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When you consider performance and safety factors the balance swings to cellulose building insulation

Thermal Resistance (R-Value)

Thermal resistance (R-Value) is one of several factors that contribute to the performance of the "thermal envelope" of a building. It is a mistake to consider only R-Value when specifying insulation, but R-Value is important. Knowing what the R-value is may be the biggest challenge for a buyer or specifier.

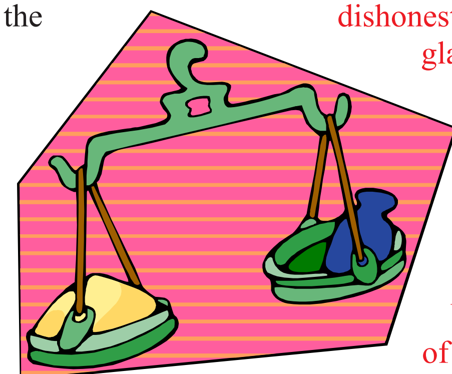
Cellulose

The R-factor of cellulose insulation is approximately 3.8 per inch and it does not vary significantly over a wide range of densities. In an attic, 10 inches of cellulose insulation will have an R-value of about R-38, regardless of the density of the material.

"Fluffing" cellulose by adding excessive air during installation does not change the R-factor of the insulation, so it is easy for an inspector or home owner to check the R-value of the installation. As long as the insulation maintains the required thickness it will have the specified R-value. (Refer to the section on Settlement for more information.)

In addition to maintaining R-value over a wide density range, cellulose insulation also maintains R-value under cold conditions. At an attic temperature of 20° F below zero the R-value of cellulose insulation is *higher* than at 70° above zero.

It's important to emphasize that while R-value is important, many other factors are nearly as significant in determining the real world thermal performance of buildings. Focusing on R-value to the exclusion of these can lead to poorly-performing buildings.



Fiber Glass

Fiber glass R-value changes with density. Light, fluffy blown-in fiber glass may have an R-factor of 2.2 per inch, or less; high density glass batts may have an R-factor of 4.0 per inch. The dishonest practice of "fluffing" blown-in fiber glass both reduces the R-factor of the material and increases the amount of settlement that will occur.

Depending on the density of the material, 12 inches of blown fiber glass may have an R-value anywhere between R-26 and R-38.

Under winter conditions the R-value of fiber glass is further reduced. The actual R-value of blown-in fiber glass in an extremely cold attic may be 30, 40, or even 50 percent lower than the purchaser thought he was buying. The more you need it the less insulating performance it delivers.

The stated R-value of fiber glass batts is based on full thickness. Batts stuffed into wall cavities are often compressed to less than full thickness and lose R-value.

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Settling and Loss of R-Value

All loose-fill insulation settles after installation. Cellulose insulation is always specified and sold at settled density, so compensation for settling is built into the bag count and material weight columns of cellulose coverage charts. Other loose-fill insulation materials may or may not compensate for expected settlement in coverage chart data.

Cellulose

The Federal Trade Commission R-Value Rule and accepted industry standards all require cellulose insulation to be specified and sold at settled density.

The bag count and weight of material columns on cellulose coverage charts give precise and accurate information on the amount of material that must be installed to produce the specified R-value. It is not necessary to install more material than is indicated by these columns to compensate for settling. Compensation for settlement is built into the coverage chart. In fact, it is commonly believed the test specified results in *overcompensation* for settlement.

Fiber Glass

There are no industry or government standards that address settlement of fiber glass insulation, in spite of the fact that several studies indicate blown fiber glass settles. The FTC R-Value Rule acknowledges that fiber glass settles, but contains no provisions requiring manufacturers to account for loss of thickness after installation.

Settlement will be greatest (and the R-value less) if the material is deliberately fluffed during installation, an all too common occurrence.

ASTM has adopted a test method that can accurately determine the installed thickness of any loose-fill insulation. If manufacturers use this test accurate coverage charts can be developed.

Air Infiltration

Uncontrolled leakage of air through exterior walls and ceilings of homes is almost as important as R-value in determining how much energy will be required to heat and cool a building. This factor is all too often totally ignored in specifying insulation.

Cellulose

Cellulose insulation, either spray-applied or dense-packed in walls, is very effective at sealing buildings against air infiltration. And air infiltration is almost as important as R-value in the thermal performance of a building.

Scientific studies have confirmed anecdotal reports and "conventional wisdom" about the superiority of cellulose at tightening buildings. Research shows cellulose to be up to 40% better than fiber glass at controlling air infiltration. Infiltration of unconditioned ambiant air means that heating and cooling systems must expend more energy to compensate for the infiltration.

Many authorities believe insulating a building with cellulose makes air barriers (housewrap) unnecessary. Canadian engineers tested a new cellulose-insulated home for air tightness, then slit the polyethylene air/vapor barrier in about 20

Fiber Glass

Fiber glass is used as air filter media, and fiber glass in walls and ceilings behaves much as the fiber glass in an air filter. Air rushes right through it. When fiber glass-insulated walls are opened the batts are usually found to be covered by dust, just as an air filter would be. Additional materials to control air movement are essential in fiber glass-insulated building assemblies. In addition, extreme care must be taken to seal all areas around pipes, windows, electrical boxes, and along studs in fiber glass-insulated walls.

High R-values won't assure comfort or energy savings if cold air (or hot air) can leak into the building around and through the insulation.

It is possible, but difficult, to build tight fiber glass-insulated assemblies. By using overlapping foam sheathing, a separate air barrier, and extensive amounts of tape, caulk, and injected foam places and retested the building. *There was absolutely no change in measured air leakage*. Smoke pencil testing at the slits showed “not a breathe” of air leakage. No attempt was made to tighten the exterior sheathing and the siding had not yet been installed when the test was performed.

sealant fairly tight walls and ceilings can be constructed under controlled conditions.

Builders often are reluctant to use these measures. The extra materials and the painstaking attention to details add considerably to the cost of the building. Why not just use insulation that "automatically" tightens walls and ceilings?

Convection

Hot air rises, and when this happens cold air rushes in to replace it. When this occurs in insulation installed in an attic the air circulation carries heat through the insulation, reducing its effective R-value. Under cold winter conditions the R-value loss can be significant.

Cellulose

The R-value of insulation materials tends to increase slightly as the temperature difference between the hot side and the cold side of the insulation increases. With cellulose insulation this is exactly what happens. Scientists at Oak Ridge National Laboratory have reported that "R-values [of cellulose insulation] measured under winter conditions increased as the temperature difference across the insulation increased."

Based on air permeability, the Oak Ridge scientists have calculated that cellulose insulation will not lose R-value due to convective heat loss at temperatures as low as 40^{o} F below zero. This means that cellulose insulation maintains its resistance to heat transfer under virtually all weather conditions that occur in North America.

Fiber Glass

Maintaining R-value at below freezing temperatures is a problem for light, fluffy blown fiber glass, because of a phenomenon called convective heat loss. At about 32^{o} F air begins to circulate within the insulation. These air flows carry heat through the insulation, reducing its effective R-value, often by a very significant amount.

Studies at Oak Ridge National Laboratory showed loss of nearly 15% of R-value at 20^{o} F. At 18^{o} F below zero the insulation had only about 60% of its nominal R-value. At least one northern state (Minnesota) has required fiber glass producers to change coverage charts to reflect this cold temperature R-value loss. A layer of cellulose on top of the fiber glass has been found to be effective at controlling convective heat loss.

Water Vapor Sorption

Moisture is one of the more misunderstood aspects of building shell performance. Different insulation materials exhibit different moisture handling characteristics. These characteristics must be considered in designing insulated assemblies.

Cellulose

No insulation "attracts" moisture, but various materials exhibit different moisture handling characteristics. Cellulose insulation is a "storage layer" in an assembly. This means it can safely hold moisture that might otherwise move into more vulnerable parts of the assembly and still maintain its thermal resistance.

Exfiltration of moisture-laden air into walls and ceilings is the major moisture transfer mechanism. The low air permeability of cellulose all but eliminates this means of moisture movement.

In a paper presented at a 1999 conference two of the world's leading moisture experts reported

Fiber Glass

Glass fibers do not absorb moisture, however, moisture can condense in air spaces within the insulation and migrate to parts of the insulated assembly that may be damaged. Especially vulnerable are bottom plates in walls insulated with batts, which may exhibit the so called "thatched roof effect" of condensed moisture trickling down the vertically-oriented fibers.

Fiber glass is susceptible to air exfiltration, the major cause of moisture migration into walls and ceilings. Vapor retarders, air barriers, and careful caulking and sealing are necessary to prevent moisture buildup in walls in colder climates.

data based on computer modeling that showed cellulose insulation in a wall resulted in lower moisture levels in other wall components than in an uninsulated wall.

Fire Safety

"Fire safety" is a complex matter that can't be defined by a single factor or material characteristic. It's a mistake to assume that a "noncombustible" building material is necessarily more "fire safe" than a combustible material. Most building materials are classified as "combustible," and some combustible materials actually offer greater fire protection to building occupants than "noncombustible" materials.

Cellulose

In the United States cellulose insulation must meet the strict flammability standards of the Consumer Products Safety Commission. Fire retardants are applied during the manufacturing process to insure fire safety.

Cellulose insulation products routinely qualify for Class A flame spread ratings. Cellulose insulation has been tested and qualified as a fire stop around steel through penetrations and as a fire block in wood frame walls.

In several demonstration burns, buildings with cellulose have retained structural integrity significantly longer than buildings with other fiber materials. In one demonstration the ceiling of a fiber glass-insulated building collapsed 22 minutes after fires were ignited. A ceiling with cellulose insulation stayed in place for 70 minutes -- an important margin of safety for building occupants and fire fighters.

The National Research Council Canada added scientific support to the burn demonstrations with a study that concluded fiber glass reduced the fire resistance of insulated assemblies while cellulose improved fire resistance 22% to 55%.

NRCC tested a cellulose insulated floor/ceiling assembly in 1995 and found it to have approximately 50% higher fire resistance than a fiber glass-insulated assembly. The cellulose assembly resisted direct fire exposure about 30 minutes longer than the fiber glass test assembly.

A cellulose-insulated wall tested in 1999 by Omega Point Laboratories was found to be 46% to 77% more fire resistant than an uninsulated wall.

As a result of this fire resistance, under some

Fiber Glass

Fiber glass is an inorganic material, and is therefore noncombustible. This does not mean fiber glass provides greater fire safety. The National Fire Academy notes: "It is critical to recall that noncombustible does not mean 'safe.' It certainly does not mean 'fireproof.' The concept of fire-resistance goes beyond that of noncombustibility. It refers to the capacity of a material or construction to withstand fire or give protection from it." Fiber glass does not measure up to either standard.

The open structure of fiber glass makes abundant amounts of oxygen available to wood and other combustible materials in ceilings and walls. Assemblies insulated with fiber glass are much less fire resistant than walls and ceilings insulated with cellulose, as studies by the National Research Council Canada proved.

In a paper presented at an ASTM symposium a prominent fire protection expert noted that: "Standard fiber glass has an operating temperature of 350° F. Temperatures above that tend to make it shrink. Before fiber glass loses its physical characteristics, it can contribute to the fire. Generally speaking fiber glass does not provide adequate protection in a fire. A panel composed partly of fiber glass can lose its physical properties within 10 minutes, depending on the extent of the fire."

Facings of fiber glass batts are usually combustible and may accelerate the progress of a fire, especially if batts are inset stapled, a practice that creates miniature "chimneys" lined with paper or petrochemicals with absolutely no fire retardants.

These fiber glass deficiencies account for the opinion of a contractor who is also a fire fighter fire conditions, cellulose gives building occupants more time to reach safety and fire fighters more time to save the structure.

with 19 years experience who said: "Being in the construction business and in the fire service there is no one who could convince me that fiber glass insulation is safer than cellulose in an attic."

Health & Safety

Disease can have causes other than bacteria and viruses. A number of health problems are now known to be "environmental diseases." Identified environmental diseases include black lung disease, asbestosis, and several forms of cancer. In some cases building materials have been identified as causing or contributing to health problems. Specifiers, contractors, and home owners need to be informed of known and possible health risks associated with various building materials and follow handling and installation precautions recommended by the manufacturers of these products.

Cellulose

Cellulose insulation is not a unique substance. It is a combination of paper fibers and other materials whose physical, chemical, and biological characteristics are well known.

Cellulose fibers are classified as "nuisance dust," that is, dust which while possibly irritating and unpleasant, is not a health hazard. Cellulose insulation fire retardants are also well-characterized and regarded as nonhazardous. The toxicity of boric acid, a common fire retardant in cellulose insulation, is virtually identical to that of table salt. Other cellulose insulation ingredients are equally benign.

Because of the scientific community's thorough familiarity with the materials used in manufacturing cellulose insulation, it has not been considered necessary to conduct health effects studies specifically on cellulose insulation. Cellulose producers can supply material safety data sheets for all relevant components of their products.

A 2001 health hazard evaluation report from the National Institute for Occupational Safety and Health (NIOSH) states that the highest concentration of respirable airborne fibers and particles released during cellulose insulation installation was five times lower than the federal OSHA exposure limit. NIOSH concluded that a common N95 dust mask provides adequate worker protection.

Mold has become an important indoor air quality and health issue. For various reasons associated with the manufactuuring process and its moisture control properties few cases of mold contamination of cellulose insulation have been reported. Insulation that becomes wet should be inspected for mold

Fiber Glass

After years of testing the National Toxicology Program listed fiber glass as a substance "reasonably anticipated to be a carcinogen in humans."

Studies by Cornell University concluded that man-made mineral fibers, including fiber glass, may be one of the major causes of "Sick Building Syndrome" (SBS). SBS is said to exist when one or more similar health problems apparently related to interior environment factors are endemic among occupants of a specific building.

Fungi have also been linked to SBS and other environmental diseases. Serious incidents of fungal contamination of fiber glass duct insulation and wall insulation have been reported in the professional literature and by the general media, including two of the three largest broadcast television networks. If insulation becomes wet it should be inspected for mold growth.

Care should be taken to protect construction workers and building occupants from exposure to airborne glass fibers. Insulation installers may be exposed to high levels of airborne glass fibers, but protective clothing and a suitable respirator can reduce risk to negligible levels.

Corrosion Resistance

Corrosion problems associated with insulation are not common, but they do occur, usually because of moisture in contact with metal building components. In such cases it's important that the insulation not aggravate the problem.

Cellulose

Federal and industry standards for cellulose insulation specify strict corrosiveness requirements. Many laboratories and other organizations that certify building materials require periodic corrosiveness testing of cellulose insulation as a condition for gaining and maintaining certification or labeling privileges.

Fiber Glass

Fiber glass is a relatively inert substance that is not inherently corrosive. Some fiber coatings and materials used in batts may be potentially corrosive, but few problems have been reported.

Installation in Limited Spaces

In wide open attic areas with plenty of room between the joists and the roof the R-factor of insulation makes little difference. Enough material can be installed to produce any required R-value. But what happens when space is limited, as may be the case with flat roofs, and is always the case near the eaves of sloped roof buildings?

Cellulose

Cellulose insulation is preferred for installation in limited spaces since it generally has a higher R-factor than other loose-fill fiber insulation materials. Perimeter areas of attics and other tight spaces are examples.

Fiber Glass

Loose-fill fiber glass insulation generally has a lower R-factor than cellulose insulation. This means that 12, 15, or more, inches of blown fiber glass may be required to produce installed R-value equal to 10 inches of cellulose insulation. In cold climates even more fiber glass may be necessary to compensate for convective heat loss. In some cases there simply may not be enough space to permit installation of sufficient insulation.

Recycled Content & Environmental Issues

Today recycling and environmental concerns are mainstream issues. Even people who do not identify themselves as "environmentalists" want to make environmentally-responsible buying decisions.

Cellulose

Cellulose insulation is an inherently recycled material with approximately 80% recovered content. Most of the recovered content of cellulose insulation is postconsumer waste. In addition, cellulose insulation has low embodied energy -- less than 750 BTU/lb by one conservative estimate -- which results in less air pollution from the manufacturing process and greater energy efficiency.

Fiber Glass

The recovered content of fiber glass ranges from zero to a maximum of about 30%. In many cases factory waste accounts for much of the recovered content

Fiber glass is produced in furnaces that burn natural gas and release CO_2 and other greenhouse gases into the air. Estimates of the embodied energy of fiber glass range from about 8,500 BTU/lb to more than 12,000 BTU/lb