8-, 9-, or 10-foot lengths to allow complete coverage of the wall. Once it is installed, patch all holes, penetrations, and seams with caulk or housewrap tape.

Metal T-bracing nailed to studs provides a net of let-in bracing. Let-in bracing reduces air leakage. Some types use carbon dioxide in the manufacturing process rather than more environmentally harmful gases such as pentane or hydrochlorofluorocarbons.

Some builders use blow-in insulation (BIBS) that involves blowing insulation into open stud cavities behind a net. This is easier to cut and install than heavier weight sheathing products. It is easier to cut and install than heavier weight sheathing products.

VAPOR BARRIER PLACEMENT BY GEOGRAPHICAL LOCATION
In most cold climates, vapor barriers should be placed on the interior (heat-in-winter) side of walls. However, the map shows that in some southern climates, the vapor barrier should be omitted, while in hot and humid climates, such as along the Gulf coast and in Florida, the vapor barrier should be placed on the exterior of the wall.

<table>
<thead>
<tr>
<th>Region</th>
<th>Vapor Barrier Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior of house, heat-in-winter side</td>
<td>No vapor barrier</td>
</tr>
<tr>
<td>Exterior of house, heat-outside side</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Perm Ratings of Different Materials
<table>
<thead>
<tr>
<th>Material</th>
<th>Perm Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt-impregnated paper backing on insulation</td>
<td>0.40</td>
</tr>
<tr>
<td>Polyethylene plastic (6 mil)</td>
<td>0.06</td>
</tr>
<tr>
<td>Plywood with exterior glue</td>
<td>0.50</td>
</tr>
<tr>
<td>Plastic-coated impregnated foam sheathing</td>
<td>0.4 to 0.8</td>
</tr>
<tr>
<td>Aluminum foil (1.5 mil)</td>
<td>0.05</td>
</tr>
<tr>
<td>Vapor barrier paper or primer</td>
<td>0.45</td>
</tr>
<tr>
<td>Drywall (crudely finished)</td>
<td>50</td>
</tr>
<tr>
<td>Drywall (painted - less paint)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

The home designer has an increasing array of insulation products from which to choose to insulate wood-framed walls. The wide variety of insulation materials often makes it difficult to determine the most cost-effective products and techniques.

Refer to the Model Energy Code (MEC) or DOE Insulation Fact Sheet for R-value recommendations for your climate and building type. The DOE Insulation Fact Sheet (DOE/CE-0180) can be ordered from the Energy Efficiency and Renewable Energy Clearinghouse or accessed from the Internet at www.ornl.gov/roofs+walls.

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Thicker insulated sheathing may be a less expensive way to increase overall R-value than 2x6 construction, especially in homes with more window and door area. Another factor to consider is that the interior finish or exterior siding may bow slightly between studs when using 24-inch centers.

WALL SHEATHINGS

<table>
<thead>
<tr>
<th>Type of Insulation</th>
<th>Incidental Harm</th>
<th>HFP</th>
<th>HFCs</th>
<th>PFCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberglass and rock wool batts</td>
<td>2x4 walls can hold R-13 or R-15 batts; 2x6 walls can have R-19 or R-21 products. Generally, batt insulation is the least expensive wall insulation material but requires careful installation for effective performance (see page 4).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellulose insulation; made from recycled newsprint, comes primarily in loose-fill form. It can be installed in walls using a dry-pack process or a moist-spray technique. It generally costs more than batt insulation, but it offers reduced air leakage through the wall cavity plus improved sound deadening.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiberglass and rock wool loose-fill insulation provide full coverage with a &quot;Blow-in Blanket&quot; System (BIBS) that involves blowing insulation into open stud cavities behind a net.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rigid foam insulation has a higher R-value per inch than fiberglass or cellulose and stops air leaks, but it is considerably more expensive. It is manufactured in sheet-good dimensions and is often used as the outer layer of insulation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The continuous layer of insulation reduces thermal bridging through wood studs, saving energy and improving comfort.

Metal T-bracing nailed to studs provides a net of let-in bracing. Let-in bracing reduces air leakage. Some types use carbon dioxide in the manufacturing process rather than more environmentally harmful gases such as pentane or hydrochlorofluorocarbons.

The home designer has an increasing array of insulation products from which to choose to insulate wood-framed walls. The wide variety of insulation materials often makes it difficult to determine the most cost-effective products and techniques.

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Thicker insulated sheathing may be a less expensive way to increase overall R-value than 2x6 construction, especially in homes with more window and door area. Another factor to consider is that the interior finish or exterior siding may bow slightly between studs when using 24-inch centers.

WALL INSULATION
Some builders use 1½-inch wood sheathing (R-0.6) or asphalt-impregnated sheathing, usually called blackboard (R-1.3), to cover the exterior framing before installing siding. Instead, consider using ½-inch foam insulated sheathing (R-2 to R-3.5). Sheathing thicker than 1/4 inch will yield even higher R-values.

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- It is easier to cut and install than heavier weight sheathing products.
- It protects against condensation on the inside wall by keeping the interior of the wall warmer.
- It usually costs less than plywood or oriented strand board (OSB).

Ensure that the sheathing completely covers, and is sealed to, the top plate and band joint at the floor. Most sheathing products come in 8-, 9-, or 10-foot lengths to allow complete coverage of the wall. Once it is installed, patch all holes, penetrations, and seams with caulk or housewrap tape.

Because of its insulation advantages over plywood and OSB, foam sheathing is best when used continuously in combination with let-in bracing, which provides structural support similar to that offered by plywood or OSB. Some builders use two layers of sheathing—plywood or OSB for structural support and a seam-staggered layer of rigid foam for insulation. When the total depth of the sheathing material exceeds 1½ inch, make certain the framing factor is 15-25%.

Some flanged windows are readily adaptable to this approach.

Insulated headers and let-in bracing

Insulated headers

Let-in bracing

Metal T-bracing nailed to studs provides a net of let-in bracing. Let-in bracing reduces air leakage. Some types use carbon dioxide in the manufacturing process rather than more environmentally harmful gases such as pentane or hydrochlorofluorocarbons.

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WHAT TYPE OF INSULATION SHOULD I USE?

The home designer has an increasing array of insulation products from which to choose to insulate wood-framed walls. The wide variety of insulation materials often makes it difficult to determine the most cost-effective products and techniques.

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WALL INSULATION

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- Complete insulation coverage—advanced framing to maximize insulation coverage and reduce thermal bridging, no gaps or compressed insulation, and continuous insulated sheathing.

**Air Sealing**

Air sealing reduces heat flow from air movement (convection) and prevents water vapor in the air from entering the wall. In a 100-square-foot wall, one cup of water can diffuse through drywall without a vapor barrier in a year, but 50 cups can enter through a 1-inch gap in the wall system. A drainage plane in a wall system creates an easy pathway for water to drain away from the house.

**Control Moisture in Walls**

All climates require these steps:

- Install a polyethylene ground cover on the earth floor of houses with crawlspaces and slope the ground away from the foundations of all houses.
- Use面向staple batts to avoid gaps and compressed insulation, and continuous insulated sheathing.

**Prevent Rain Penetration**

Causes of rain leaks through exterior walls include improper installation of siding materials; poor-quality flashing, weatherstripping, or caulking around joints in the building exterior (such as windows, doors, and plate bottoms); and wind-driven rain that penetrates the exterior finish. To enhance protection against rain penetration, create a drainage plane within the wall system of the home.

**WALL INSULATION FACT SHEET**

Printed with a renewable-source ink on paper containing at least 30% recycled paper with 3% postconsumer waste. October 2008 DOE/GO-10390-0772

For more information, contact:

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<tr>
<th>Thickness</th>
<th>R-value</th>
<th>Cost (¢/square ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot;</td>
<td>11</td>
<td>12.95</td>
</tr>
<tr>
<td>6&quot;</td>
<td>15</td>
<td>17.20</td>
</tr>
<tr>
<td>8&quot; (high density)</td>
<td>18.40</td>
<td>23.64</td>
</tr>
<tr>
<td>10&quot;</td>
<td>20</td>
<td>27.92</td>
</tr>
<tr>
<td>12&quot;</td>
<td>22</td>
<td>31.54</td>
</tr>
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</table>

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

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- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use
- Provides support and grants to states and communities for deployment of energy-efficient technologies and practices

**STEPS FOR EFFECTIVE WALL CONSTRUCTION AND INSULATION**

1. Review the plans and specifications and identify all walls (including bandstands) between conditioned (heated and cooled) spaces and unconditioned spaces (exterior, attic, crawl spaces, garages, and mechanical rooms). Use advanced framing techniques to increase insulation levels and reduce lumber use.

2. Use diagonal corner bracing (let-in bracing) on exterior walls to substitute for corner plywood sheathing and allow continuous insulated sheathing.

3. Use foam sheathing for insulating headers to reduce framing heat loss.

4. Seal all air leaks through walls before insulating, including under the bottom plate, band joint areas between floors, electrical boxes, and all electrical, plumbing, and HVAC penetrations.

5. Use caulk and backer rod or non-expanding spray foam, not insulation, to seal around window and door joints.

6. If features such as stairs or shower/tub enclosures cover exterior walls and do not allow easy installation of insulation after the sheathing is attached, insulate behind these components in advance using R-13 or R-19 batts and cover with a weatherproof barrier (1/2-inch drywall, plastic, or other sheath material).

7. Select insulation levels based on the MEC and the DOE Insulation Fact Sheet.

8. Face-staple batts because side stapling creates channels for air flow and compresses the insulation, thus reducing the R-value. If face stapling is not an option, use unfaced batts or carefully side staple within ½ inch of the stud face.

9. Obtain full coverage of batt or blown wall insulation. Cut batt insulation to fit snugly into non-standard stud spaces and to completely fill cavity.

10. Silt batt insulation to fit around the back and front side of electrical wiring and plumbing without compressing or tearing the insulation.

11. Notch out batt insulation around electrical boxes and use scraps to insulate behind the box.

12. Once the interior drywall is in place, seal all penetrations with durable caulking.

**Effective Wall Insulation**

Proprietary, moisture-protected, and insulated walls help increase comfort, reduce noise, and save on energy costs. However, walls are the most complex component of the building envelope to insulate, air seal, and control moisture. The keys to an efficient wall are:

- Airtight construction-will air leaks seal the wall in the sealed construction and prior to installation.
- Moisture control-exterior drainage system, continuous air barrier, and vapor barrier located on the appropriate side of the wall.
- Complete insulation coverage—advanced framing to maximize insulation coverage and reduce thermal bridging, no gaps or compressed insulation, and continuous insulated sheathing.

**CAUSES OF RAIN PENETRATION**

Rain leaks through exterior walls include:

- Improper installation of siding materials;
- Poor-quality flashing, weatherstripping, or caulking around joints in the building exterior (such as windows, doors, and plate bottoms); and wind-driven rain that penetrates the exterior finish.

**CONTROL MOISTURE IN WALLS**

All climates require these steps:

- Install a polyethylene ground cover on the earth floor of houses with crawl spaces and slope the ground away from the foundations of all houses.
- Install a continuous vapor barrier that has a Perm rating of less than one (see page 3).
- Place a termite shield, sill gaskets, or other vapor-impermeable membrane on top of the foundation wall. This action will prevent moisture from wicking into the framed wall from the concrete foundation wall by capillary action.

**Provide Moisture Control and Insulation in Wall Systems**

- Install a continuous vapor barrier that has a Perm rating of less than one (see page 3).
- Use面向staple batts to avoid gaps and compressed insulation, and continuous insulated sheathing.
- Install a polyethylene ground cover on the earth floor of houses with crawlspaces and slope the ground away from the foundations of all houses.
- Use面向staple batts to avoid gaps and compressed insulation, and continuous insulated sheathing.
- Place a termite shield, sill gaskets, or other vapor-impermeable membrane on top of the foundation wall. This action will prevent moisture from wicking into the framed wall from the concrete foundation wall by capillary action.