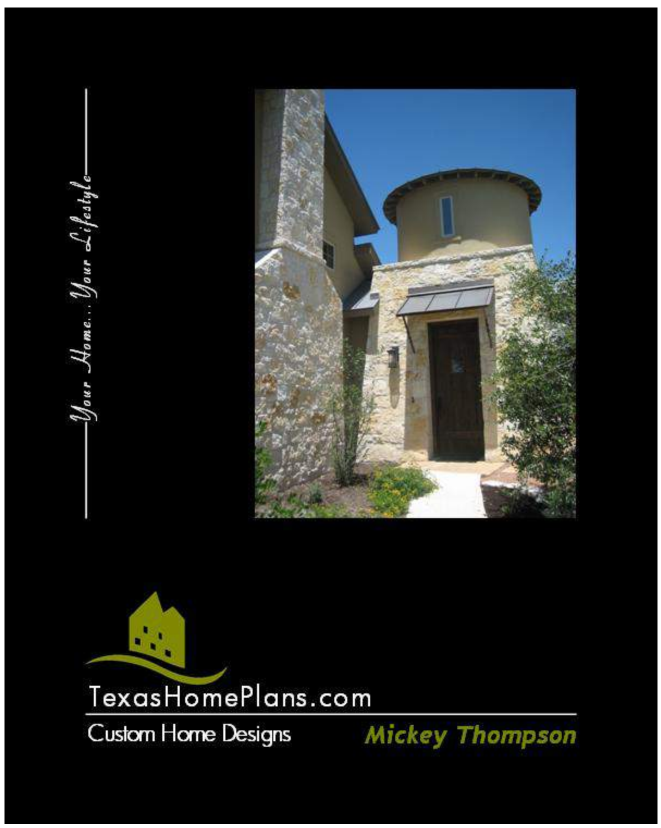
THE HIGH PERFORMANCE HOME MANUAL



THE HIGH PERFORMANCE HOME

MANUAL

This document, along with the detailed drawings, is presented to offer our clients a roadmap in developing an "High Performance" home. This is not necessarily a "Green" home and does not take into consideration air-quality. It focuses on resource efficiency, energy efficiency, water conservation, and "providing for the future"; all of which are a part of a “green” home design, but not exhaustive. In some instances, we have provided “preferred” options as well as less costly means of attaining a near "High Performance" home.

IMPORTANT: It is important to note that this information (these parameters) and the related detailed drawings are specifically for homes that are to be built in Southwest Texas (primarily the "hill country" type climate). The Climate Zone is three (3).

Site Design Features:

- Heat Mitigation:
    a. Shade hardscape (drives, walks, etc.) with shade trees or such.
    b. Utilize turf pavers for drive and/or walks, patios, etc.

Resource Efficiency:

- Drip edge (eaves and gables):
    a. Minimizes wicking and water distribution off roof material, decking, and fascia.
- Roof Water Discharge:
    a. Provide gutters and downspout system with splash blocks (or such) to carry water a minimum of five feet from foundation (or utilize water harvesting system – see below).
- Finish Grade:
    a. Provide a minimum fall of six inches for each ten feet from edge of building.
- Flashing (galvanized metal):
    a. Flash roof valleys.
    b. Flash deck/balcony to building intersections.
    c. Flash at roof-to-wall intersections and roof-to-chimney intersections.
    d. Provide a drip cap above windows and doors that are not flashed or protected by coverings like pent roofs or are recessed in the exterior wall at least 24 inches.
- Roofing:
    a. Composition: Consider Energy Star®”Cool Roofing”. This can reduce heating and cooling costs as much as 20% by reflecting solar heat gain.

b. Metal roof: Develop a vented space between the metal "skin" and the roof decking (and moisture membrane) by using slotted metal furring strips horizontally 16" o.c. (verify spacing with roofing manufacturer.

- Advanced Framing Techniques:
  a. See our framing details for certain types of construction, namely wood or metal stud framing (e.g. as follows). The purpose of this item is to conserve materials.
     1. Staggered stud walls.
     2. Raised plate to enhance and simplify the venting of the attic space.
     3. Raised heel truss to enhance and simplify the venting of the attic space.
     4. Pre-fabricated truss system(s).
     5. Have the contractor and the framing sub-contractor to jointly prepare a framing plan and material list. Assuming they are sufficiently sophisticated trades, this will save you material.

Energy Efficiency:

- Appliances:
  a. All appliances shall meet or exceed Energy Star® rating. These appliances shall include but not be limited to refrigerators, ovens, ranges, dishwashers, clothes washers, dryers, ice makers, beverage coolers, etc.
- Building Systems:
  a. Framing: See detailed drawings concerning the various enhanced framing techniques.
     1. Staggered stud wall *
     2. Raised plate *
     3. Engineered trussed (not shown)

     *Purpose is to develop a structure that will enable an advanced insulation system and enhanced ventilation. Raised plate is designed to prevent insulation filling up air cavity, omit need for baffles and prevent air flow below insulation.

  b. Sheathing: OSB (oriented structural board or plywood; as specified by engineer.
  c. Moisture membrane: Tyvek© or equal.
  d. Flashing of windows and exterior doors: Tyvek© tape (see manufacture's detailed application of said flashing tape.
  e. Roof decking: Tech Shield © (foil back, face down toward attic floor).
  f. Venting (see detailed drawings also):
     1. Soffit: utilize a continuously perforated product, like Hardi Soffit panel.
     2. Ridge vent: continuous (see detailed drawings).
     3. Gable vent: Sizing—Minimum of one inch for each 500 square feet of attic. (If, for some reason, air does not flow by natural convection, use a solar powered vent fan.)

- Fenestration:
    a. Windows and exterior doors:
        1. Must be NFRC-certified (National Fenestration Registration Council) or equivalent, relating to their "*U-Factor*" and "*SHGC*".

            The **U-Factor** is an energy efficiency term measuring the rate of *thermal transmission (*or heat loss). The lower the number, the better (less heat loss).

            The **SHGC** is the *Solar Heat Gain Coefficient*. It is the ration relating the amount of heat gain. The lower the number is, the better the resistance to heat gain.

            Maximum coefficients: (Climate Zone 3) **

	U-Factor	SHGC
Windows and exterior doors	.35	.30
Skylights and "TDD" *	.35	.35

            * TDD = Tubular Daylighting Device
            ** Climate zone (see IECC, www.iccsafe.org)

        2. Window glazing must be "southern" low-e dual pane, insulated.

- Air-Conditioning and Heating:
    a. Sizing of system: Must be according to heating and cooling loads calculated using *ACCA* (Air-Conditioning Contractors of America) **Manual J**, or equivalent.
    b. Utilization of a **two-stage** heat pump unit is recommended for many situations.
    c. Also, we recommend zoning for multi-story structures or wings of homes that will be used infrequently or occasionally.
    d. Ducting system:
        1. To be designed per *ACCA* **Manual D** or equivalent.
        2. We highly recommend that every bedroom, den, study, or such (with doors) have a separate distribution and return air duct system.
        3. Ducts shall be sealed with tape complying with **UL-181**, mastic, gaskets, or an approved system as required by the **ICC IRC**, section M1601.3.1 or ICC IMC, section 603.9 to reduce leakage.
        4. Duct insulation shall be a minimum per **IEC** (International Energy Code).
    e. Geo-thermal, if cost effective, is worthy of consideration.
    f. Solar heating with photo plastic cell panels is not recommended at this time unless electricity is not available to the site.
    g. SEER rating: (Heat pump)
        Climate Zone 3 = *SEER* – 15 to 17
        EER – 12.5

h. Third party testing may be utilized to verify contractor's installation:
    1. Balanced system: The air flow at each supply and return register shall be within 25 % of design flow.
    2. Total air flow shall be within 10 % of design flow.
    3. Building leakage rate: Minimum 2-ACH-50.
    4. Duct system, including air handlers and register boots tested at a 0.1 inch w.g. (25 Pa) shall have a maximum leakage as a percent of system design flow rate of 6 %.

i. Thermostat: We recommend a programmable thermostat that includes humidity monitoring and management.

- Air Sealing: (Air and Thermal Barrier)

a. This is one of the most important, most abused, and least expensive energy saving item if applied correctly. It often requires one to check and re-check the application in order to ensure its effectiveness. (See drawings for correct application.)

    However, if a spray foam insulation is utilized, this process is not necessary, since the foam typically seals the gaps and penetrations. The air permeance of the spray foam to provide this seal must be 0.02 L/s-m² or less @ 75 Pa.

b. Methods of sealing:
    1. Non-expandable spray foam (Latex)
    2. Dupont Weatherization sealant (preferred)
    3. Bottom (toe plate) seal tape

c. What to seal: (see drawings)
    1. **After framing**, but prior to sheathing (see drawings):
        - Framing "T": Spray foam and fill the cavity.
        - Framing corners: Spray foam and fill the cavity.
        - Headers: Utilize spaced headers and fill gaps with foam, or build headers with foam board between members.
    2. **Prior to applying wallboard** (ceiling board) and after electrical rough-in and plumbing top out:

        Toe plate:
        - Foam all penetrations in toe plate. (If a toe plate [sill plate] seal is not used during framing, this gap between the toe (bottom) plate and foundation must be sealed.) It would not be wrong to foam seal it regardless (or Dupont weatherization seal).

        Top plate: Seal all penetrations:
        - Electrical conductor holes
        - Plumbing pipe penetrations
        - Framing gaps (butt joints) of top plate

Sheathing:

- Sheathing butt joints (seal from inside)
- Penetrations (i.e. exterior duplex outlets, wall lights, water faucets, etc)

Studs:

- Holes between stud bays (i.e. electrical or plumbing)
- Any other penetrations

3. **After wallboard** and ceiling board has been installed, air-conditioning ducts penetrations have been made. (see drawings)
   - Ceiling: (Seal around)
     - Recessed light boxes
     - J-boxes (lights, etc.)
     - Air-conditioning returns and distribution duct penetrations
     - Any other penetrations
   - Skylights and other such penetrations
   - Attic stairs

- Moisture Control:

  There are a number of potential moisture penetrations problems:

  a. Walls: House wraps are very helpful in preventing moisture penetration from the outside environment into the wall cavity. The following are recommended (pursuant to the application) to cover the sheathing:
     1. Wood siding, cement fiber board, hardboard siding (we never recommended this product) - use Tyvek® DrainWrap behind these veneer products.
     2. Stucco – use Tyvek® StuccoWrap behind this veneer product.
     3. Stone and/or brick - use Tyvek® HouseWrap with a water drainage product (spacer between masonry and Tyvek membrane which prevents water from being dammed by mortar build-up).
     4. Flashing - Tyvek® Tape according to manufacturer's instructions (window manufacture and Dupont – see www.dupont.com/tyvek).
        - Windows
        - Doors
        - Base flashing for masonry veneers
        - Skylights

- Insulation: (Air and Thermal Barrier)
  a. Installation
     1. Installation "grade" (per **NGBS**) preferably "1"; minimum "2".
     2. Installed according to manufacturer's instructions (or industry standard).

3. Wall cavities shall be enclosed on all (6) six sides and is in substantial contact with the sheathing.
4. See Attached.

b. Types of insulation:
   1. Walls (conventional*):
      - Blow-in (not batts) fiberglass insulation R:22 min.
      - Spray or rigid foam insulation – must have permeance of 0.02 L/s-m² or less at 75 Pa. Further, said material must fill the cavity (leaving no voids). * Other wall systems that satisfy this would include ICF (Insulated Concrete Forms), SIPS (Structural Insulated Panels) which utilize EPS (Extruded Poly-Styrene) material and provide their own air barrier.
   2. Attic floor:
      - Most cost effective insulation is blown-in fiberglass – min R-38. Other substitutes are cellulose (treated for insect abuse).
      - An alternate fiberglass installation would be two layers of R-19 fiberglass batts each layer laid perpendicular to the other. The shortcoming to this is the affect that the roof bracing will interrupt the installation, therefore, leaving gaps.
      - Reportedly the foam insulation in an unclosed situation can be a fire hazard. There also reportedly is a fire retardant that reduces this problem. Not sure of this effectiveness; however, some bio-foams could be utilized in this application.
   3. Attic ceiling:
      - For Southwest Texas, we recommend a vented attic with a radiant barrier surface on the face down side of the roof decking; therefore, we do <u>not</u> recommend insulating the attic ceiling (see "Radiant Barriers" below).
   4. Special items:
      - Attic openings: Seal with a gasket and insulate using rigid foam insulation.
      - Fireplace openings: Utilize glass doors that seal tight and uses outside make-up air.
   5. Miscellaneous items:
      - Take special precautions to properly insulate the area behind a pre-fab tub/shower. Once the unit is installed, it is difficult to insulate and seal properly.
      - Knee walls should receive foil backed sheathing with the foil facing the attic.
   6. Air-conditioning ducts:
      - Preferred = R - 8 minimum
      - Satisfactory = R - 6 minimum

- Radiant Barrier:
    a. Roof Decks:
        1. The preferred system for dealing with thermal heat gain in the attic is the Dupont "Tyvek" AtticWrap – under decking without foil.
        2. The alternate product is a foil backed sheathing (i.e. TechShield).
    b. Knee walls (including such as skylight tunnels):
        Radiant barrier sheathing with foil toward attic.

- Lighting:
    a. All light fixtures shall be Energy Star® approved or equal.
    b. Bulbs:
        1. Efficiency: Bulbs shall provide a minimum of 40 lumens per watt or be solar powered.
        2. Preferred: Utilize LED (Light Emitting Diodes) bulbs where possible.
        3. Secondary will be the use of CFs or Compact Fluorescent bulbs.
        4. In the case of emergency lights, it might be advisable to use halogen or LED. These lights need to shine brightly and quickly. However, the halogen bulbs need to be used only in fixtures that are utilized infrequently.
    c. Occupancy sensors: Utilize occupancy sensors (with adjustable timers) in rooms or locations where one spends a minimal amount of time (i.e. closets, storage rooms, etc.) Lutron makes an occupancy sensor for which the time of occupancy can be adjusted.
    d. Outdoor lighting:
        1. NGBS suggests occupancy sensors or motion sensors to be utilized for outdoor lighting. Assuming we are referring to "Emergency Lights" (flood lights), if the home is in an area where deer are prevalent, these are not a good option. We suggest using only a switch to be conveniently activated when the need arises and only use these fixtures for security lighting.
        2. Decorative light fixtures which one might desire illuminated all night could be controlled (activated and turned off) via a photo-electric cell switch that can be screwed into the light fixture.
        3. Hands-free lighting: There are situations where one would like an area lit as he approaches (i.e. outdoor trash bin). For this lighting, an occupancy sensor activating a LED bulb would be recommended.
    e. Recessed lights: It is advisable to minimize the number of these fixtures. Since the rough-in box penetrates the ceiling board, it is difficult to adequately seal and insulate them.

- Plumbing (energy related):
    a. Water Heaters:

1. Electric – We recommend the "Marathon" by Rheem or equal. It has a fiberglass tank (rust free), polyurethane insulation, polyethylene shell. The efficiency rate is .90 to .94 EFI; recovery rate is 20 GPN @ 90° (www.rheem.com). The energy factor should be a minimum of .95 for 30 to 40 gallons; .94 for 40 to 50 gallons; .92 above.
2. For weekend cabins, out buildings, "wings" of a home that will be seldom utilized, we recommend gas (or propane) fired tank-less water heaters.
3. Natural gas or propane – The propane industry brags that a propane water heater is the most efficient and effective use of propane. The energy factor should be a minimum of .94 (30 to 40 gallons); .62 for 40 to 50 gallons; .60 above.

   The discussion as to which is more energy efficient (cost effective) between electricity and natural gas or propane is in much debate. For now, natural gas if available; however, we do not know what the future holds. We will leave the speculation up to the client.

4. Solar powered and wind powered – We believe that neither of these are yet cost effective and require management and maintenance that the typical homeowner might not appreciate.

b. Plumbing System:
   1. Keep runs for hot water lines 40 ft. or less from water heater to kitchen and bathrooms. (The shorter the distance, the better, 30 ft. preferred.)
   2. Special piping system designs are recommended as follows:
      - Structured-type plumbing with demand controlled hot water loops, in which the volume of water contained in the pipe and fixture fittings downstream of the re-circulating trunk link is a maximum of 4 cups (57.75 cubic inches) or (0.25 gallons) of water, or
      - Engineered parallel piping system (i.e. manifold system) in which the hot water line(s) distance from the water heater to the parallel piping system is less than 15 ft. and the parallel piping to the fixture fittings contain a maximum of 8 cups (0.50 gallons).
      - Central core plumbing system with all plumbing fixture fittings (e.g. faucets, showerheads) located such that the volume of water contained in each pipe run between the water heater and fixture fitting is a maximum of 6 cups (0.38 gallons).
   3. Alternates to runs in excess of 40 ft.:
      When or if hot water pipe runs exceed 40 ft., consider:
      - Utilizing a tank-less water heater at point of use being served by cold water (could be boosted by heat recovery in stored tank or solar system booster).
      - Or, install an on-demand hot water re-circulating system.

4. Water heating energy is considered most efficient when the water lines are installed in the slab vs. the attic in Climate Zone 3.
5. Heat recovery: If the project will utilize an electric water heater and a heat pump air-conditioning system, then one might consider a "Heat Recovery" system which circulates water through the heat pump coils and heats the water. Keep in mind, that this is only effective when the compressor is in operation. It will not heat the water when it is not running.

Water Efficiency:

- Water Conserving Appliances: Washing machines and dishwashers shall be Energy Star® rated (or equivalent) with respect to water conservation, as well as energy conserving. A food disposer is recommended for its water conserving quality.
- Water Conserving Plumbing Fixtures:
  a. Showerheads
     Preferred: The total showerhead flow rate at any point in time in each shower compartment is 1.6 to less than 2.5 gpm. The total flow rate is tested at 80 psi (552 kPa) in accordance with ASME A112.18.1. Showers are equipped with an automatic compensating valve that complies with ASSE 1016 or ASME A112.18.1 and specifically designed to provide thermal shock and scald protection at the flow rate of the showerhead.

     Good: Showerhead flow rate: 2.0 to less than 2.5 gpm

     Fair: Showerhead flow rate: 1.6 to less than 2.0 gpm

     Note: One (1) gallon per minute = 3.785 liters/minute.

  b. Faucets: Water-efficient lavatory faucets shall be 1.5 gpm (5.68 L/m) or less maximum flow rate when tested at 60 psi (414 kPa) in accordance with ASME A112.18.1 are installed.
  c. Water Closets: A water closet is installed with an effective flush volume of 1.28 gallons (4.85 L) or less when tested in accordance with ASME A112.19.2 (all water closets) and ASME A112.19.14 (all dual flush water closets), and is in accordance with EPA WaterSense Tank-Type High-Efficiency Toilet.
  d. Urinals: A urinal shall be installed with a flush volume of 0.5 gallons (1.9 L) or less when tested in accordance with ASME A112.19.2.
  e. Irrigation Systems: For each landscape type there shall be an individual run and all runs shall be low-volume.

     Preferred: The system shall be designed in accordance with EPA (Environmental Protection Agency) WaterSense requirements or equivalent.

Suggestion: Utilize irrigation controller with a rain sensor to measure ET (EvapoTranspiration).

f. Automatic shut off water devices:
    1. Excess water flow shut off, or
    2. Leak detection system
       Note: If a fire sprinkler system is installed, ensure that these devices will not interfere with the system.

g. Grey Water Reclamation: See "***Planning for the Future***" below.
h. Rainwater Harvesting: We highly recommend a rainwater harvesting system for the following uses:
    1. Water closets
    2. Irrigation
    3. Hose bibs and/or
    4. Clothes washing

   Utilizing water harvesting for potable water uses (drinking, showers, and dishwashing) as well as non-potable uses first requires a large volume of storage tanks. It also involves a rather sophisticated mechanical system for managing the sanitation of the water. Most will not want to spend their time doing so. The exception, naturally is where there is no public or private sources of water available.

Planning For the Future:

Some of the below mentioned items (systems) should be strongly considered prior to construction, even if not utilized at this time.

- Grey Water utilization: (See above)

  We recommend that one consider a system that would utilize a portion of the grey water that is only, say, from one side of the house (the side which would produce the most volume of waste water - usually the kitchen side). The purpose of this is that grey water systems require a separate drain system for the grey water and for the brown water. In effect, the commodes and kitchen sink have to have their own drain system and cannot be used for secondary use. So to have two systems for the entire house gets rather expensive.

  Assuming two drain systems have been developed and you are not ready to utilize the grey water, you will want to tie the grey water system back into the brown water system until you are ready to use this water. At this time a good grey water system will have a filtering system (requires maintenance) and a temporary holding tank (currently the water must be dispensed within 24 hours) into the sun exposed environment. The system therefore needs an overflow option once the holding tank becomes full. So the system at this point needs to divert waste into the brown water system.

Note: At this time systems for filtering water for even commode usage is not feasible for residential use. It is not cost effective.

- Separate Light Panel with a transfer switch:
  If the lights circuits (and perhaps refrigerator) can be separated from the power, it could serve several different uses:
  a. Emergency generator (natural gas or propane fueled): The contractor will need to provide a receptacle for the generator plug and a transfer switch that will transfer from public power to generator power.
  b. Low Voltage, LED lighting system: As LED light bulbs decline in price, one will be able to utilize a LED lighting system powered by a **low-voltage** system. A transfer switch installed during construction would make this transition easier when needed.
  c. Solar or Wind power: Neither of these is cost effective at this time; however, could become so in the future. You might consider providing a transfer switch to accommodate future battery source of fuel for the lighting.
- Rainwater Harvesting:
  (also see "Water Efficiency: f" above)

  Think ahead of how you desire to utilize the harvested rainwater. Even if it will not now be developed at the time of initial construction, it is wise to prepare the plumbing system during construction to receive the water from the harvested water storage tank. If the water is to be utilized for irrigation (and/or hose bibs) then this needs to have a separate line with a valve that can switch back and forth between public (or well) water to harvested water.
  a. If also to be used for commode usage, we recommend a modified manifold system that would have three options:
     1. Hose bibs (and irrigation)
     2. Commode
     3. Other (the remainder of the system)
  b. If the system will be utilized for potable water in addition to the other, then only a transfer valve will be needed.
  c. If the system will utilize the potable water in addition to one of the other options, then as mentioned above, separate systems with transfer valves will be required.
  d. Underground PVC piping should be installed under walks, driveways, etc. to enable easier future installation of a harvesting system. Tank locations (and quantity) shall be established up front (during construction). Typically the water harvesting tank should be 75 ft. away from a septic system.
- Whole House Fan:

Consider a whole house fan. One must utilize non-air-conditioned air movement in order for the whole house fan to be of benefit. Things to consider:

a. Location. Usually near center of the house.
b. The fan should be located remotely from its penetration through the ceiling; and perhaps a bend in the duct between the two. The purpose is to reduce noise.
c. The louvered vent must seal very well.
d. Assuming there is a vented attic, exhausting the air could force the hot air in the attic to move out replacing it with cooler air. (Some fire codes might have a problem with this).

SYLLABUS:

ACH=Air Changes per hour (ACH at 50 Pa) ,measurement of a building's airthightness.
Pa=Pascal (pressure measurment
IEC = International Energy Code
NGBS = National Green Building Standard - 2008
ICF = Insulated Concrete Forms
SIPS = Structural Insulated Panels
EPS = Extruded Poly-Styrene
LED = Light Emitting Diodes
ASSE = American Society of Safety Engineers
ASME = American Society of Mechanical Engineers
EPA = Environmental Protection Agency
NFRC = National Fenestration Registration Council
SHGC = Solar Heat Gain Coefficient
TDD = Tubular Daylighting Device
ET = evapotranspiration
Gpm=Gallons per minute

http://www.greenbuildingadvisor.com/blogs/dept/musings

Musings of an Energy Nerd

Understanding Energy Units

Posted on June 22, 2012 by Martin Holladay, GBA Advisor

If you've ever been confused by the difference between 500 Btu and 500 Btu/h, you probably can use a handy cheat sheet to explain energy units. As a guide through the thorny thickets of energy, power, and the units used to measure them, I've assembled some questions and attempted to answer them.

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Joe Lstiburek Discusses Basement Insulation and Vapor Retarders

Posted on June 15, 2012 by Martin Holladay, GBA Advisor

Dr. Joseph Lstiburek needs little introduction. The well-known Canadian engineer is a principal of the Building Science Corporation in Massachusetts. He's also a regular GBA podcaster and *Fine Homebuilding* author.

On Wednesday, June 6th, I attended an all-day building science class presented by Dr. Joe in Westford, Massachusetts. As usual, his presentation combined salty language, corny jokes, light-hearted insults, and rock-solid building science information.

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Broken Ventilation Equipment Goes Unnoticed for Years

Posted on June 8, 2012 by Martin Holladay, GBA Advisor

Years ago, when I worked as a home inspector, I was hired to perform a capital needs assessment at a Buddhist retreat center in rural Vermont. In an obscure mechanical closet I discovered a heat-recovery ventilator that the facilities manager didn't even know existed.

The HRV had been installed at least a dozen years before. The filter, which had never been changed since the day it was installed, was totally clogged. The HRV was no longer working — perhaps the motor had burned out years ago. I advised the owners to call an HVAC contractor to have the unit serviced.

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Belgian Passivhaus is Rendered Uninhabitable by Bad Indoor Air

Posted on June 1, 2012 by Martin Holladay, GBA Advisor

The first single-family Passivhaus in the U.S. was completed by Katrin Klingenberg in 2004. Klingenberg's superinsulated home in Urbana, Illinois includes two unusual features: a ventilation system that pulls fresh outdoor air through a buried earth tube, and walls that include an interior layer of OSB. These details were not invented by Klingenberg; she adopted practices that were commonly used by European Passivhaus builders.

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[Window-Mounted Air Conditioners Save Energy](#)

Posted on May 25, 2012 by [Martin Holladay, GBA Advisor](#)

Window-mounted air conditioners (also called room air conditioners) aren't particularly efficient; the best available models have an EER of about 10 or 11. Central air conditioners (also called whole-house air conditioners or split-system air conditioners) are significantly more efficient; it's possible to buy one with an EER of 14 or even 15.

So if you care about energy efficiency, you should use a central air conditioner, not a window air conditioner — right? Well, not necessarily.

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[Choosing an Energy-Efficient Refrigerator](#)

Posted on May 18, 2012 by [Martin Holladay, GBA Advisor](#)

Because federal appliance efficiency standards have gotten more stringent, new refrigerators use much less energy than those sold in the 1970s. These days, it's fairly easy to find a full-size refrigerator that requires only 350 to 500 kWh per year — significantly less than the 1,000 kWh/year energy hogs of yore.

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When Do I Need to Perform a Load Calculation?

Posted on May 11, 2012 by Martin Holladay, GBA Advisor

In my last three blogs, I discussed the basics of heat-loss and cooling load calculations. The unfortunate truth about these calculations is that fast methods aren't particularly accurate, and accurate methods require making measurements, checking specifications, and entering data into a computer program — in other words, a significant investment of time.

So how should builders go about making these calculations?

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Calculating Cooling Loads

Posted on May 4, 2012 by Martin Holladay, GBA Advisor

A few decades ago, residential air conditioning was very rare in colder areas of the U.S., and cooling load calculations were usually unnecessary. These days, however, new U.S. homes routinely include air conditioning equipment, even in Minnesota, so most U.S. builders are faced with the need to calculate cooling loads.

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Report from the NAHB Green Conference

Posted on May 1, 2012 by Martin Holladay, GBA Advisor

The NAHB Green conference is being held this week (April 29 to May 1, 2012) in Nashville, Tennessee. Several GBA employees and bloggers — including Dan Morrison, Michael Chandler, Peter Yost, Ted Clifton, and me — are attending.

Nashville has a number of famous buildings, including a full-scale replica of the Parthenon. Nashville's Parthenon isn't made of quarried marble, however; it's made of concrete. So how's the concrete quality? Do the columns resemble marble?

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How to Perform a Heat-Loss Calculation — Part 2

Posted on April 27, 2012 by Martin Holladay, GBA Advisor

To continue last week's discussion of heat-loss calculation methods, let's consider a simple rectangular building, 20 feet by 30 feet, with 8-foot ceilings. Let's assume it has an 8-foot-high basement with uninsulated concrete walls; the below-grade portion of the basement is 7 feet high, with 1 foot above grade.

To keep things simple, we'll assume that the house has a flat roof, and that each side of the house has two windows (each 3 ft. by 4 ft.) and one door (3 ft. by 7 ft.). The house doesn't have a chimney.

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About the Author

Martin Holladay has worked as a plumbing wholesale counterperson, roofer, remodeler, and builder. He built his first passive solar house in northern Vermont in 1974, and has lived off the grid since 1975. In 1980, Holladay bought his first photovoltaic module, which is still producing electricity after 29 years of service. Read more...

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- Large-Scale Solar at Fort Bliss in Texas
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Explanation of Blower Door Terms and Results

Information taken from "TECTITE BUILDING AIRTIGHTNESS TEST" by The Energy Conservatory

AIRFLOW AT 50 PASCALS

CFM50: This is the airflow (in Cubic Feet per Minute) needed to create a change in building pressure of 50 Pascals. CFM50 is the most commonly used measure of building airtightness.

ACH at 50 Pa: The Air Changes per Hour (ACH at 50 Pa) is another commonly used measure of building airtightness. ACH at 50 Pa is the number of complete air changes that will occur in one hour with a 50 Pascal pressure being applied uniformly across the building envelope. ACH at 50 Pa is a useful method of adjusting (or normalizing) the leakage rate by the size (volume) of the building. If you did not enter the building volume on the Building Information screen, ACH50 will not be calculated.

ACH at 50 Pa = (CFM50 x 60) / building volume in cubic feet

CFM50/square foot of floor area: This is the CFM50 reading for the building divided by the floor area of the building. CFM50/square foot adjusts (or normalizes) the leakage rate by the size (floor area) of the building. If you did not enter the floor area on the Building Information screen, this variable will not be calculated.

CFM50/square foot = CFM50 / floor area in square feet

CFM50/square foot of surface area (MLR): Also known as the Minneapolis Leakage Ratio (MLR), this is the measured CFM50 divided by the above grade surface area of the building. MLR is a useful method of adjusting (or normalizing) the leakage rate by the amount of envelope surface through which air leakage can occur. The MLR has been particularly useful for weatherization crews working on wood frame buildings. Experience to date has shown that for buildings with a MLR above 1.0, very large cost-effective reductions in infiltration can often be achieved using blower door guided infiltration and insulation techniques. In buildings with a calculated MLR in the 0.5 to 1.0 range, it is often more difficult to achieve economical improvements in airtightness. If you did not enter an Above Grade Surface Area value into the Building Information screen, MLR will not be calculated.

MLR = CFM50 / above grade surface area in square feet

LEAKAGE AREAS

Once the leakage rate for the building has been measured, it is useful to estimate the cumulative size (in square inches) of all leaks or holes in the building's air barrier. The estimated leakage areas not only provide us with a way to visualize the physical size of the measured holes in the building, but they are also used in infiltration models to estimate the building's natural air change rate (i.e. the air change rate under natural weather conditions).

The results screen includes two leakage area calculations, based on differing assumptions about the physical shape of the hole, which are compatible with the two most commonly used infiltration models.

Equivalent Leakage Area (EqLA):EqLA is defined by Canadian researchers at the Canadian National Research Council as the area of a sharp edged orifice (a sharp round hole cut in a thin plate) that would leak the same amount of air as the building does at a pressure of 10 Pascals. The EqLA is used in the AIM infiltration model (which is used in the HOT2000 simulation program).

Effective Leakage Area (ELA): ELA was developed by Lawrence Berkeley Laboratory (LBL) and is used in their infiltration model. The Effective Leakage Area is defined as the area of a special nozzle-shaped hole (similar to the inlet of your Blower Door fan) that would leak the same amount of air as the building does at a pressure of 4 Pascals.

Notes on Leakage Areas: When using leakage area calculations to demonstrate physical changes in building airtightness, we recommend using the EqLA measurement. Typically, EqLA more closely approximates physical changes in building airtightness.

For example, if you performed a Blower Door test, and then opened a window to create a 50 square inch hole and repeated the test, the estimated EqLA for the building will have increased by approximately 50 square inches from the initial test results.

BUILDING LEAKAGE CURVE

Coefficient (C) and Exponent (n):Once an automated airtightness test sequence (or manual entry of data into the table) has been completed, a best-fit line (called the Building Leakage Curve) is drawn through the collected Blower Door data. The Building Leakage Curve can be used to estimate the leakage rate of the building at any pressure. If you conduct a single point test (i.e. input a single target pressure into the custom pressure list), the program assumes an exponent (n) of 0.65 in its calculation procedures.

The Building Leakage Curve is defined by the variables Coefficient (C) and Exponent (n) in the following equation:

$Q = C \times P^n$
where: Q is airflow into the building (in CFM).

C is the Coefficient.
P is the pressure difference between inside and outside of the building.
n is the Exponent.

Example: Use the Building Leakage Curve to estimate the exhaust fan airflow in a building needed to create a 5 Pa negative pressure. From our Blower Door test we determined the following Building Leakage Curve variables.

C = 110.2 n = 0.702 From the equation above:

Airflow (at 5 Pa) = 110.2 x 5^.702 = 341 CFM. In other words, we estimate from the Building Leakage Curve that it would take exhaust fans with a combined capacity of 340 CFM to cause a 5 Pa pressure change in this building.

Correlation Coefficient: The correlation coefficient is a measure of how well the collected Blower Door data fit onto the best-fit Building Leakage Curve. The closer all data points are to being exactly on the Building Leakage Curve, the larger the calculated correlation coefficient (note: the largest possible value for the correlation coefficient is 1.0). Under most operating conditions, the correlation coefficient will be at least 0.99 or higher.

Testing in very windy weather can sometimes cause the correlation coefficient to be less than 0.99. In this case, you may want to repeat the test, or increase the number of Samples Per Station. Achieving a correlation coefficient of 0.99 or higher is particularly important in the estimation of Leakage Areas, or when using the Building Leakage Curve to estimate leakage rates at low building pressures.

ESTIMATED ANNUAL INFILTRATION

Estimating the natural infiltration rate of a building is an important step in evaluating indoor air quality and the possible need for mechanical ventilation. Blower Doors do not directly measure the natural infiltration rates of buildings. Rather, they measure the building leakage rate at pressures significantly greater than those normally generated by natural forces (i.e. wind and stack effect). Blower Door measurements are taken at higher pressures because these measurements are highly repeatable and are less subject to large variations due to changes in wind speed and direction.

In essence, a Blower Door test measures the cumulative hole size, or leakage area, in the building's air barrier (see Leakage Areas above). From this measurement of leakage area, estimates of natural infiltration rates can be made using mathematical infiltration models. TECTITE uses the calculation procedure contained in ASHRAE Standard 136-1993 to estimate the average annual natural infiltration rate of the building.

CFM, ACH and CFM/person: The estimated annual natural infiltration rate (based on ASHRAE Standard 136-1993) is expressed in Cubic Feet per Minute (CFM), Air Changes Per Hour (ACH), and CFM per person. When determining occupancy for the CFM/person calculation, the program uses the number of bedrooms plus one, or the number occupants, whichever is greater.

Notes on Estimated Infiltration Rates: Daily and seasonal naturally occurring air change rates will vary dramatically from the estimated average annual rate calculated here due to daily changes in weather conditions(i.e. wind and outside temperature).

The physical location of holes in the building air barrier compared to the assumptions used in the infiltration model will cause actual annual infiltration rates to vary from the estimated values. Research done in the Pacific Northwest on a large sample of houses suggests that estimated infiltration rates for an individual house (based on a Blower Door test) may vary by as much as a factor of two when compared to measured infiltration rates using PFT tracer gas. (PFT tracer gas tests are one of the most accurate methods of measuring actual natural infiltration rates). The annual average infiltration estimates from ASHRAE Standard 136-1993 should be used only for evaluating detached single-family dwellings, and are not appropriate for use in estimating peak pollutant levels or energy loss due to infiltration. If any of the building leakage is located in the forced air distribution system, actual air leakage rates may be much greater than the estimates provided here. Duct leaks result in much greater air leakage because they are subjected to much higher pressures than typical building leaks.

ESTIMATED DESIGN INFILTRATION

In addition to estimating an annual infiltration rate above, the program estimates the design winter and summer infiltration rates for the building. The design infiltration rates are the infiltration rates used to calculate winter and summer peak loads for purposes of sizing heating and cooling equipment. The calculated design infiltration rates can be used in ACCA Manual J load calculations in lieu of the estimation procedures listed in Manual J. The estimation procedure uses the design wind speed and temperature difference values input into the Climate Information Screen, and are based on the calculation procedures listed in the ASHRAE Fundamentals Handbook, Chapter on Infiltration and Ventilation.

Winter and Summer: CFM, ACH: The estimated design infiltration rates are expressed in Cubic Feet per Minute (CFM), and Air Changes per Hour (ACH).

MECHANICAL VENTILATION GUIDELINE

It is possible (even easy) to increase the airtightness of a building to the point where natural air change rates (from air leakage) may not provide adequate ventilation to maintain acceptable indoor air quality. To help evaluate the need for mechanical ventilation in buildings, national ventilation guidelines have been established by ASHRAE. The recommended whole building mechanical ventilation rate presented in this version of TECTITE is based on ASHRAE Standard 62-2003, and is only appropriate for low-rise residential structures.

Recommended Whole Building Mechanical Ventilation Rate: This value is the recommended whole building ventilation rate to be supplied on a continuous basis using a mechanical ventilation system. The recommended mechanical ventilation rate is based on 7.5 CFM per person (or number of bedrooms plus one, whichever is greater), plus 1 CFM per 100 square feet of floor area. This guideline assumes that in addition to the mechanical ventilation, natural infiltration is providing 2 CFM per 100 square feet of floor area.

For buildings where the estimated annual natural infiltration rate (based on the Blower Door test) is greater than 2 CFM per 100 square feet of floor area, the recommended mechanical ventilation rate is reduced to provide ventilation credit for excess infiltration. In these cases, the recommended mechanical ventilation rate is reduced by the following amount:

0.5 x (est. annual natural infiltration rate (CFM) minus 0.02 CFM x sq. ft. of floor area)

Notes on the Ventilation Guideline: ASHRAE Standard 62.2-2003 also contains requirements for local kitchen and bathroom mechanical exhaust systems. These local exhaust systems may be incorporated into a whole building ventilation strategy. Consult Standard 62.2-2003 for more information on ventilation strategies and specific requirements and exceptions contained in the Standard.

Compliance with the ventilation guideline does not guarantee that a moisture or indoor air quality (IAQ) problem will not develop. Many factors contribute to indoor air quality including ventilation rates, sources and locations of pollutants, and occupant behavior. Additional testing (including combustion safety testing) is needed to fully evaluate air quality in buildings. In many cases, a combination of pollutant source control and mechanical ventilation will be required in order to ensure adequate indoor air quality.

Previous versions of TECTITE used ASHRAE Standard 62-1989 to determine an annual ventilation guideline. The Standard 62-1989 guideline (which was superceded by Standard 62.2-2003) was based on 15 CFM per person or 0.35 Air Changes per Hour (whichever was greater).

ESTIMATED COST OF AIR LEAKAGE

The program estimates the annual cost associated with air leakage, both for heating and cooling. Because these cost estimates are based on estimated infiltration rates and many other assumptions, actual cooling costs may differ significantly from the estimates. The equations used to calculate the annual cost for air leakage are:

$$\text{Annual Heating Cost} = \frac{26 \times \text{HDD} \times \text{Fuel Price} \times \text{CFM50}}{\text{N} \times \text{Seasonal Efficiency}} \times 0.6$$

- HDD is the annual base 65 F heating degree-days for the building location.
- The Fuel Price is the cost of fuel in dollars per Btu.
- N is the Energy Climate Factor from the Climate Information Screen (adjusted for wind shielding and building height). See Appendix E of the Model 3 Blower Door Operation Manual for more information on this calculation procedure.
- Seasonal Efficiency is the AFUE rating of the heating system.

$$\text{Annual Cooling Cost} = \frac{.026 \times \text{CDD} \times \text{Fuel Price} \times \text{CFM50}}{\text{N} \times \text{SEER}}$$

- CDD is the base 70 F cooling degree days for the building location.
- The Fuel Price is the cost of electricity in dollars per kwh.
- N is the Energy Climate Factor from the Climate Screen (adjusted for wind shielding and building height). See Appendix E of the Model 3 Blower Door Operation Manual for more information on this calculation procedure.
- SEER is the SEER rating for the air conditioner.

Note: The Cooling Cost procedure does not include latent loads. In humid climates, latent loads due to air leakage can be greater than the sensible loads, which are estimated by this procedure.

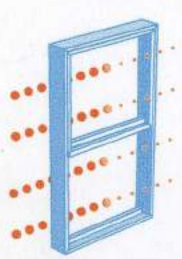
The Facts About
Windows & Heat Loss

We spend millions of dollars every year to heat our homes and businesses. That is why it is so important to understand the role that windows play in how buildings use energy. One of the best ways to measure the effect of windows on building energy use is known as a **U-factor rating**.

Windows Are Not Like Walls and Insulation

The high prices for natural gas, electricity, and home heating fuel that followed the first oil embargo in the early 1970s made energy a high profile, pocketbook issue. Many consumers became aware of **R-values** – a measurement of a product's resistance to heat loss – and learned that materials (floors, walls, and roofs) with higher R-values are more energy efficient. R-values are still used by many building materials, especially insulation.

Windows are very different from insulation in walls and ceilings. Windows let the light in and allow people to see out, and they interact with their environment in ways that insulation does not. They react to outside air temperatures, sunlight, and wind, as well as indoor air temperatures and occupant use. Windows are strongly affected by solar radiation and the airflow around them. R-value does not accurately reflect this interaction. Therefore, the window industry measures the energy efficiency of their products in terms of **thermal transmission**, or **U-factor**. U-factor measures the rate of heat transfer through a product. Therefore, *the lower the U-factor, the lower the amount of heat loss*, and the better a product is at insulating a building.



What's the Difference between U-factor and R-value?

The biggest difference between U-factor and R-value is that U-factor measures the rate of heat transfer (or loss) while R-value measures the resistance to heat loss. R-value is a measure of **conductivity**.

A product with high conductivity will transfer heat quickly, like a hot pan on the stove or a single pane of glass on a cold day. U-factor, on the other hand, takes into account more than conductivity. It also is affected by the airflow around the window and the **emissivity** of the glass.

Emissivity is the ability of a product to absorb certain types of energy (specifically infrared) and radiate that energy through itself and out of a room. A product with high emissivity, such as one pane of clear glass, will transfer over 84 percent of the infrared energy from a warm room outside to the cold air. The lower the conductivity and emissivity of the glass, the lower the rate of heat loss and the lower the U-factor.

There have been significant technological developments over the last 10 years involving **low emissivity (low-e) coatings** on the glass. There are now many glass products available with these low-e coatings, which are typically used in dual pane windows and insulating glass units.

Where NFRC-Certified Products Are Required or Encouraged

NFRC administers an independent, uniform rating and labeling system for the energy performance of fenestration products, including windows, curtain walls, doors, and skylights. For more information on NFRC, please visit our Web site at www.nfrc.org or contact NFRC directly at 301-589-1776.

NFRC 100 – The Standard For U-factor Ratings

Prior to the formation of NFRC, window manufacturers used different tools to measure and report the energy efficiency of their products. In 1993, NFRC developed the first consensus method for evaluating the thermal transmission of windows. NFRC 100 "*Procedures for Determining Fenestration Product U-factors*" is now the accepted standard for rating windows, doors, and skylights for U-factor. NFRC 100 established standardized environmental conditions, product sizes, and testing requirements, so that architects, specifiers, builders, and consumers can make an informed choice by comparing the performance of different products fairly and accurately. One of the most important improvements NFRC 100 offered the industry was that the standard determined the heat loss of the entire window unit, including both the frame and the glass. As a result, consumers were provided with a more accurate, credible, and uniform energy rating for fenestration products.

Certified Window Performance

A window rated in accordance with NFRC 100 gets credit for all of the energy efficient features, including low-e glass, thermally improved frames, etc. When comparing window performance, always look for products that have U-factors determined in accordance with NFRC 100. For more assurance that the window has been rated accordingly, ask for NFRC Certified Performance – which is indicated by the use of an **NFRC Label** or **Label Certificate**.

Manufacturers who participate in the NFRC Certification Program have their products listed in the NFRC *Certified Products Directory*, which contains thousand of certified products. The *Directory* is available on-line at **www.nfrc.org**.

NFRC
National Fenestration Rating Council®
CERTIFIED

World's Best
Window Co.

Millennium 2000+
Vinyl-Clad Wood Frame
Double Glazing • Argon Fill • Low E
Product Type: **Vertical Slider**

ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
(A) **0.35**	(B) **0.32**
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance	Air Leakage (U.S./I-P)
(C) **0.51**	(D) **0.2**
Condensation Resistance	
(E) **51**	

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. Consult manufacturer's literature for other product performance information.
www.nfrc.org

(A) ***U-Factor*** *measures how well a product prevents heat from escaping a home or building. U-Factor ratings generally fall between 0.20 and 1.20. The lower the U-Factor, the better a product is at keeping heat in. U-Factor is particularly important during the winter heating season. This label displays U-Factor in U.S. units. Labels on products sold in markets outside the United States may display U-Factor in metric units.*

(B) ***Solar Heat Gain Coefficient*** *(SHGC) measures how well a product blocks heat from the sun. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the better a product is at blocking unwanted heat gain. Blocking solar heat gain is particularly important during the summer cooling season.*

(C) ***Visible Transmittance*** *(VT) measures how much light comes through a product. VT is expressed as a number between 0 and 1. The higher the VT, the higher the potential for daylighting.*

(D) ***Air Leakage*** *(AL) measures how much outside air comes into a home or building through a product. AL rates typically fall in a range between 0.1 and 0.3. The lower the AL, the better a product is at keeping air out. AL is an optional rating, and manufacturers can choose not to include it on their labels. This label displays AL in U.S. units. Labels on products sold in markets outside the United States may display AL in metric units.*

(E) ***Condensation Resistance*** *(CR) measures how well a product resists the formation of condensation. CR is expressed as a number between 1 and 100. The higher the number, the better a product is able to resist condensation. CR is an optional rating, and manufacturers can choose not to include it on their NFRC labels.*

The Facts About
Solar Heat Gain & Windows

Today and every day, the sun rains down immense quantities of energy on the earth. In colder climates and winter months, this energy can be quite beneficial, warming our homes and reducing our need for heating fuel. In some climates (with the proper designs) solar energy can be used to heat buildings and generate hot water. And there is technology available to create electricity with sunlight (photovoltaics). However, for homes in the warm summer months and for commercial office buildings most of the year, unmanaged solar energy creates a thermal heating load that must be removed by air-conditioning.

The majority of this solar heat gain comes through your windows, glazed doors, and skylights (also called fenestration). The most effective way to manage the amount of solar gain that enters your home or office is to block it before it gets into the building. One way to accomplish this is to install awnings or other exterior shading devices. A simpler method, however, is to simply specify and install windows that have a low Solar Heat Gain Coefficient (or SHGC) rating.

The National Fenestration Rating Council (NFRC) has established a standard method for rating the amount of solar heat gain that is admitted through a window. This standard is **NFRC 200** "*Procedure for Determining Fenestration Product Solar Heat Gain Coefficients at Normal Incidents.*" This standard provides a uniform methodology for indicating the ability of a window, skylight or other glazed product to admit solar heat gain. Therefore, the **lower** the SHGC rating, the **better** the ability of the window to block the heat from the sun.

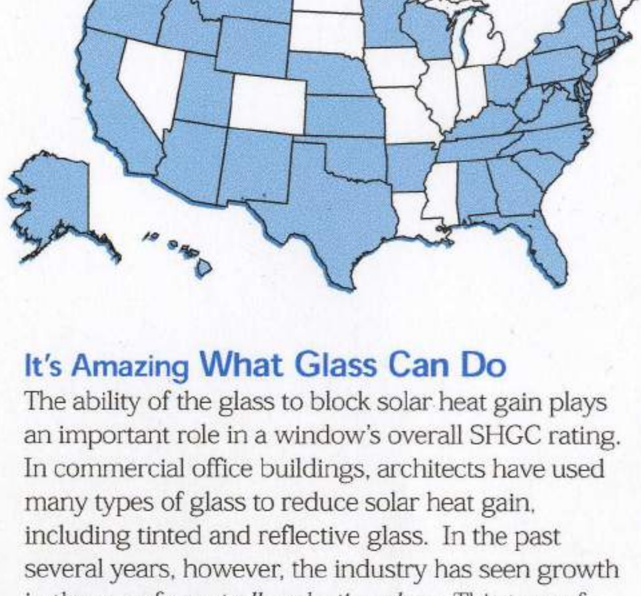
What is SHGC?

A simple way to explain SHGC is in terms of a ratio; where 1 is the maximum amount of solar heat gain that can come through a window and 0 is the least amount. An SHGC of 0.40 then means that 40% of the available solar heat is coming through the window.

0	Solar Gain	1
I ------------------------	V --	I
	0.40	

It should be noted that SHGC ratings, like all NFRC ratings, express the performance rating for the entire window, not just the glass. This is important, because SHGC ratings also include the ability of a window to absorb the heat form the sun and transmit it (conduct it) through the entire window and into the room. Therefore the type of window, as well as the glass, can affect the SHGC rating.

Where NFRC-Certified Products Are Required or Encouraged



It's Amazing What Glass Can Do

The ability of the glass to block solar heat gain plays an important role in a window's overall SHGC rating. In commercial office buildings, architects have used many types of glass to reduce solar heat gain, including tinted and reflective glass. In the past several years, however, the industry has seen growth in the use of *spectrally selective glass*. This type of

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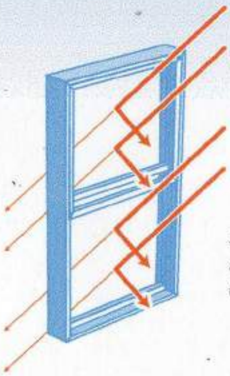
glass can be either *tinted* or *coated*, having special properties that actually block or re-radiate the energy from the sun, reducing solar heat gain through the windows. This type of product is also available for use in residential windows, typically with a spectrally selective low-e coating on the surface of the glass. **NFRC 200** ratings provide a simple and uniform means of comparing the Solar Heat Gain performance of these products.



Spectrally selective glass can actually block or re-radiate much of the energy from the sun.

Certified Solar Heat Gain Ratings

Any fenestration manufacturer that wishes to obtain **certified SHGC Ratings** must participate in the NFRC's Certification Program. When a manufacturer follows the certification guidelines, they can place an *NFRC Label* on their product showing the certified SHGC rating, along with ratings for U-factor and visible transmittance. For commercial buildings, a *Label Certificate* can be used to indicate that the fenestration products on that building have been rated in accordance with NFRC standards and programs. Homeowners, builders, architects, and code officials should use these labels to compare products and to assure that the products meet specifications and local code requirements.

NFRC *Certified Products Directory*

Manufacturers who participate in the NFRC Certification Program have their products and product energy ratings listed in the NFRC *Certified Products Directory*. This directory lists thousand of certified products. The simplified Solar Heat Gain ratings noted above are found in the appendix of the *Directory* under the heading "Specialty Products." In addition, please note that a manufacturer may have an NFRC certified SHGC rating and not be listed in the *Directory*. To be sure that products have an NFRC Certified rating, look for the NFRC Label. The NFRC *Certified Products Directory* is available online at **www.nfrc.org**.

NFRC National Fenestration Rating Council® CERTIFIED	World's Best Window Co. Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Argon Fill • Low E Product Type: **Vertical Slider**
ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./I-P) (A) **0.35**	Solar Heat Gain Coefficient (B) **0.32**
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance (C) **0.51**	Air Leakage (U.S./I-P) (D) **0.2**
Condensation Resistance (E) **51**	
Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. Consult manufacturer's literature for other product performance information. www.nfrc.org	

(A) ***U-Factor*** *measures how well a product prevents heat from escaping a home or building. U-Factor ratings generally fall between 0.20 and 1.20. The lower the U-Factor, the better a product is at keeping heat in. U-Factor is particularly important during the winter heating season. This label displays U-Factor in U.S. units. Labels on products sold in markets outside the United States may display U-Factor in metric units.*

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LED lamp

From Wikipedia, the free encyclopedia
Jump to: navigation, search

An assortment of LED lightbulbs commercially available as of 2010 as replacements for screw-in bulbs, including floodlight fixtures (left), reading light (center), household lamps (center right and bottom), and low-power accent light (right) applications.

A 17W tube of LEDs which has the same intensity as a 45W fluorescent tube

LED spotlight using 60 individual diodes for mains voltage power

An **LED lamp** (or **LED light bulb**) is a solid-state lamp that uses light-emitting diodes (LEDs) as the source of light. LED lamps offer long service life and high energy efficiency, but initial costs are higher than those of fluorescent and incandescent lamps. Chemical decomposition of LED chips reduces luminous flux over life cycle as with conventional lamps.

The LEDs involved may be conventional semiconductor light-emitting diodes, organic LEDs (OLED), or polymer light-emitting diodes (PLED) devices. However, PLED technologies are not commercially available. Diode technology improves steadily.

LED lamps can be made interchangeable with other types of lamps. Assemblies of high power light-emitting diodes can be used to replace incandescent or fluorescent lamps. Some LED lamps are made with identical bases so that they are directly interchangeable with incandescent bulbs. Since the luminous efficacy (amount of visible light produced per unit of electrical power input) varies widely between LED and incandescent lamps, lamps are usefully marked with their lumen output to allow comparison with other types of lamps. LED lamps are sometimes marked to show the watt rating of an incandescent lamp with approximately the same lumen output, for consumer reference in purchasing a lamp that will provide a similar level of illumination.

Efficiency of LED devices continues to improve, with some chips able to emit > 100 lumens per watt. LEDs do not emit light in all directions, and their directional characteristics affect the design of lamps. The efficiency of conversion from electric power to light is generally higher than with incandescent lamps. Since the light output of many types of light-emitting diodes is small compared to incandescent and compact fluorescent lamps, in most applications multiple diodes are assembled.

Diodes use direct current (DC) electrical power. To use them from standard AC power they are operated with internal or external rectifier circuits that provide a regulated current output at low voltage. LEDs are degraded or damaged by operating at high temperatures, so LED lamps typically include heat dissipation elements such as heat sinks and cooling fins.

Contents

Technology overview

Dropped ceiling with LED lamps

General-purpose lighting needs white light. LEDs emit light in a very small band of wavelengths, emitting light of a color characteristic of the energy bandgap of the semiconductor material used to make the LED. To emit white light from LEDs requires either mixing light from red, green, and blue LEDs, or using a phosphor to convert some of the light to other colors.

The first method (RGB- or trichromatic white LEDs) uses multiple LED chips, each emitting a different wavelength, in close proximity to generate the broad spectrum of white light. The advantage of this method is that the intensity of each LED can be adjusted to "tune" the character of the light emitted. The major disadvantage is high production cost. The character of the light can be changed dynamically by adjusting the power supplied to the different LEDs.

The color rendering of RGB LEDs, however, is worse than one would expect; the wavelength gap between red and green is much larger than that between green and blue, resulting in an uneven spectral density. An orange fruit, for example, does reflect some red and it does reflect some green, but not in a ratio that the human retina interprets as orange. Neglecting to poll the orange line makes most orange objects appear reddish. RGB LEDs are therefore suitable for display purposes, but less so for illumination, which prompted some manufacterers to add a fourth, amber LED, marketing the product as RGBA LED (not to be confused with the RGBA color space) or tetrachromatic white LED. It can be expected that the number of colors will be further increased to six or more, equally-tempered wavelengths.

The second method, phosphor converted LEDs (pcLEDs) uses one short wavelength LED (usually blue or ultraviolet) in combination with a phosphor which absorbs a portion of the blue light and emits a broader spectrum of white light. (The mechanism is similar to the way a fluorescent lamp emits white light from a UV-illuminated phosphor.) The major advantage is the low production cost, and high CRI (color rendering index), but the phosphor conversion reduces the efficiency of the device, partly due to the Stokes shift effect. The character of the light cannot be changed dynamically. The low cost and adequate performance makes it the most widely used technology for general lighting today.

A single LED is a low-voltage solid state device and cannot be directly operated on standard high-voltage AC power without circuitry to control the current flow through the lamp. In principle a series diode and resistor could be used to limit the current and to control its direction, but this would be very inefficient since most of the applied power would be dissipated by the resistor. A series string of LEDs would minimize dropped-voltage losses, but one LED failure would extinguish the whole string. Paralleled strings increase reliability by providing redundancy. In practice, three or more strings are usually used. To be useful for illumination a number of LEDs must be placed close together in a lamp to combine their illuminating effects because, as of 2011, the largest available LEDs emit only a small fraction of the light of traditional light sources. When using the color-mixing method a uniform color distribution can be difficult to achieve, while the arrangement of white LEDs is not critical for color balance. Further, degradation of different LEDs at various times in a color-mixed lamp can lead to an uneven color output. LED lamps usually consist of clusters of LEDs in a housing with driver electronics, a heat sink, and optics.

Application

LED lamps are used for both general and special-purpose lighting. Where colored light is needed, LEDs naturally emitting many colors are available, with no need for filters. This improves the energy efficiency over a white light source that generates all colors of light then discards some of the visible energy in a filter.

BAPS Shri Swaminarayan Mandir Atlanta Illumination with color mixing LED fixtures.

Compared to fluorescent bulbs, introduced at the 1939 World's Fair, advantages claimed for LED light bulbs are that they contain no mercury (unlike a Compact fluorescent lamp or CFL), that they turn on instantly, and that lifetime is unaffected by cycling on and off, so that they are well suited for light fixtures where bulbs are often turned on and off. LED light bulbs are also mechanically robust; most other artificial light sources are fragile.

White-light light-emitting diode lamps have longer life expectancy and higher efficiency (the same light for less electricity) than most other lighting. LED sources are compact, which gives flexibility in designing lighting fixtures and good control over the distribution of light with small reflectors or lenses. Because of the small size of LEDs, control of the spatial distribution of illumination is extremely flexible,[1] and the light output and spatial distribution of a LED array can be controlled with no efficiency loss.

LED lamps have no glass tubes to break, and their internal parts are rigidly supported, making them resistant to vibration and impact. With proper driver electronics design, an LED lamp can be made dimmable over a wide range; there is no minimum current needed to sustain lamp operation.

LEDs using the color-mixing principle can emit a wide range of colors by changing the proportions of light generated in each primary color. This allows full color mixing in lamps with LEDs of different colors.[2] In contrast to other lighting technologies, LED emission tends to be directional (or at least lambertian). This can be either an advantage or a disadvantage, depending on requirements. For applications where non-directional light is required, either a diffuser is used, or multiple individual LED emitters are used to emit in different directions.

Household LED lamps

LED lamps

LED Lamp with E27 Edison screw, interchangeable with incandescent lamps

Top view of a Philips 12.5 W LED lamp, interchangeable with a 60 watt incandescent lamp

LED spotlight using 38 individual diodes for mains voltage power

LED tubes in various lengths

LED lamp with GU5.3 base and aluminum heat sink, intended to replace halogen reflector lamps

Lamp sizes and bases

LED lamps intended to be interchangeable with incandescent lamps are made in standard light bulb shapes, such as an Edison screw base, an MR16 shape with a bi-pin base, or a GU5.3 (Bipin cap) or GU10 (bayonet socket) and are made compatible with the voltage supplied to the sockets. LED lamps include circuitry to rectify the AC power and to convert the voltage to a level usable by the LED.

LED light bulbs

LED lamps are made that replace screw-in incandescent or compact fluorescent light bulbs. Most LED lamps replace incandescent bulbs rated from 5 to 60 watts. As of 2010, some LED lamps replace higher wattage bulbs; For example, one manufacturer claims a 16-watt LED bulb as bright as a 150W halogen lamp.[3] A standard general-purpose incandescent bulb emits light at an efficiency of about 14 to 17 lumens/W depending on its size and voltage. According to the European Union standard, an energy-efficient bulb that claims to be the equivalent of a 60W tungsten bulb must have a minimum light output of 806 lumens.[4]

A selection of consumer LED bulbs available as drop-in replacements for incandescent bulbs in screw-type sockets

Some models of LED bulbs work with dimmers as used for incandescent lamps. LED lamps often have directional light characteristics. The lamps have declined in cost to between US$30 to $50 each as of 2010. These bulbs are more power-efficient than compact fluorescent bulbs[5] and offer lifespans of 30,000 or more hours, reduced if operated at a higher temperature than specified. Incandescent bulbs have a typical life of 1,000 hours, compact fluorescents about 8,000 hours.[*citation needed*] The bulbs maintain output light intensity well over their life-times. Energy Star specifications require the bulbs to typically drop less than 10% after 6000 or more hours of operation, and in the worst case not more than 15%.[6] They are also mercury-free, unlike fluorescent lamps. LED lamps are available with a variety of color properties. The higher purchase cost than other types may be more than offset by savings in energy and maintenance.[7]

Several companies offer LED lamps for general lighting purposes. The technology is improving rapidly and new energy-efficient consumer LED lamps are available.[8]

Specialty uses

LED Flashlight replacement bulb (left), with tungsten equivalent (right)

White LED lamps have achieved market dominance in applications where high efficiency is important at low power levels. Some of these applications include flashlights, solar-powered garden or walkway lights, and bicycle lights. Monochromatic (colored) LED lamps are now commercially used for traffic signal lamps, where the ability to emit bright monochromatic light is a desired feature, and in strings of holiday lights.

LED lights have also become very popular in gardening and agriculture by 2010. First used by NASA to grow plants in space, LEDs came into use for home and commercial applications for indoor horticulture (aka grow lights). The wavelengths of light emitted from LED lamps have been specifically tailored to supply light in the spectral range needed for chlorophyll absorption in plants, promoting growth while reducing wastage of energy by emitting minimal light at wavelengths that plants do not require. The red and blue wavelengths of the visible light spectrum are used for photosynthesis, so these are the colors almost always used in LED grow light panels.

Pioneering mass use

In 2008 Sentry Equipment Corporation in Oconomowoc, Wisconsin, USA, was able to light its new factory interior and exterior almost solely with LEDs. Initial cost was three times more than a traditional mix of incandescent and fluorescent lamps, but the extra cost will be repaid within two years via electricity savings, and the lamps should not need replacing for 20 years.[9] In 2009, the Manapakkam, Chennai office of the Indian IT company iGate spent Rs 3,700,000 (US$80,000) to light 57,000 sq ft (5,300 m^2) of office space with LEDs. The firm expects the new lighting to pay for itself fully within 5 years.[10]

LEDs as Christmas illumination in Viborg, Denmark.

In 2009 the exceptionally big Christmas tree standing in front of the Turku Cathedral in Finland was hung with 710 LED bulbs, each using 2 watts. It has been calculated that these LED lamps will pay for themselves in three and a half years, even though the lights run for only 48 days per year.[11]

In 2009 a new highway (A29) was inaugurated in Aveiro, Portugal, it included the first European public LED-based lighting highway[12]

By 2010 mass installations of LED lighting for commercial and public uses were becoming common. LED lamps have also been used for a number of demonstration projects for outdoor lighting and LED street lights. The United States Department of Energy has available several reports on the results of many pilot projects for municipal outdoor lighting.[13] Many additional streetlight and municipal outdoor lighting projects have been announced.[14]

Comparison to other lighting technologies

See luminous efficacy for an efficiency chart comparing various technologies.

- Incandescent lamps (light bulbs) generate light by passing electric current through a resistive filament, thereby heating the filament to a very high temperature so that it glows and emits visible light. A broad range of visible frequencies are naturally produced, yielding a "warm" yellow or white color quality. Incandescent light is highly inefficient, as about 98% of the energy input is emitted as heat.[15] A 100 W light bulb emits about 1,700 lumens, about 17 lumens/W. Incandescent lamps are relatively inexpensive to make. The typical lifespan of an AC incandescent lamp is around 1,000 hours.[16] They work well with dimmers. Most older light fixtures are designed for the size and shape of these traditional bulbs.

- Fluorescent lamps (light bulbs) work by passing electricity through mercury vapor, which in turn emits ultraviolet light. The ultraviolet light is then absorbed by a phosphor coating inside the lamp, causing it to glow, or fluoresce. While the heat generated by a fluorescent lamp is much less than its incandescent counterpart, energy is still lost in generating the ultraviolet light and converting this light into visible light. If the lamp breaks, exposure to mercury can occur. Linear fluorescent lamps are typically five to six times the cost of equivalent incandescent lamps but have life spans around 10,000 and 20,000 hours. Lifetime varies from 1,200 hours to 20,000 hours for compact fluorescent lamps. Most fluorescent lamps are not compatible with dimmers. Those with "iron" ballasts flicker at 100 or 120 Hz, and are less efficient.[*citation needed*] The latest T8-sized triphosphate fluorescent lamps made by Osram, Philips, Crompton and others have a life expectancy greater than 50,000 hours, if coupled with a warm-start electronic ballast. The life expectancy depends on the number of on/off cycles, and is lower if the light is cycled often. The efficiency of these new lamps approaches 100 lumens/W.[*citation needed*] The efficiency of fluorescent tubes with modern electronic ballasts and compact fluorescents commonly ranges from 50 to 67 lumens/W. For comparison, general household LED bulbs available in 2011 emit 64 lumens/W,[17] with the best LED bulbs coming in at about 100 lumens/W.[18]

Cost Comparison

	Incandescent	Halogen	Fluorescent	LED (Generic)	LED (Philips)	LED (Philips L-Prize)
Purchase price	$2[19]	$4[20]	$4[21]	$20[18]	$25[22]	$50[23]
Electricity usage	60 W	42 W	13 W	9 W	12.5 W	10 W
Lumens	660	570	660[24]	900	800	940
Lumens/Watt	11	13.6	50.8	100	64	94
Color Temperature Kelvin	2700	3100[25]	2700	3000	2700	2700
CRI	100	100	82	>75[26]	85	92
Lifespan (hours)	2,000	3,500	8,000	25,000	25,000	30,000
Bulb cost over 10 years – @6hours/day	$21.90	$25.03	$10.95	$17.52	$21.90	$36.50
Energy cost over 10 years – @15cents/kWhr	$197.10	$137.97	$42.71	$29.57	$41.06	$32.85
Total	$219.00	$163.00	$53.66	$47.09	$62.96	$69.35

Comparison based on 6 hours use per day (21,900 hours over 10 yrs)

Research and development

US Department of Energy

Comparison of Philips LED bulbs intended as screw-in replacements for the 60-W incandescent bulb. The original Philips A-19 "Endura LED" bulb is on the left, and the L-Prize bulb on the right.

In May 2008, the U. S. Department of Energy (DOE) announced details of the Bright Tomorrow Lighting Prize competition, known as the "L Prize". This is the first government-sponsored technology competition designed to spur lighting producers to develop high quality, high efficiency solid-state lighting products to replace the common light bulb. The competition will award cash prizes, and may also lead to opportunities for federal purchasing agreements, utility programs, and other incentives for winning products.

The Energy Independence and Security Act (EISA) of 2007 authorized the DOE to establish the Bright Tomorrow Lighting Prize competition. The legislation challenges industry to develop replacement technologies for the most commonly used and inefficient products, 60 W incandescent lamps and PAR 38 halogen lamps. The L Prize specifies technical requirements for these two competition categories. Lighting products meeting the competition requirements would use just 17% of the energy used by most incandescent lamps in use today. A future L Prize program announcement will call for developing a new “21st Century Lamp,” as authorized in the legislation.

The EISA legislation establishes basic requirements and prize amounts for each category. The legislation authorizes up to $20 million in cash prizes.[27] On September 24, 2009 the DOE announced that Philips Lighting North America was the first to submit lamps in the category to replace the standard 60 W A-19 "Edison screw fixture" light bulb,[7] with a design based on their earlier "EnduraLED" consumer product. On August 3, 2011, DOE awarded the prize in the 60 W replacement category to Philips bulb after 18 months of extensive testing.[28] The same day, CREE demonstrated a prototype lamp producing 1330 lumens with a mere 8.7 W of input power.[29] While the CREE lamp has not undergone DOE reliability testing and no commercial release date was promised, it is an indication that the "21st Century Lamp" performance levels may soon be within reach of commercial products.

The 10-W, 900-lumen Philips bulb was made available to consumers in April 2012.[30]

National Institute of Standards and Technology

In June 2008, scientists at the National Institute of Standards and Technology (NIST) announced the first two standards for solid-state lighting in the United States. These standards detail the color specifications of LED lamps and LED light fixtures, and the test methods that producers should use when testing these solid-state lighting products for total light output, energy use, and chromaticity or color quality.

The Illuminating Engineering Society of North America (IESNA) published a documentary **standard LM-79**, which describes the methods for testing solid-state lighting products for their light output (lumens), energy efficiency (lumens per watt) and chromaticity.

The solid-state lights being studied are intended for general illumination, but white lights used today vary greatly in chromaticity, or specific shade of white. The American National Standards Institute (ANSI) published the **standard C78.377-2008**, which specifies the recommended color ranges for solid-state lighting products using cool to warm white LEDs with various correlated color temperatures.[31]

DOE launched the Energy Star program for solid-state lighting products in 2008. NIST scientists assisted DOE by providing research, technical details and comments for the Energy Star specifications. Energy Star certification assures consumers that products save energy and are high quality and also serves as an incentive for producers to provide energy-saving products for consumers.

Environmental Protection Agency

In the United States and Canada, the Energy Star program since 2008 labels lamps that meet a set of standards for starting time, life expectancy, color, and consistency of performance. The intent of the program is to reduce consumer concerns due to variable quality of products, by providing transparency and standards for the labeling and usability of products available in the market.[32] Energy Star Light Bulbs for Consumers is a resource for finding and comparing Energy Star qualified lamps.

Other venues

In the United Kingdom a program is run by the Energy Saving Trust to identify lighting products that meet energy conservation and performance guidelines.[33]

Philips Lighting has ceased research on compact fluorescents, and is devoting the bulk of its research and development budget, 5 percent of the company's global lighting revenue, to solid-state lighting.[9]

In January 2009, it was reported that researchers at Cambridge University had developed an LED bulb that costs £2 (about $3 U.S.), is 12 times as energy efficient as a tungsten bulb, and lasts for 100,000 hours.[34] Honeywell Electrical Devices and Systems (ED&S) recommend world wide usage of LED lighting as it is energy efficient and can help save the Climate.[35]

Remaining problems

The production process of white LEDs is complex and many aspects have room for improvement. This means that the production price of volume products is still relatively high compared to traditional light sources. The process used to deposit the active semiconductor layers of the LED is constantly improved to increase yields and production throughput. The phosphors, which are needed for their ability to emit a broader wavelength spectrum of light, problems tuning the absorption and emission, and inflexibility of form have been issues.[*citation needed*]

More apparent to the end user, however, is the color rendering index (CRI) of low quality LEDs. CRI measures a light source's ability to render colors, with 100 being the maximum. LEDs with CRI below 75 are not recommended use in indoor lighting.[36] Better CRI LEDs are more expensive, and more research and development is needed to reduce costs.

LEDs also have limited temperature tolerance and falling efficiency as component temperature rises. This limits the total LED power that can practically be fitted into lamps that physically replace existing filament and compact fluorescent types. Much research and development is invested in improving thermal traits. Thermal management of high-power LEDs is a significant factor in design of solid state lighting equipment.

The long life of solid-state lighting products, expected to be about 50 times the most common incandescent bulbs, poses a problem for bulb makers, whose current customers buy frequent replacements.[9]

Some critics assert that producers may over-represent the efficiency and traits of their products to sell into a rapidly growing marketplace, suggesting that consumers still need to be wary of claims made about products in this market.[37]

Applications

This garden light can use stored solar energy because of the low power use of its LED

- Automotive lighting
- Bicycle lighting
- Billboard displays
- Display lighting in art galleries to reduce heating on works to low values
- Domestic lighting
- Emergency lighting
- Flashlight (Electric torches)
- Floodlighting of buildings
- Grow lights for plants
- Public transit vehicle route and destination signs
- Railway signals
- Stage lighting
- Street lighting
- Traffic lights
- Train lights

See also

Energy portal

- List of emerging technologies
- List of light sources
- Lux
- Photometry (optics)
- Radiation angle
- Solar lamp
- Spectrometer

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Further reading

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External links

Wikimedia Commons has media related to: ***LED lamps***

- e-lumen.eu – a website from the European Commission about the second generation of energy-saving lightbulbs
- Notes on LEDs, gizmology.net
- U. S. Department of Energy, Using Light Emitting Diodes
- U. S. Department of Energy, Solid-State Lighting GATEWAY Demonstration Results
- Detailed spectra plots, of hundreds of LEDs etc, ledmuseum.home.att.net
- Efficient LED lighting in conjunction with low-voltage domestic solar PV and mains, earth.org.uk

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Lamps and lighting

Concepts	• Lamp (electrical component) • Light fixture • Lightbulb sockets • Color temperature • Task lighting • Glare • Light pollution
Incandescent	• Regular

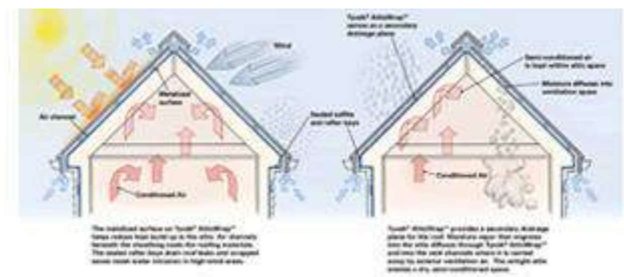
	• Halogen • Parabolic aluminized reflector (PAR) • Nernst
Fluorescent	• Fluorescent o Compact • Fluorescent induction
High-intensity discharge (HID)	• Mercury-vapor • Hydrargyrum medium-arc iodide (HMI) • Hydrargyrum quartz iodide (HQI) • Metal halide o Ceramic • Sodium vapor
Gas discharge	• Deuterium arc • Neon • Sulfur • Xenon arc • Xenon flash • Black light • Tanning lamp • Germicidal • Growth light
Electric arc	• Carbon arc • Yablochkov candle
Combustion	• Acetylene/Carbide • Argand • Candle • Diya • Gas • Kerosene • Lantern • Limelight • Oil • Safety • Rushlight • Tilley • Torch
Other	• Light-emitting diode (LED) • **LED lamp**

- Solid-state (SSL)
- Plasma
- Electroluminescent wire
- Chemiluminescence
- Radioluminescence
- Glow stick
- ESL

DuPont™ Tyvek® AtticWrap™

DuPont™ Tyvek® AtticWrap™ is a revolutionary breathable membrane designed to provide superior attic insulation for improved energy efficiency and attic moisture control. The unique, metallized surface helps to deliver unparalleled attic insulation by reflecting radiant heat while the breathable membrane helps prevent moisture build-up by allowing attic moisture to pass into the designed air space and vent to the outside of the roof structure.

How It Works:



The metallized surface on DuPont™ Tyvek® AtticWrap™ helps reduce heat build up in the attic. Air channels beneath the sheathing cools the roofing materials. The sealed rafter bays

drain roof leaks and wrapped eaves resist water intrusion in high-wind areas. DuPont™ Tyvek® AtticWrap™ provides a secondary drainage plane for the roof. Moisture vapor that migrates into the attic diffuses through DuPont™ Tyvek® AtticWrap™ and into the vent channels where it is carried away by exterior ventilation air. The sealed attic creates a dry, semi-conditioned space.

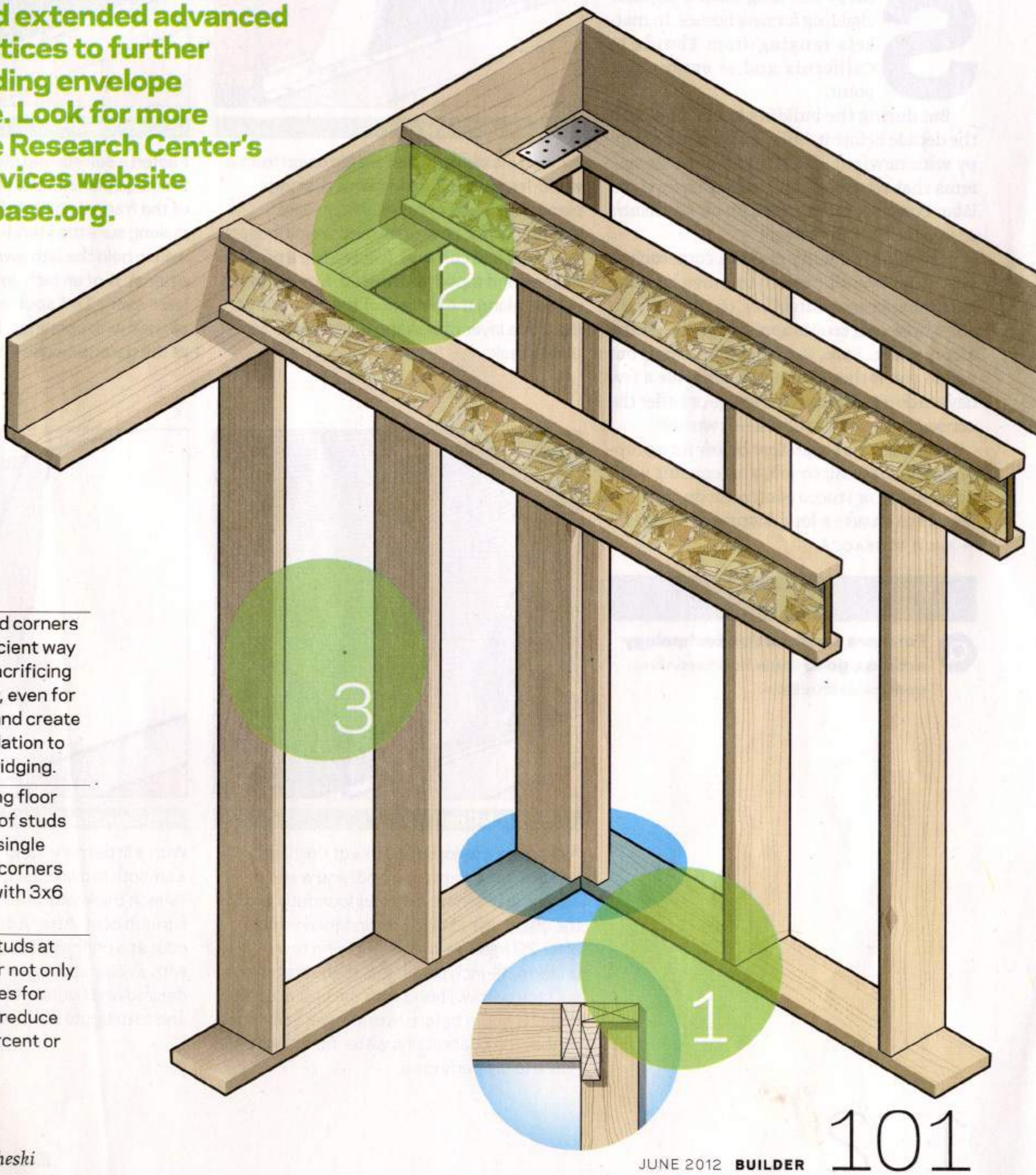
DuPont Weatherization Systems are an important part of the ENERGY STAR® Home Sealing labeling program and NAHB Green Home Building Guidelines.   According to ENERGY STAR®, “sealing the building envelope is one of the most cost-effective ways to lower the home’s utility bills and improve comfort.” With DuPont™ Tyvek® AtticWrap™, you get not only the most advanced weather-resistant protection available, you also get the peace of mind that comes from working with DuPont and ENERGY STAR®. And, our DuPont Certified Installer Program also provides trained installation services, which is one more way to put the building science expertise of DuPont right at your fingertips.

Related Documents
2008 Architectural Binder
DuPont™ Tyvek® AtticWrap™ introduction video
Building Science Bulletin: DuPont™ Tyvek® AtticWrap™ Bulletin
Product Guide Specifications: DuPont™ Tyvek® AtticWrap™ Product Specs
Physical Properties Data Sheet: DuPont™ Tyvek® AtticWrap™

Build Smart

Advanced Framing, Part III

The NAHB Research Center has amended and extended advanced framing practices to further improve building envelope performance. Look for more details at the Research Center's Toolbase Services website at www.toolbase.org.



1 Corners Three-stud corners are a resource-efficient way to frame without sacrificing structural integrity, even for two-story homes, and create more room for insulation to mitigate thermal bridging.

2 Line 'Em Up Aligning floor joists within 1 inch of studs allows the use of a single top plate. Connect corners and intersections with 3x6 galvanized plates.

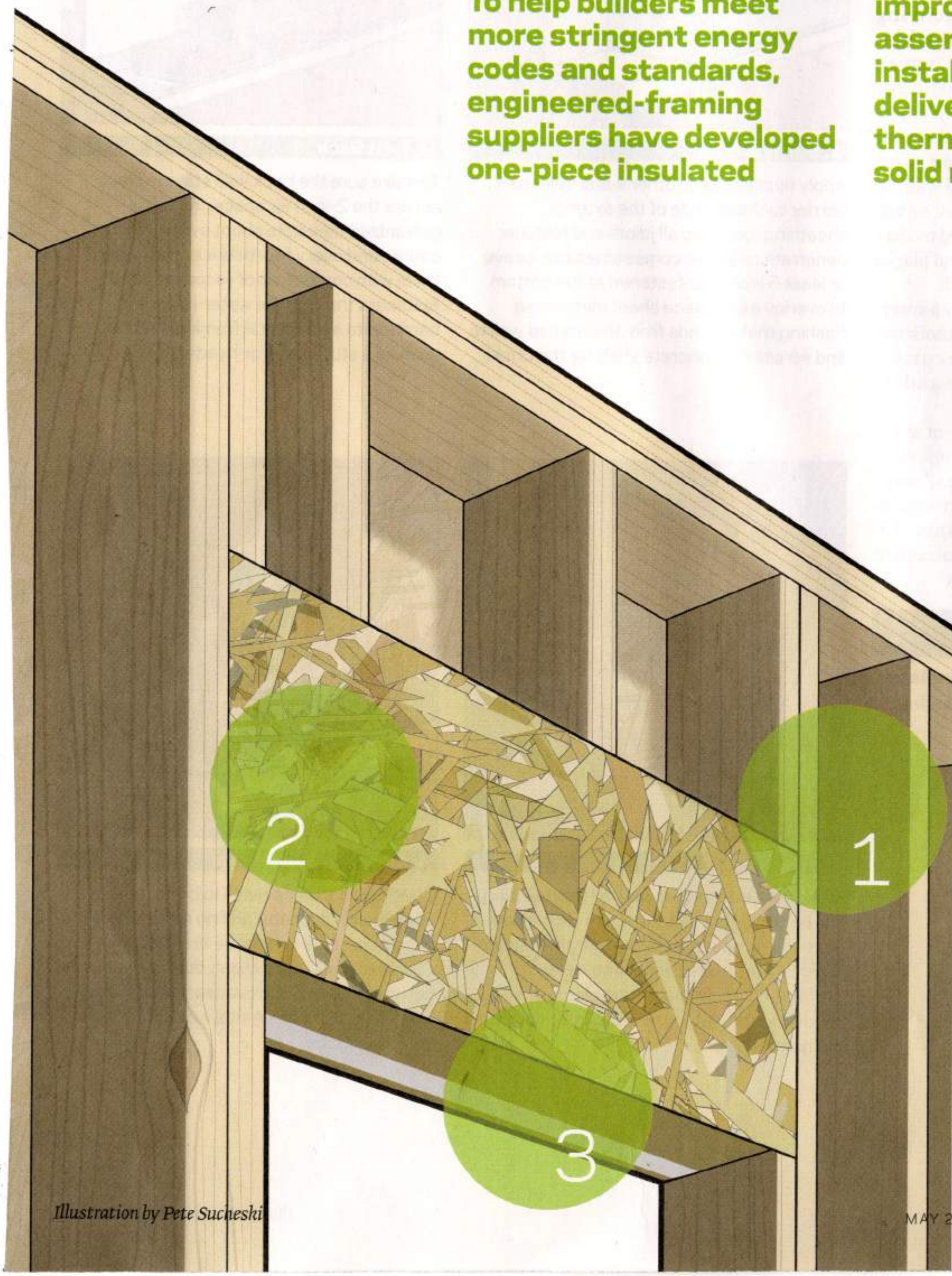
3 Wider Walls Wall studs at 24 inches on center not only create larger cavities for insulation, but also reduce wood use by 20 percent or more.

Illustration by Pete Sucheski

Build Smart

Insulated Header

To help builders meet more stringent energy codes and standards, engineered-framing suppliers have developed one-piece insulated structural headers that improve on piecemeal assemblies, making installation easy, and delivering superior thermal resistance and solid nailing surfaces.



1 Flush Fit Sized to run flush to 2x6 wall framing, an engineered header also retains its shape in fluctuating climate conditions and with shifting foundations to ensure thermal values and proper load transfer and mitigate cracks at studwall connections.

2 Stable Surfaces A 3 ⁹⁄₁₆-inch-thick structural member and a ⁷⁄₁₆-inch-thick layer of OSB sandwich the insulation, providing structural stability and nailing surfaces for drywall and exterior sidewall sheathing and claddings.

3 Core Component Securely laminated to the engineered-wood components on either side, the header's insulating layer is a 1.5-inch-thick, glass-fiber-reinforced polyisocyanurate foam with a 1.0 mil. reflective aluminum foil face. By itself, the insulation achieves an R-9.8 thermal value.

Illustration by Pete Sucheski

HOW-TO

Tall Heel Truss

Energy conservation is driving thick, high R-value ceiling insulation, which, in turn, requires tall truss heels to contain it.

The truss to shear wall connection is one of the most important links in the lateral force load path, but that extra heel height makes the connection a challenge.

When the wind howls or the earth shakes, roofs and walls must work together or the entire building can fold like a paperback novel. That's because roofs are horizontal diaphragms that distribute lateral (wind and seismic) loads to walls, which, in turn, transfer them to the foundation.

When a structural failure occurs it's usually a *connection* coming apart rather than the rupture of a beam, column, or other structural element. With stick-framed construction, the two most notorious connection failures are the roof to wall, and the floor to foundation.

Building codes are thorough at describing the forces involved but sketchy at best when it comes to detailing it all out. Here are three methods to ensure positive load transfer at a tall heel truss. — TIM GARRISON, P.E., THE BUILDER'S ENGINEER

[redacted]

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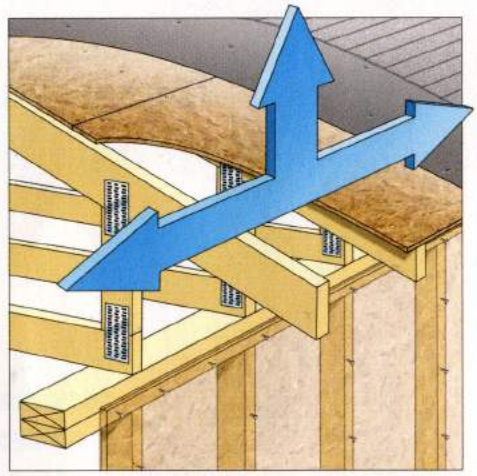
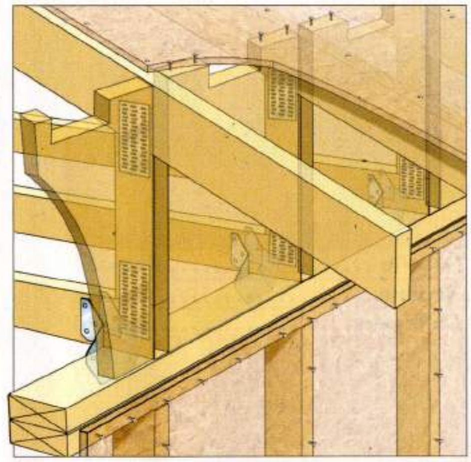


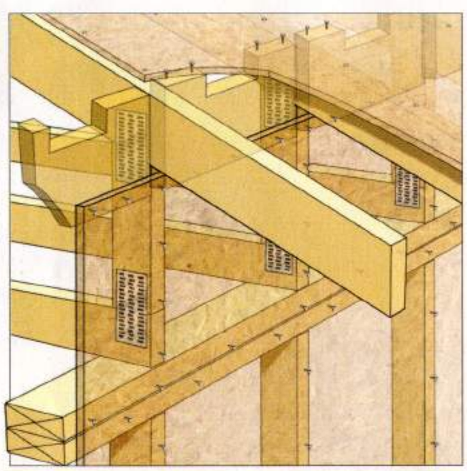
1. The Forces

In a wind or seismic event, there are typically two forces involved. Lateral load is the sideways force, also called "shear", that causes trusses or rafters to want to slide on the top plate. The second force is uplift that causes the roof to lift vertically from the wall. Proper design connects each truss or rafter to the wall strongly enough so that these forces are transmitted positively.



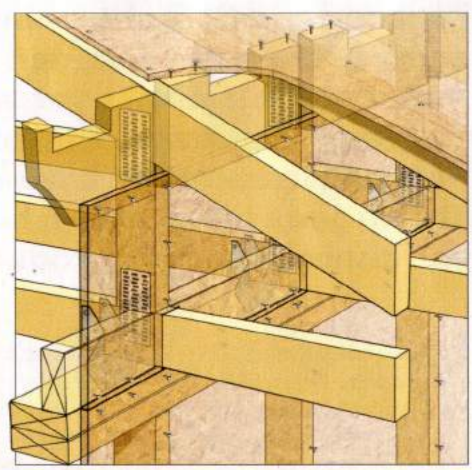
2. Tall Block

In this method, a tall block of LSL, LVL, or 2x is placed between each truss. The roof diaphragm is edge nailed to the block, and the truss bottom chord is connected to the shear wall with a hurricane clip. Vent holes may be notched or drilled into the block as necessary.



3. Sheathing—No Splice

In this case, the connection is made by the wall sheathing itself. If the sheathing is continuous over the truss/top plate intersection, as shown, a hurricane clip is not needed. This method requires a block large enough to be edge nailed to both the roof sheathing and the wall sheathing.



4. Sheathing—Spliced

This method is similar to the previous one except that the wall sheathing stops at the truss/top plate intersection. Separate sheathing is added between each truss, and edge nailed to blocking. Note that this blocking could be simple 2x blocks, a prefabricated wall section, or truss piece. A hurricane clip is required.

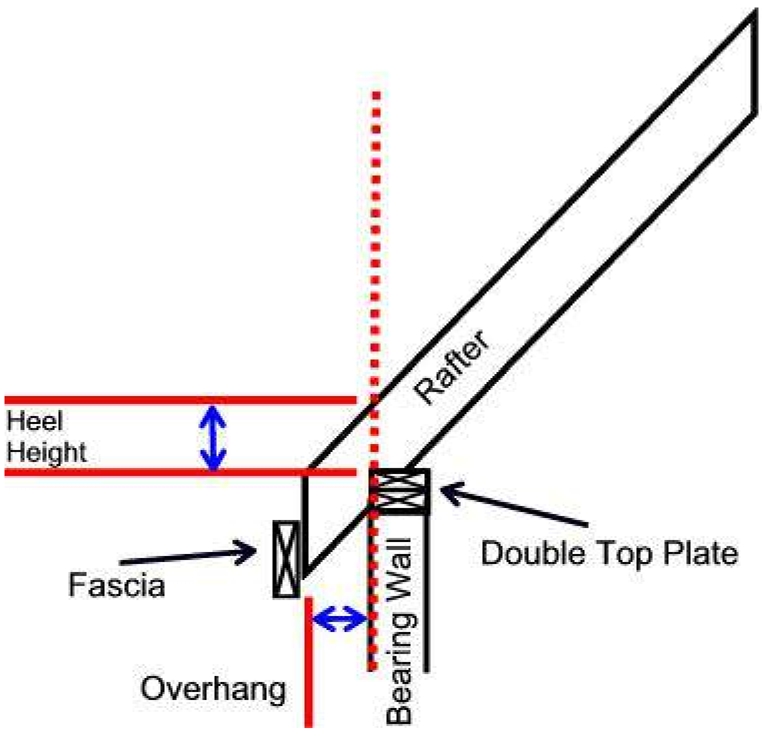
Illustrations by Harry Whitver

How to Measure Heel Height

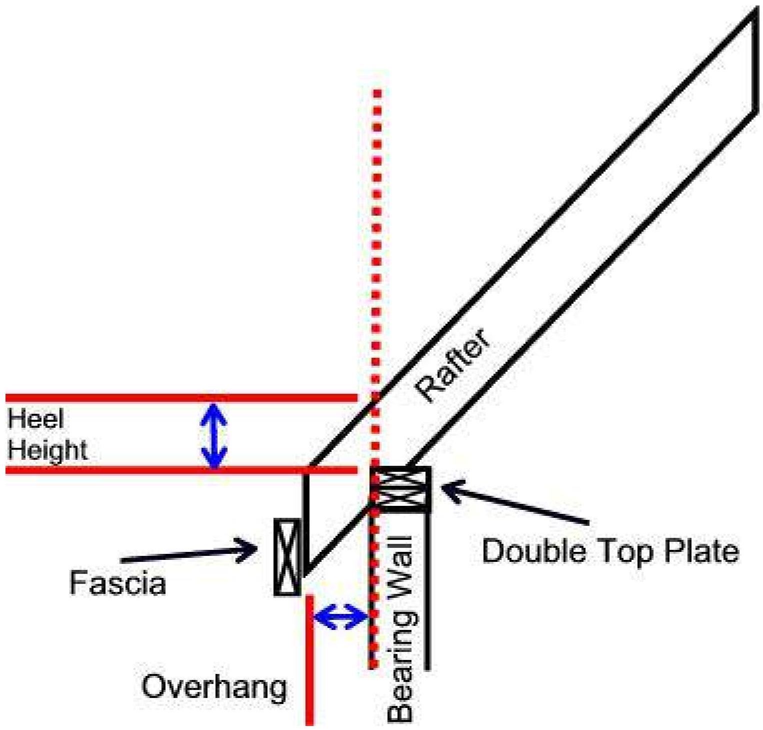
Other than Roof Pitch and Span, the most importand measurement need to match an existing roof is called the heel height.

Simply, it is the "thickness" of the truss or rafter measured from the outside of the wall from the top of the top plate to the underside of the sheathing.

Below are two diagrams to help illustrate the point



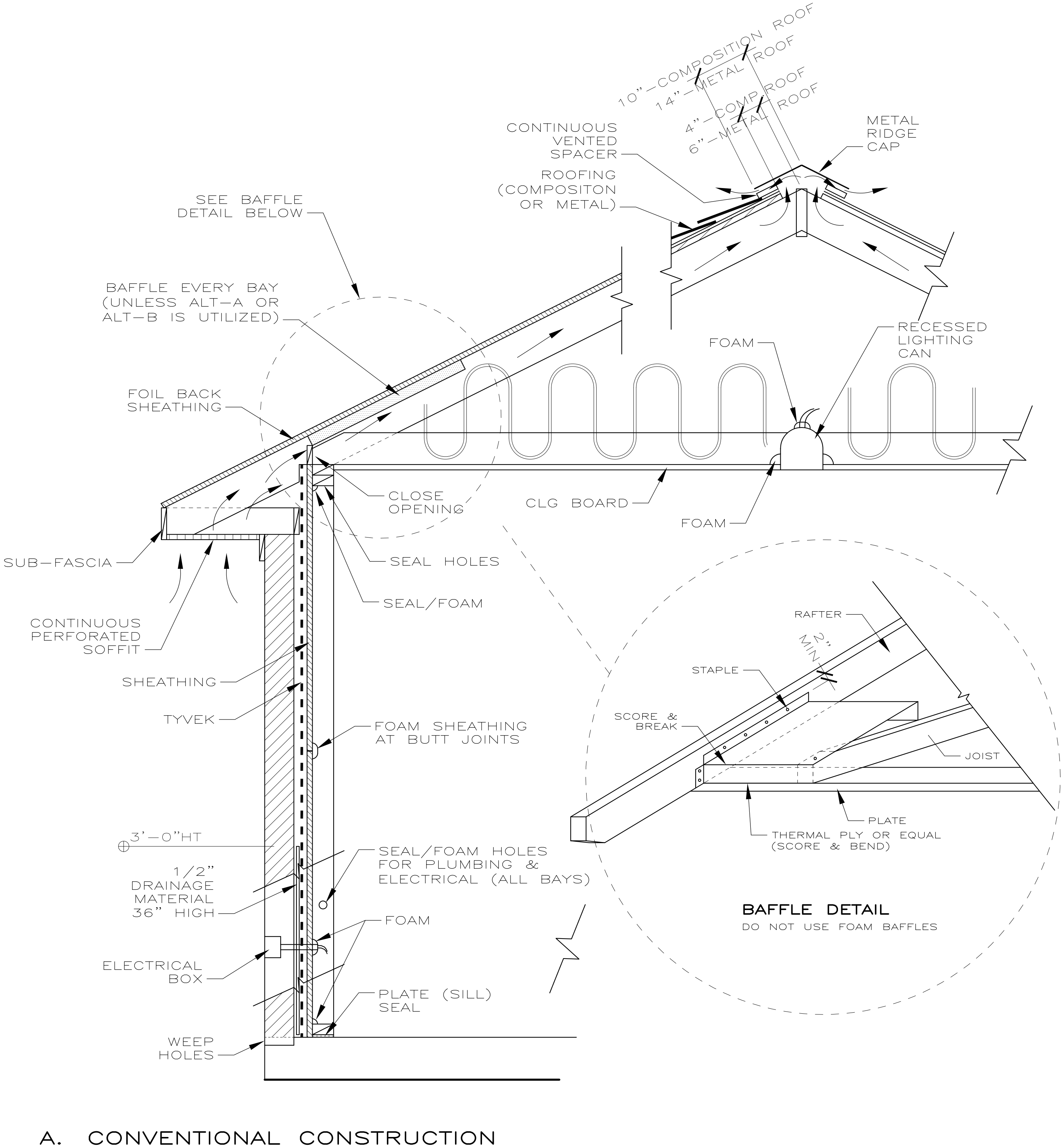
Heel Height and Overhang for a Trussed Roof.



Heel Height and Overhang for a Stick Framed Roof

FRAMING DETAILS FOR

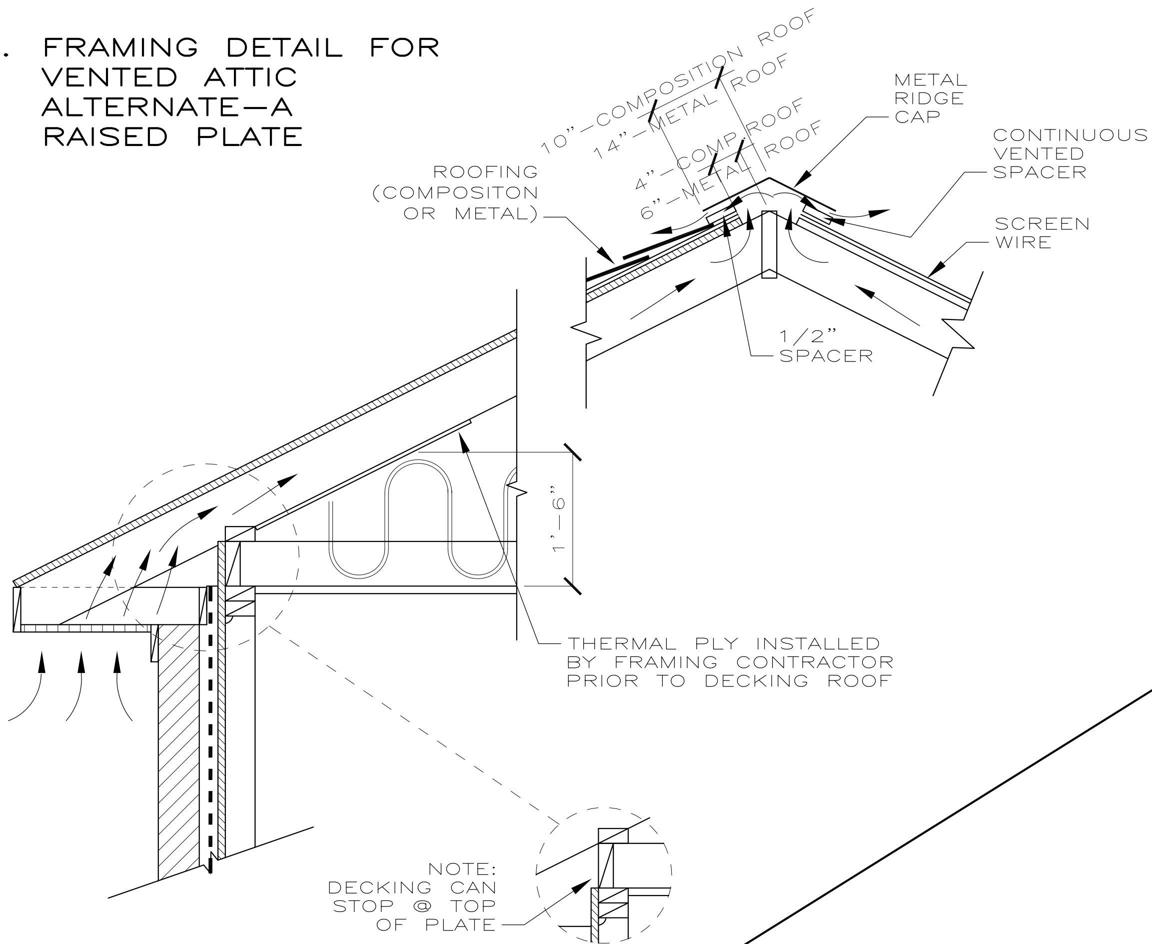
HIGH PERFORMANCE HOME DESIGN

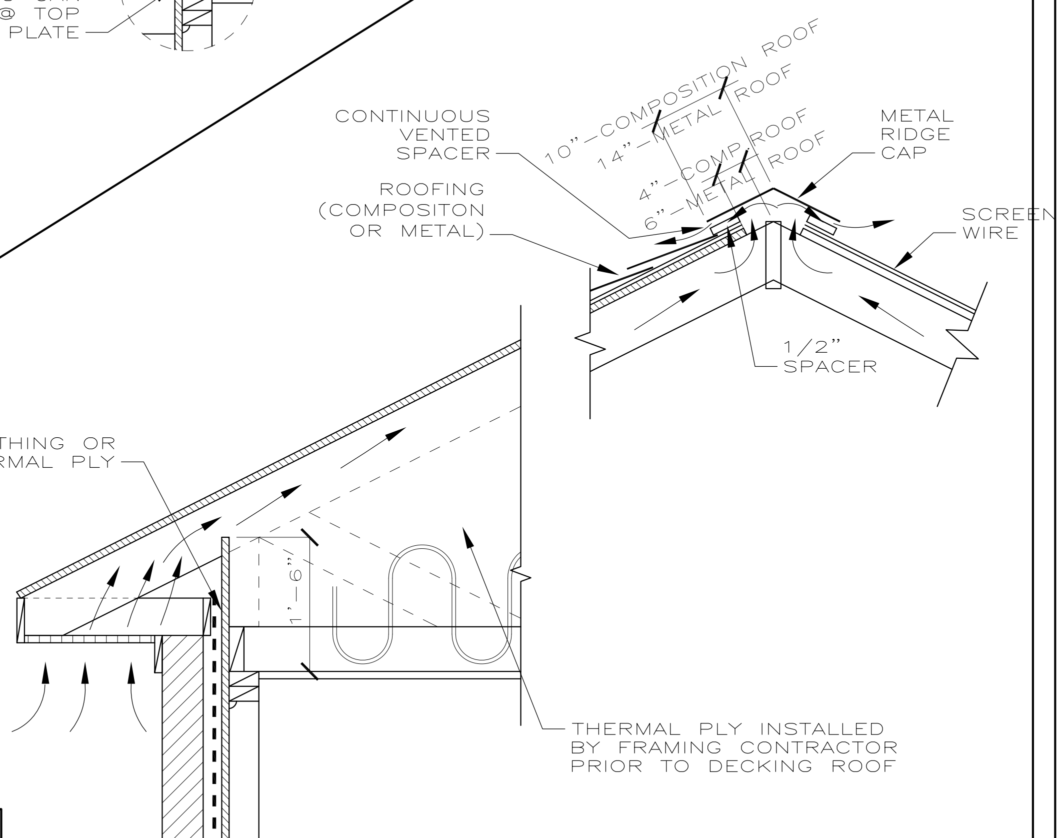


A. CONVENTIONAL CONSTRUCTION

NEVER USE PRE–FAB POLYSTYRENE BAFFLES. PRIOR TO DECKING, CUT, SCORE, & STAPLE THERMAL PLY UTILIZING THE FULL BAY WITH A 2" AIR SPACE.

B. FRAMING DETAIL FOR VENTED ATTIC ALTERNATE—A RAISED PLATE





C. FRAMING DETAIL FOR VENTED ATTIC ALTERNATE—B RAISED—HEEL TRUSS

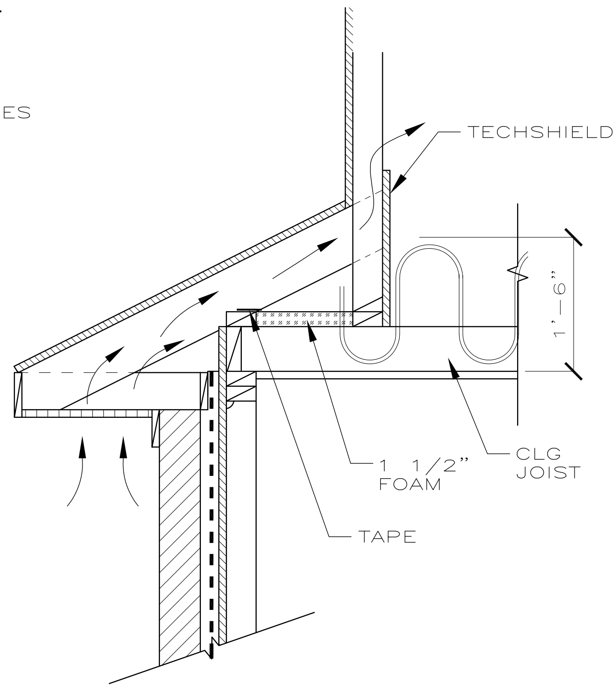
NOTE:

"B" OR "C" CONSTRUCTION IS PREFERRED FOR AN HIGH PERFORMANCE HOME.

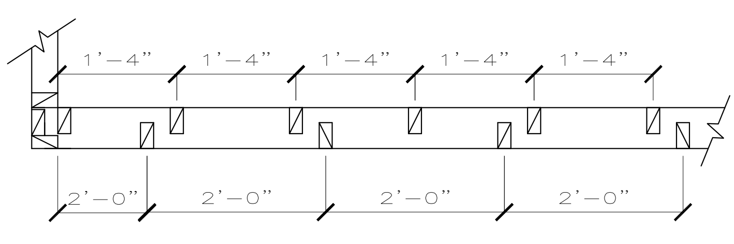
FRAMING DETAIL FOR "DUTCH" GABLE END ALTERNATE—A RAISED PLATE

NOTE:

DO NOT USE TRUSSES FOR GABLE END.



FRAMING DETAIL FOR STAGGERED STUD WALL

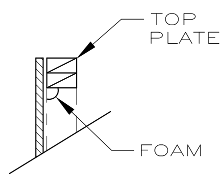


(SPACING ASSUMES SHEATHING IS OSB OR PLYWOOD.

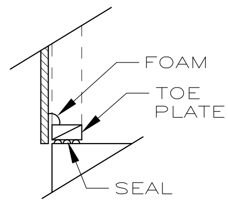
.PROPER SEALING TECHNIQUES FOR A

HIGH PERFORMANCE HOME

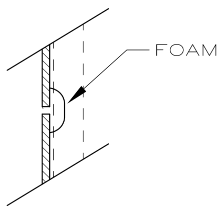
• TOP PLATE



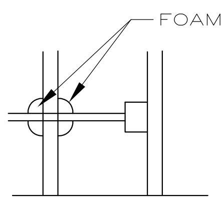
• TOE PLATE



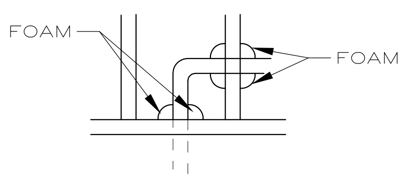
• BUTT JOINTS SHEATHING



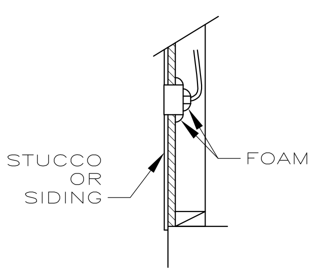
• CAVITY TO "STUD" CAVITY ELECTRICAL & PLUMBING PENETRATIONS (ALL EXTERIOR WALLS)

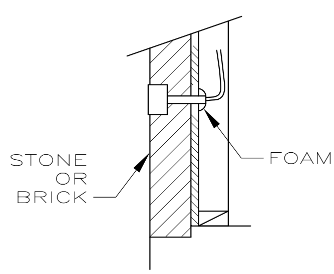


• TOE PLATE PENETRATION



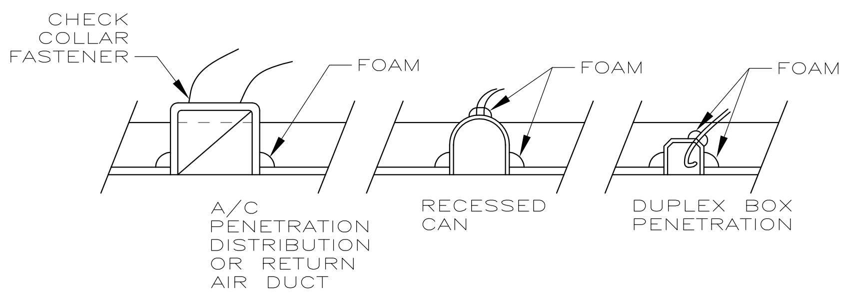
• EXTERIOR SHEATHING PENETRATION





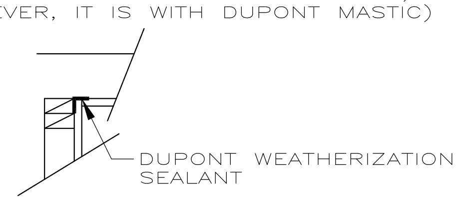
PROPER SEALING TECHNIQUES FOR A HIGH PERFORMANCE HOME

• CEILING BOARD PENETRATION

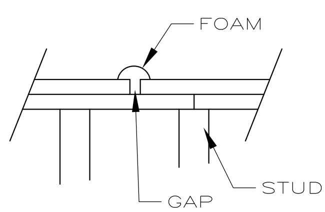


• WALL BOARD/CEILING BOARD JUNCTION

(THIS IS NOT PRACTICAL WITH FOAM, HOWEVER, IT IS WITH DUPONT MASTIC)

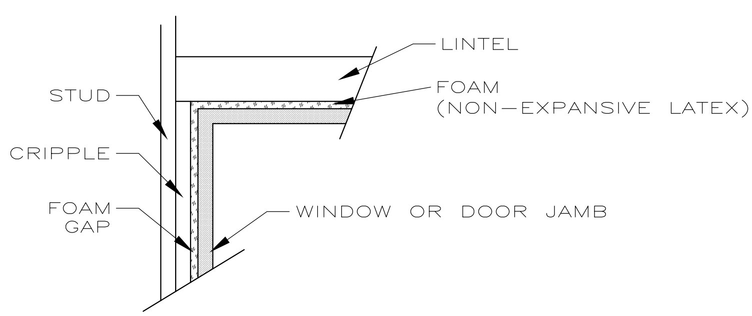


• GAPS IN TOP PLATE (BUTT JOINTS)



• FENESTRATIONS

(WINDOW/DOOR) SEALING

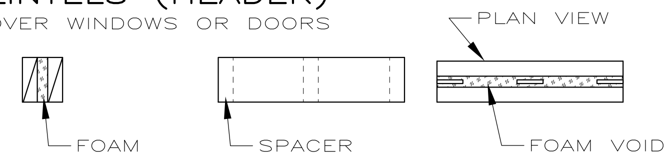


PROPER SEALING TECHNIQUES FOR A

HIGH PERFORMANCE HOME

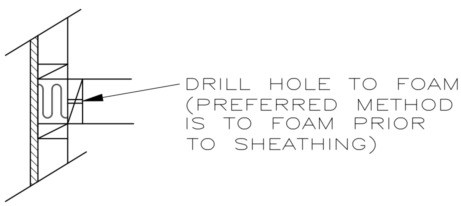
• LINTELS (HEADER)

OVER WINDOWS OR DOORS

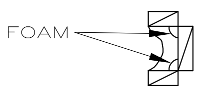


1. PRIOR TO WINDOW INSTALLATION
2. OR PLACE FOAM BOARD BETWEEN AT TIME OF LINTEL CONSTRUCTION
3. OR DRILL HOLES ON INTERIOR SIDE OF LINTEL & FOAM LATER

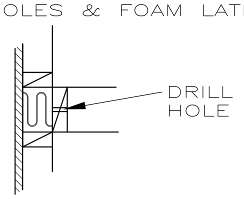
• INSULATING "T" & CORNERS



1. SPRAY FOAM PRIOR TO SHEATHING PARTICULARLY AT JOINTS.

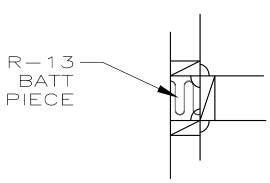


2. OR DRILL HOLES & FOAM LATER



3. SEAL JOINTS & INSERT FIBERGLASS BATTS

NOTE: #3 IS MOST PRACTICAL (BUT LEAST EFFECTIVE).

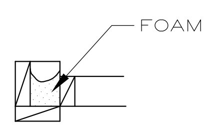


• CORNERS

PREFERRED OPTION:

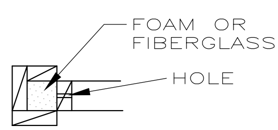
- FOAM BEFORE SHEATHING IS INSTALLED.

CONVENTIONAL



- FOAM AFTER SHEATHING IS INSTALLED.

BOX



PROPER SEALING TECHNIQUES FOR A

HIGH PERFORMANCE HOME

• FURDOWNS

- CONSTRUCTING FURDOWNS AFTER SHEETROCK (OR CEILING/WALL BOARD) IS INSTALLED IS NOT A PROBLEM FOR PROPER SEALING (PREFERRED WAY)

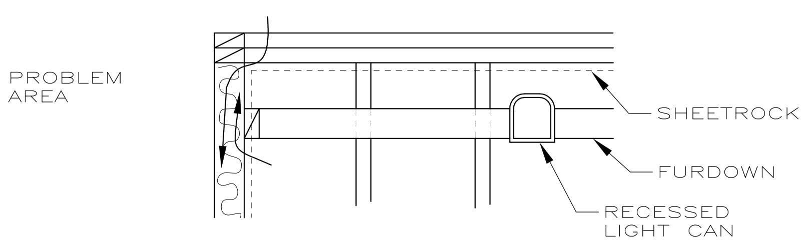
  IN EFFECT, IF THE FURDOWN IS CONSTRUCTED AFTER THE CEILINGS AND WALLS HAVE RECEIVED WALL BOARD, TAPED, & FLOATED, THEN THE CAVITIES ARE ALREADY SEALED. IF, HOWEVER, THEY ARE DEVELOPED DURING THE FRAMING STAGE, SEE BELOW.

- CONSTRUCTING FURDOWNS PRIOR TO THE INSTALLATION OF SHEETROCK (OR CEILING/WALL BOARD IS A PROBLEM FOR PROPER SEALING. SEE BELOW.

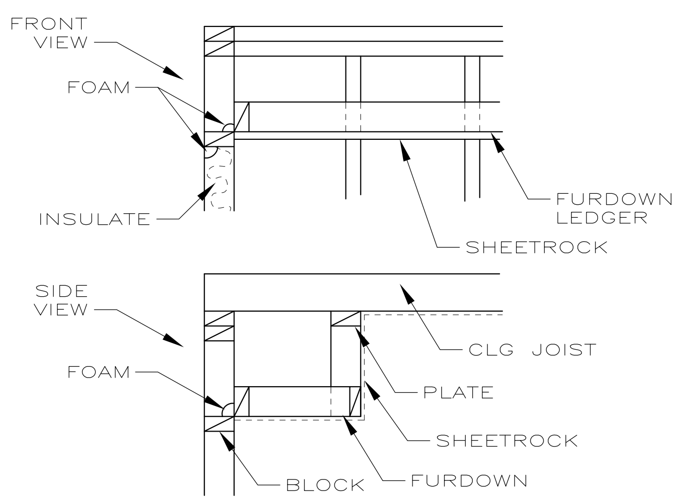
  ONE CAN SHEETROCK THE CEILING ABOVE THE FURDOWN AFTER FRAMING THE FURDOWN; HOWEVER, IT IS DIFFICULT AND CANNOT EASILY BE SEALED (IT IS DIFFICULT TO DO & WILL MOST ASSUREDLY BE OVERLOOKED.)

  THE PROBLEM WITH FRAMING THE FURDOWN AFTER SHEETROCKING, IS THAT IT IS OUT OF SEQUENCE FOR THE SHEETROCK AND FRAMER (CAUSING BOTH TO MAKE ADDITIONAL TRIP(S), HOWEVER, IT MIGHT BE WORTH IT.

1. CONSTRUCT FURDOWN AFTER SHEETROCK (TAPE & FLOAT):



2. CONSTRUCT FURDOWN DURING FRAMING STAGE THEN BLOCK & SEAL:



PROPER SEALING TECHNIQUES FOR A

HIGH PERFORMANCE HOME

- KNEEWALL