Chapter

1

A Brief History of Thermal Insulation

From caves to superinsulated houses, human beings have demonstrated the need for protection from the elements. The true origins of the science of thermal insulation, however, are difficult to identify. Organic materials have served as the natural prototype for thermal insulators. Evolutionary examples include fur covering the polar bear or feathers on a bird, cotton, wool, straw, and even hair. Similarly, prehistoric human beings clothed themselves with wool and skins from animals and built homes of wood, stone, earth, and other materials for protection from the cold winter and the heat of summer.

For thousands of years, house structures were designed to best suit the climate of their location. For example, using the earth as an insulator, the Egyptians retired to the coolness of subterranean chambers and grottoes on hot days.[1] Historians believe that the ancient Greeks and Romans discovered asbestos and found many uses for it because of its resistance to heat and fire. The Romans even used cork for insulation in shoes in order to keep their feet warm. Pliny, in the first century, referred to the use of cork as an insulating material for roofs. Early inhabitants of Spain lined their stone houses with cork bark, and North African natives used cork mixed with clay for the walls of their dwellings.[2]

As technology developed, so did innovations to improve the comfort of human beings. Introduction of the fireplace and chimney by the Norwegians and people of Iceland during the twelfth and thirteenth centuries provided controlled, artificial heat.[1] It was evident

that the task soon became not only how to keep heat out but also how to keep heat in. The thatched huts of northern Europe were built with a roof, up to 2 ft thick, of woven straw and walls of clay and straw (Fig. 1.1) Early Spanish mission houses of the southwestern United States, where temps rose to 120 to 140°F, were comparatively cool due to clay straw walls several feet thick. Similarly, the indigenous peoples of the South Seas built huts of dried sea grass. The hollow fiber of the dried sea grass provided a good degree of thermal resistance.[2] Mineral fiber—another important insulating material—was first used by the natives of the Hawaiian Islands to blanket their huts. The fibers came from volcanic deposits, where escaping steam had broken the molten lava into fluffy fibers.

It was not until the advent of the industrial revolution of the late nineteenth century that deliberate commercial application of thermal insulations became mainstream. For example, blanket-type insulations were being developed throughout the 1890s. One such product, known as Cabot's Quilt, was introduced by Samuel Cabot in 1891. The material consisted of a matting of *Zostera marina,* a marine plant also known as *eel grass,* sandwiched or stitched between two layers of kraft paper. (An unrefined use of this material was found in the Pierce house of Dorchester, Massachusetts, built in 1635, with *Zostera marina* stuffed between the framing members.)[2]

Mineral wool was first commercially produced as a pipe insulator in Wales in 1840 and in the United States for the first time in 1875.[3] It was almost 60 years later, in 1897, that C. C. Hall, a chemical engineer, produced rock wool. By 1901, he was producing this product commercially at a plant in Alexandria, Indiana.[2] Hall formed a partnership to make the new product and later founded Banner Rock Products Co. (which was purchased by Johns Manville Co. in 1929). By 1928, there were eight plants manufacturing either rock wool or slag wool insulation in the United States. (By the 1950s, this number had increased to approximately 90 but has since declined to about 15 to 20 today.[4])

Fiberglass had its first beginnings in ancient Egypt, when people discovered that they could draw hot glass into threads, which were placed around vessels for decoration. The modern technique of making fiberglass insulation, developed in 1931, involves jetting of molten glass through tiny heated holes into high-speed air streams, wherein the resulting fibers are drawn very thin and to great length.[5] Developed by Owens-Illinois, the Corning Glass

Company was the sole producer of this material, later known as Owens-Corning fiberglass, until an antitrust action filed in 1949 by the Department of Justice.[4]

Wood shavings were a very popular insulation product due to the wide availability of raw materials and their low cost at the turn of the century. Shavings often were treated with lime or some other chemicals to increase resistance to water absorption, fire, and fungal growth. These were called *balsa wool* or *balsa batt* (actually sawdust wrapped in paper) and were popular in homes of northeastern United States.

Straw bale construction also has been around since the "frontier days" of the United States and is most common in the western Plains states. When the Kincaid Act of 1904 opened part of Nebraska to homesteading, straw was one of the only indigenous materials available. Housing became an urgent necessity for frontiersmen, and straw bale construction flourished in the Sandhills of Nebraska more than any other known location. Although these settlers planned to build a "real" house as soon as enough money could be saved, such houses often were left exposed on the outside, but they were plastered on the inside to enhance tidiness and prevent drafts. Although the process sometimes took as long as 10 years, the outside walls would finally get a thick coat of mud plaster or cement stucco.

Straw bale construction was an appropriate, sometimes necessary response to a unique combination of legislative, geologic, natural resource, and socioeconomic factors that prevailed in that region. The building of railroads through the Midwest is one factor that added to the reduction of straw use. Railroads and merchandizing enabled wood products to replace Nebraska's indigenous materials for buildings needs.

Reflective insulation materials, using bright metallic surfaces, were first patented in 1804. Aluminum eventually became the predominant reflective material, but it did not achieve commercial popularity until the 1930s.[2]

The genesis of insulation board products dates to 1910. Two semirigid insulation products made from flax (a textile fiber made from plants) were manufactured in Minnesota, called *Flaxlinum* and *Fibrofelt.* These ultimately were replaced by rigid insulation board products, also first produced in Minnesota, in 1914. Insulite was manufactured by taking wood pulp waste products, known as *sulfite screenings,* and processing and drying them into a rigid,

lightweight insulating material. This plant produced up to 60,000 square feet of Insulite per day.[6] By 1920, Celotex Company introduced an insulating board made from bagasse, a waste by-product of sugar cane after the juice has been extracted.[2] This was followed by Celotex's Cenesto, a fire-resistant insulation board surfaced on one or both sides with asbestos cement, used primarily for low-cost housing.[6] Lower-density insulation boards, generically belonging to the family of fiberboard products, were available in thicknesses ranging from 7/16 to 1" and in some cases up to 3". Fiberboard insulation commonly was used as an insulating lath over the wood studs, a plaster base over masonry, and even in some cases as an interior finish.[6]

The 1920s saw a measurable rise in public awareness of the value of thermal insulation. While fiberboard was advertised as the most economical insulation of its time, batts began a rise in popularity as well. Aluminum and copper also were applied to the batts as reflective foils.[6] *Slag wool* is a material made by blowing steam through fluid slag (molten rock). Also known as *rock wool,* this product was later replaced by asbestos, similar in appearance and promoted as the best alternative by heating engineers who dealt with the control and handling of steam. Glass fiber production started in the mid-1930s.

The case also can be made that insulation was not as necessary prior to the 1920s as it is now because of the construction materials and methods used at that time. Materials were heavier, including windows and door sashes, which provided adequate weather resistance. The growing popularity and use of lighter building materials increased the need for insulation products.[3] The gradual introduction of air-conditioning systems into home design also contributed to a greater need for thermal insulation.

In 1928, the Milam Building in San Antonio, Texas, became the first high-rise office building to be completely air conditioned. In that same year, Willis Carrier installed the first residential air conditioner, called the Weathermaker, that heated, cooled, humidified, cleaned, and circulated air in homes.[7] One year later, in 1929, the Frigidaire division of General Motors introduced its first room cooler. Several other manufacturers, including York and General Electric, began to offer room coolers soon after. The first window air conditioners were developed in the 1930s, but it was 1936 when Philco-York introduced a 3675 Btu/h window unit. Popularity increased throughout the next two decades, sales of window units approaching 300,000 in 1952. The early 1950s also saw the evolu-

tion of smaller central air-conditioning systems, using water-cooled condensers, and they become more commonplace in residential use.[8]

During World War II, the use of building insulation was made mandatory to conserve metal required for heating and air-conditioning equipment and to save fuel.[9] This probably contributed to a greater awareness by the general population of the sensible applications of insulation in residences as well. This was explored further by a special report developed by the Secretary of Defense in 1957. Capehart housing was rented to civilian employees at remote military institutions. The study concluded that if the 72,000 Capehart act houses would have been designed to sufficient thermal standard s, the United States government, which pays the heating bill as part of the rent, would save $52 million over a 30-year period.[9]

Extruded polystyrene insulation originally was developed by the Dow Chemical Company in the United States in the early 1940s. Known proprietarily as *Styrofoam,* it was first used as a flotation material in liferafts and lifeboats because its fully closed cell structure renders it highly resistant to water absorption. The insulating properties of Styrofoam, combined with the advantage of the closed cell structure, led to its development as a thermal insulation material. Initial applications were in low-temperature situations for cold-store floors, wall, and ceiling panels and pipe insulation. In the 1950s, Dow's extruded polystyrene foam extended its impact to other areas of the construction industry—as a thermal insultant in commercial and residential buildings.

The 1970s saw a dramatic shift in public awareness and sensibility toward energy conservation. The production of domestic oil had peaked in 1970, which subsequently created a greater dependence on foreign exports. Many researchers point to the Arab oil embargo of 1973 and 1974 as the catalyst for the energy crisis. A second sharp rise in oil prices occurred in 1979 following the Iranian revolution, further contributing to public discussion as well as new energy programs. Government mandates have continued this trend, with the Federal Energy Management Improvement Act (FEMIA) of 1988 requiring a 10 percent reduction in per-square-foot energy use by federal buildings between 1985 and 1995, followed by the sweeping Energy Policy Act of 1992 (EPACT). This act increased conservation and energy-efficiency requirements for government, energy, and consumers. Federal agencies, for example, were required to attain a 20 percent reduction in per-square-foot energy consumption by 2000 compared with a 1985 baseline. All

these initiatives contributed to a greater awareness of energy conservation not only by the general public but also by producers, installers, and designers of insulation installation materials and methods.

As the U.S. paper industry grew in the 1940s, it was only natural to look to paper by-products for insulation. Originally manufactured as a sound deadener, paper-based cellulose soon caught on as an effective, dense insulation material. Early cellulose insulation did not benefit from today's fiber technology and application equipment, however, so it garnered only a small portion of the market as fiberglass became increasingly popular after World War II.[10] (Cellulosic fiber insulation had several patents issued in the nineteenth century but gained little, if any, popularity.[4])

As a result of the 1970s energy crisis, heavy demand for insulation induced many new producers to enter the cellulose industry, causing a resurgence of cellulose insulation popularity. Once the crisis passed, however, only a few companies remained committed to refining the material.[11]

Urea formaldehyde foam insulation (UFFI) was introduced to the building industry in 1960. Health complaints started from the occupants of UFFI-insulated homes in 1978, and by 1980, UFFI was banned across Canada, reportedly due to long-term health risk to occupants of houses insulated with UFFI. (Urea formaldehyde is one of the main resin mixtures of formaldehyde, and of all the formaldehyde compounds, it contributes the most to indoor air problems because of its water solubility.)[12]

References

1. Albert Farwell Bemis, *The Evolving House* (Cambridge, MA: Technology Press, p. 107, 1933).
2. Paul Dunham Close, *Thermal Insulation of Buildings* (New York: Reinhold, p. 7, 1947).
3. Henry S. Harrison, *Houses: The Illustrated Guide to Construction, Design and Systems* (Chicago: Residential Sales Council, p. 20, 1998).
4. J. D. Nisson and Gautam Dutt, *The Superinsulated Home Book* (New York: John Wiley & Sons, 1985).
5. T. Neil Davis, "Fiberglass Insulation," *Alaska Science Forum,* April 30, 1981.
6. Thomas C. Jester, *Twentieth Century Building Materials* (New York: McGraw-Hill, p. 122, 1995).
7. Carrier & United Technologies Web site: *http://www.carrier.com/final/innovations/history/history3.html.*
8. Mike Pauken, "Sleeping Soundly on Summer Nights," *ASHRAE Journal,* May 1999, pp. 42–44.

9. Tyler Stewart Rogers, *Thermal Design of Buildings* (New York: John Wiley and Sons, p. 2, 1964).
10. GreenStone, Cocoon, and Simply Smarter Insulation are trademarks of GreenStone, a Louisiana-Pacific company.
11. Cellulose Insulation Manufacturers Association Web site press release: *http://www.cellulose.org/press.htm.*
12. The Residential Energy Efficiency Database (REED): *http://www.its-canada.com/reed/iaq/uffi.htm.*