Level 1 Protocol: Insulation Installation

1.0 Background

Insulation is an important component for homes in that it reduces heat flow out of a house in winter and reduces heat flow into a home during the summer. It is estimated that approximately 53% of energy consumed in a home is for heating and air conditioning[1]. Proper design and installation of insulation around the perimeter of the conditioned space (called the thermal boundary which separates areas that are heated and cooled from spaces that are not) can drastically reduce the energy required for heating and cooling homes and contribute to the comfort experienced by its occupants.

2.0 Heat Transfer

Heat moves from hot to cold based on the second law of thermodynamics[2]. In other words, cold does not enter a house but instead warmth leaves the house during winter. In summer, warmth enters the house rather than cold leaving a home. Heat can transfer in three ways: conduction, convection, and radiation.

In concept conduction of heat is very similar to conduction of electricity. Heat travels from warm to cold through material by transfer of energy from molecule to molecule much as electrons travel through a solid wire. Examples of this movement of heat include the heating or cooling of a spoon in a cup of hot or cold water.

Convection is the transfer of heat through fluids - which includes both liquids and gases - through currents. Examples of this type of heat transfer include the heating of a room by a hot water radiator and the heating of water in a pot on the stove.[3]

Radiation is the transfer of heat through electromagnetic radiation. This heat transfer can be accomplished without air, fluids, or surface contact such as the transfer of heat from the sun to the earth through the vacuum of space.

Insulation and associated materials attempt to minimize all three sources of heat transfer. Insulation can be effective in reducing conduction and convection. For example, fiberglass and air are poor conductors of heat. Fiberglass insulation is often used to insulate the walls of homes and other structures because, if properly installed, they place a large quantity of both fiberglass and air between more conductive materials such as masonry and drywall.

Fiberglass, however, does not provide a good air seal, so convective heat transfer may occur unless air movement is minimized. Air retarders such as polyethylene sheets, when attached to the stud surface just under the interior drywall, may act as an air barrier. When combined with fiberglass insulation, this can address both conductive and convective heat transfer. Some types of insulation, such as closed-cell rigid foam insulation, are poor heat conductors and impervious to air flow through the material so they also limit convective heat transfer.

[1] Energy Information Administration, 2001 Residential Energy Consumption Survey
[2] http://en.wikipedia.org/wiki/Second_law_of_thermodynamics
[3] http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/heatra.html

Finally, some insulation may come equipped with a film called a radiant barrier. The film reflects electromagnetic radiation and inhibits radiant heat transfer. Stand-alone radiant barriers are also available without insulation.[4]

3.0 Insulation Characteristics

Insulation is characterized by the type of material it is made from, the form or shape it takes, and the effectiveness of limiting heat transfer.

Fiberglass is the most widely used insulation in residential construction. It comes in rolls, batts, and loose fill forms. Insulation, including fiberglass, is rated in terms of R-value or resistance to heat flow. The higher the R-value, the greater the thermal resistance of the insulation. U-value (also know as thermal transmittance) is also an expression of thermal efficiency. It is the reciprocal of R-value. In other words, an R-value of 5 equates to a U-value of 1/5 or .2. R-values are useful in that they can be added to find the effective thermal resistance of a number of materials that are combined to form a system. For example, a wall often consists of exterior sheathing, insulation, drywall, possibly a vapor retarder, etc. If the R-values of each component are known, they can be added to form the overall R-value of the wall. U-values can't be added in this manner. However, they can be used to calculate heating and cooling loads when designing buildings and their internal systems.

Table 1 Fiberglass Insulation Characteristics[5]

Thickness (inches)	R-Value	Cost (cents/sq. ft.)
3 1/2	11	12-16
3 5/8	13	15-20
3 1/2 (high density)	15	34-40
6 to 6 1/4	19	27-34
5 1/4 (high density)	21	33-39
8 to 8 1/2	25	37-45
8 (high density)	30	45-49
9 1/2 (standard)	30	39-43

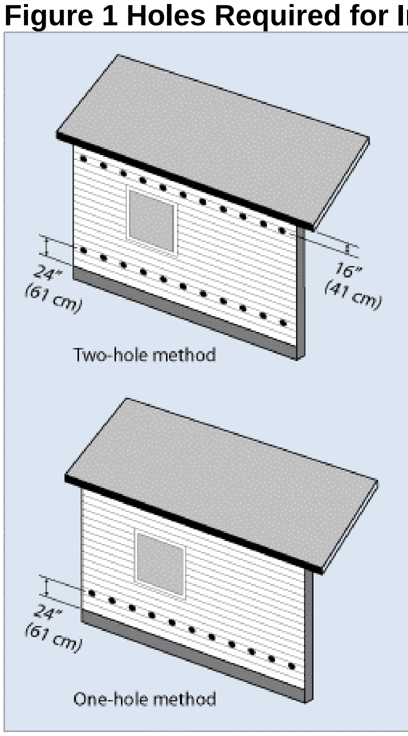
[4] http://www.ornl.gov/sci/roofs+walls/radiant/index.html
[5] http://www.eere.energy.gov/consumer/your_home/insulation_airsealing/index.cfm/mytopic=11520

12	38	55-60

Insulation rolls and batts are placed in cavities between studs, rafters, trusses, etc. around the perimeter of the home to form a "thermal boundary". The insulation's effectiveness is highly dependent upon the skill of the installer. Gaps or voids, and compressed insulation are common application errors resulting in decreased effective R-value of the insulation. Batts and rolls may come with paper or alloy films (faces) that act as vapor retarders or radiant barriers. Fiberglass also comes compressed into rigid panels.

Loose fill fiberglass is typically used in ceilings. It is generally blown into the space. As with roll or batt insulation, the thickness of the material determines the R-value. Care must be taken that thickness is uniform and coverage complete. Closed wall cavities and covered attic floors may also be filled with loose-fill fiberglass or other types of insulation. Installing insulation in walls commonly calls for a series of approximately 2" diameter holes drilled through the exterior sheathing between studs to access the wall cavities. The insulation is then blown into the cavity using specialized insulation blowers. A more detailed explanation of this process can be found in the Level 2 and 3 Protocol - Insulation Installation.

Figure 1 Holes Required for Insulating Wall Cavities



Source: U.S. Department of Energy Energy Efficiency and Renewable Energy

Cellulose insulation is a second common material used for homes and, like fiberglass, can be blown in. Commonly made from recycled newsprint and treated with a borate-based fire retardant, it shares many of the same characteristics that loose-fill fiberglass has in terms of application. Cellulose has a higher R-value per inch ranging from 3.6 to 3.8 per inch than fiberglass compared to 2.6 to 4.2 for fiberglass batts or blankets.

Foam board insulation consists of sheets or boards created from expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate (Iso), or polyurethane (PU) foam. Foam board enjoys a very high R-value per inch (ranging from R-4 for EPS up to R-8 for polyisocyanurate and polyurethane). XPS, Iso, and PU can act as an air barrier if sealed at joints and penetrations thereby limiting convective heat loss. Foam insulation, however, has its drawbacks in that building codes often mandate a fire barrier over foam to limit toxic gasses in the event of ignition. Secondly, foam can be deteriorated by ultraviolet (UV) rays from sunlight requiring protection from exposure to sun. Thirdly, foam, while not used as a food source, is easily excavated by ants and termites and might obscure these insects from visual detection in a pest management program. Degradation by insects also reduces the R-value of foam. Check with local building code officials to determine code restrictions on rigid foam insulation.

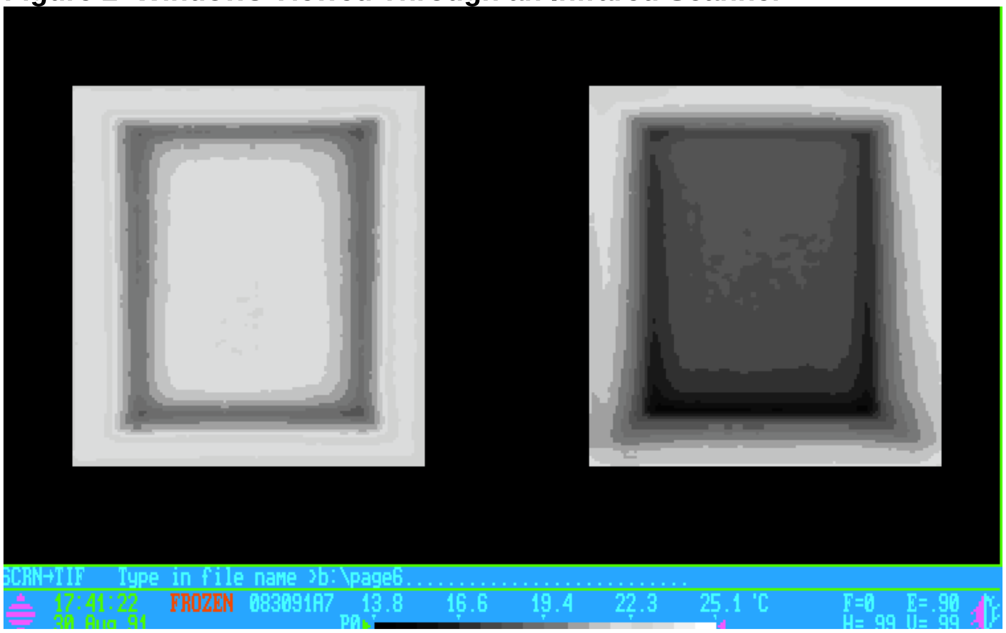
Polyisocyanurate, polyurethane, and phenolic foam can be applied to house surfaces in the form of spray. Typically applied to open wall or attic surfaces, these products are sprayed onto surfaces to be insulated where they adhere and cure to the surface. Overfilled insulation can be easily sawn flat to then facilitate drywall or other interior finish materials. Potential drawbacks stated for foam board insulation are applicable for sprayed foam as well. Additionally, spray foam requires specialized application equipment and operator protection gear to apply the foam to surfaces and prevent accidental exposure of harmful material to workers eyes, skin, or lungs. Suppliers of spray foam often require training and certification of applicators prior to providing spray foam product to the installers.

4.0 Tools

Tools are required for diagnosing where insulation is needed or determining the effectiveness of insulating activities. Additionally, some specialized tools are required for the actual installation of certain types of insulation as described above.

One very effective instrument for building diagnoses and an aid to sales is an infrared thermography scanner or camera. This device visually indicates areas of heat loss through a camera image with various shades of color or gray indicating temperature levels. In the Figure 2 below, the window on the right is displaying heat transfer through conventional glass whereas the window on the left has high-efficiency glass. The dark gray or black area illustrates heat loss. These photos were taken using an infrared scanner.

Figure 2 Windows Viewed Through an Infrared Scanner



Source: Lawrence Berkeley National Laboratory

Images such as these are easily understood by the homeowner allowing them to visually determine areas where insulation is absent or inadequate as well as determine effectiveness of remedial measures.

A blower door combined with an infrared scanner can make the images even more pronounced by creating air flows within the structure where they might be absent during scanning alone. These air flows represent convective losses. As described in Level 1 Protocol – Air Sealing, a blower door induces a pressure difference between the house interior and exterior. Most often blower door tests are done by lowering the pressure inside the house by "sucking" air out of the house with the blower door fan. Typically, a vacuum of 50 Pascal's is drawn upon the house and an air leakage level is determined in either air exchanges per hour (how many times does a home completely exchanges its volume of air in an hour) or cubic feet per minute. During this time, a contractor might use chemical smoke to look for spots where air is crossing the pressure boundary. Chemical smoke is commonly created with titanium tetrachloride in order to make smoke that is highly sensitive to air movement. Suppliers of blower door equipment also carry other associated items such as chemical smoke, auxiliary supplies for pressure testing, and user manuals.[6] [7]

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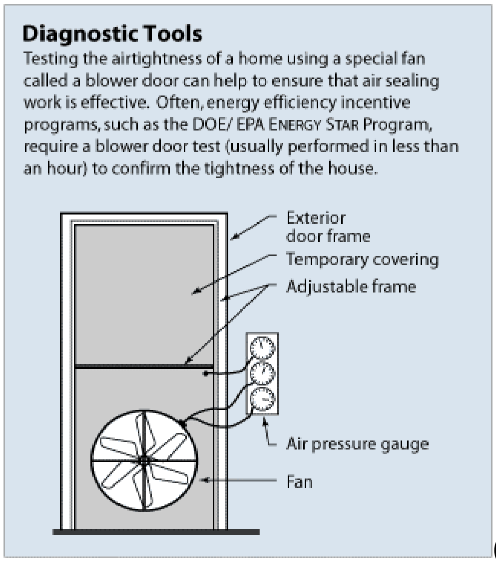
[6] http://www.energyconservatory.com/
[7] http://www.infiltec.com/inf-catb.htm

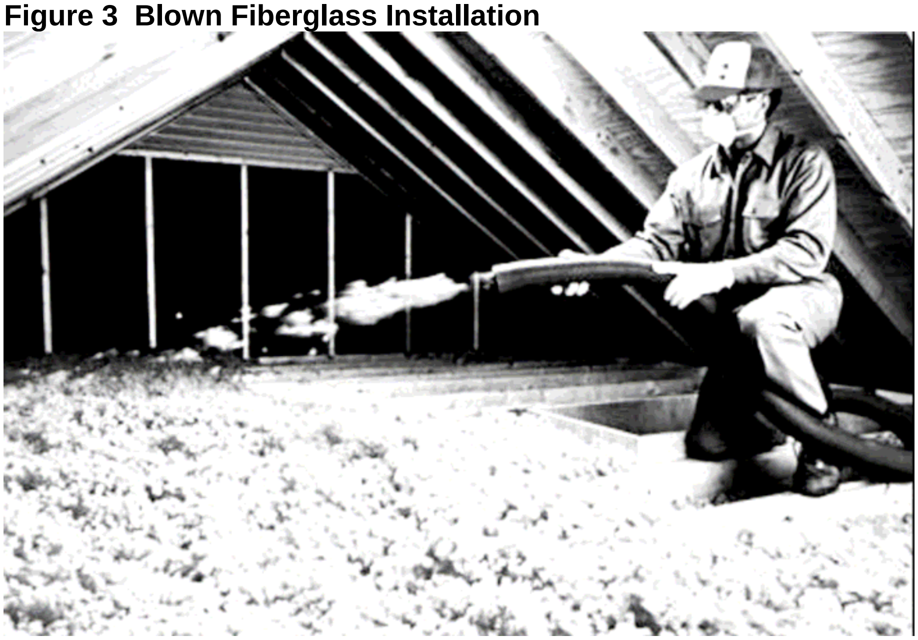


(Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy

Drafts induced by the blower door may also be felt by hand or seen by observing blowing and shifting insulation or moving window curtains or plants. Insulation with dark coloration is indicative of air movement due to the dirt collected by the insulation as air passes through it.

Loose-fill fiberglass and cellulose insulation is blown into place using machines that supply installation hoses with material at a constant rate and pressure.

Figure 3 Blown Fiberglass Installation



These machines range in size and capacity based upon intended use.

5.0 References and Suggested Reading

http://www.toolbase.org/secondaryT.asp?CategoryID=1025 — Insulation Materials standards, installation techniques and tools

http://www.pathnet.org/si.asp?id=399 - Walls Systems — Partnership for Advancing Technology in Housing

http://www.pathnet.org/si.asp?id=482 - Roof Systems — Partnership for Advancing Technology in Housing

http://www.pathnet.org/si.asp?id=481 - Foundation Systems — Partnership for Advancing Technology in Housing

http://www.buildinggreen.com/features/ins/insulation.html — Environmental Building News: Insulation Guide

Builder's Guide; Chapter 12 "Insulation" Building Science corp., Westford, MA

http://www.scespc.com/manualsandforms/Rcp-v2a2000.pdf — "Residential Contractor Program 2000R", Chapter 10 "Walls" Southern California Gas Co, Southern California Edison Co.

http://www.epa.gov/lead/rrpamph.pdf — "Reducing Lead Hazards When Remodeling Your Home" EPA

http://www.housingzone.com/probuilder/article/CA467409.html - HousingZone.com; Insulating Attics for Performance

http://www.greenbuilder.com/general/articles/AAS.atticcool.html - GreenBuilder.com; Don't Let Your Roof Take the Heat

http://www.weatherization.org/floorandfoundationinsulation.htm — Department of Energy - Energy Topics; Floor and Foundation Insulation

http://www.pathnet.org/si.asp?id=481 — Foundation Systems —Partnership for Advancing Technology in Housing