

Appendixes

Appendix A

INSULATION

INTRODUCTION

In his National Energy Plan presented to Congress on April 20, 1977, President Carter set as a national goal the insulation of 90 percent of existing homes in the United States by 1985. Given spiraling energy costs and a new tax credit, Americans have been insulating their homes in record numbers. According to the Department of Energy (DOE), 25 million to 47 million homes will be reinsulated by the end of 1985.

Nationwide increases in thermal insulation have, however, resulted in a number of actual and potential problems. For example, the absence of uniform safety standards and testing methods among various levels of government and the absence of Federal and State laws on home insulation have contributed to the risks of consumer injury, illness, and death. Although some basic laws do exist with respect to the manufacture and installation of insulation materials, their effectiveness remains questionable.

This appendix outlines and discusses some of the major problems associated with the increased use of insulation.

TYPES OF INSULATION MATERIALS

The principal applications and market segments for insulation materials in the residential sector are shown in tables A-1 and A-2. A number of properties influence the thermal performance of insulating materials. Thermal performance is expressed in terms of thermal resistance (R-value), which describes the ability of a particular material to restrict heat flow. In addition to thermal performance, this section includes a brief overview of other important properties, such as corrosiveness and degradation. Tables A-3 through A-10 provide a more extensive list of properties.

Rock Wool and Slag Wool

Rock wool and slag wool are terms used to denote glassy fibers that are produced by melting and fiberizing slags obtained from smelting metal ores ("slag wool") or by melting and fiberizing naturally occurring rock ("rock wool"). Rock and slag wool products appear in the form of batts and loose-fill for blown or poured application. The reported R-values for rock wool batts are 3.2 to 3.7, and 2.9 per 1-inch thickness for blowing wool. The thermal performance of this product is reportedly

Table A-1.—Principal Residential Applications

Locations	Fiberglass	Rock wool	Cellulose	Cellular plastics	Perlite	Vermiculite	Reflective surfaces
New construction							
Roof/ceiling	X	X	X	X			
Walls	X	X		X			X
Floors/foundation. . . .	X	X		X			X
Retrofit							
Roof/ceiling	X	X	X	X		X	
Walls	X	X	X	X			
Floors/foundation. . . .	X	X		X			X

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No. BNL-50862, June 1978, p. 9

Table A-2.—Market Segments and Product Usage

Location or building section	Products used	
	New buildings	Retrofit
Residential buildings (wood. framed)		
Ceilings	Fiberglass batt	Fiberglass Batt
	Fiberglass loose fill	Fiberglass loose fill
	Rock wool batt	Rock wool batt
	Rock wool loose fill	Rock wool loose fill
Cellulose loose fill	Cellulose loose fill	Cellulose loose fill
		Vermiculite
Sidewalls	Fiberglass batt	Fiberglass loose fill
	Rock wool batt	Rock wool loose fill
	Cellular plastic sheathings	Cellulose loose fill
	Wood fiber sheathings	
	Reflective surfaces	
Floors	Fiberglass batt	Fiberglass batt
	Rock wool batt	Rock wool batt
	Reflective surfaces	Reflective surfaces

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No BNL-50862, June 1978, p.10

unaffected by age. Its thermal conductivity can be affected by moisture content, although the material, after drying, regains its original properties. When dry, rock wool does not support fungal growth, bacteria, or vermin; exudes no odor; and is noncorrosive. ¹

Fiberglass

Fiberglass is manufactured in a high-technology process in which glass raw materials are combined and melted in a furnace, then led out through a forehearth to the fiberization devices. Phenolic resin is a commonly used binder that is applied to the fiber as it flows through a collection chamber. The fiber with resin is collected on a moving belt and passed through an oven to cure or set the resin, and the finished product is removed from the end

¹*An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No. BNL-50862 (U.S. Department of Energy, June 1978), p. 82

Table A-3.—Rock and Slag wool

Material property	Value
Density	1.5-2.5 lbs/ft ³
Thermal conductivity (k factor) at 75°F.	0.31-0.27 Btu-in/ft ² hr°F (batts)
	0.34 Btu-in/ft ² hr°F (loose fill)
Thermal resistance (R-value) per 1" of thickness at 75°F.	3.2-3.7 (batts)
	2.9 (loose fill)
Water vapor permeability	>100 perm-in
Water absorption.	270 by weight
Capillarity	none
Fire resistance.	noncombustible
Flame spread	15
Fuel contributed	0
Smoke developed.	0
Toxicity	none
Effect of age	
Dimensional stability.	none (batt)
	settling (loose-fill)
Thermal performance	none
Fire resistance	none
Degradation due to	
temperature	none
Cycling	none
A n i m a l	none
Moisture	transient
Fungal/bacterial.	does not support growth
Weathering.	none
Corrosiveness	none
Odor	none

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No BNL-50862, June 1978, p. 81

of the line and packaged. Fiberglass is usually sold in the form of batts and blankets (with or without a vapor barrier) or shredded, lubricated, and packaged as blowing wool. The R-value **for fiberglass batts or blankets is about 3.2; the R-value** for loose-fill is 2.2 per inch. It appears that fiberglass batt insulation does not settle or shrink with age, but loose fill may settle. The thermal performance of this material is reportedly unaffected by age. Fiberglass does not promote bacterial or fungal growth and provides no sustenance to vermin. Insulation materials made from fiberglass are noncorrosive and have no objectionable odor. ²

Cellulose

Cellulose insulation is manufactured by converting used newsprint, other paper feedstock, or virgin wood to fiber form with the incorporation of various chemicals (e. g., boric acid, borax, or aluminum sulfate) to provide flame

²Ibid, p 79

Table A-4.—Fiberglass

Material property	Value
Density	0.6-1.0 lbs/ft ³
Thermal conductivity γ (k factor) at 75° F.	varies with density
Thermal resistance (R-value) per 1" of thickness at 75° F.	3.16 (batts) 2.2 (loose fill)
Water vapor permeability	>100 perm-in
Water absorption	<1 % by weight
Capillarity	none
Fire resistance.	noncombustible
Flame spread	15-20
Fuel contributed	5-15
Smoke developed.	0-20
Toxicity	Some toxic fumes could develop due to combustion of binder.
Effect of age	
Dimensional stability.	none (batt) settling (loose-fill)
Thermal performance	none
Fire resistance	none
Degradation due to	
Temperature.	none below 180 °F
Cycling	none
Animal.	none
Moisture	none
Fungal/bacterial.	does not support growth
Weathering.	none
Corrosiveness	none
Odor.	none

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No. BNL-50862, June 1978, p. 78.

retardancy. Cellulose products are usually available as loose-fill or spray-on. The thermal resistance values for cellulose insulation are **in the range of 3.7 to 3.2**. However, compaction (caused by vibration and settling under its own weight) can decrease its R-value in two ways: loss in thickness and an increase **in conductivity** due to the increase in density. If cellulosic material is properly treated, its weight gain from water absorption will not exceed 15 percent. However, poor quality control and improper selection of flame-retardant chemicals may increase the level of absorption. Some chemicals added to cellulose to provide flame retardancy are known to cause corrosion on metals such as steel, aluminum, and copper. Fungal and bacterial growth can be a problem, unless chemicals are added to inhibit such growth.

Cellular Plastics

A variety of different plastics, when produced as foams, are useful as insulation

Table A-5.—Cellulose

Material property	Value
Density	2.2-3.0 lbs/ft ³
Thermal conductivity (k factor) at 75° F.	0.27 to 0.31 Btu-in/fhr°F
Thermal resistance (R-value) per 1" of thickness at 75° F.	3.7 to 3.2
Water vapor permeability	high
Water absorption.	5-200/ by weight
Capillarity	not known
Fire resistance.	combustible
Flame spread	15-40
Fuel contributed	0-40
Smoke developed.	0-45
Toxicity.	develops CO when burned
Effect of age	
Dimensional stability.	settles 0-20%,
Thermal performance	not known
Fire resistance.	inconsistent information
Degradation due to	
Temperature.	none
Cycling	not known
Animal.	not known
Moisture	not severe
Fungal/bacterial.	may support growth
Weathering.	not known
Corrosiveness	may corrode steel, aluminum, copper
Odor.	none

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No. BNL-50862, June 1978, p. 83

materials. Foamed-in-place and board stock foams exist. As differences exist in the chemical composition of these materials, a separate discussion is necessary for each cellular plastic insulation.

Polystyrene Foam

Polystyrene is a thermoplastic material produced by the polymerization of styrene in the presence of a catalyst. Polystyrene foam can be produced by either intrusion or extrusion.³ Foam produced by extrusion has a more consistent density than foam produced by the molding process, in which variations in density average about 10 percent. The R-value for molded polystyrene foam (3.85 to 4.35) is lower than the R-value for extruded polystyrene (5.0) as the former has air in the cells and the latter has a mixture of air and fluorocarbon.

Polystyrene foam must be protected from direct exposure to ultraviolet (UV) light, which can cause it to yellow and turn to dust. Its in-

³ibid , p 21

Table A-6.— Expanded Polystyrene Foam

Material property	Value
Density	0.8-2.0 lbs/ft ³
Thermal conductivity (k factor) at 75° F.	0.20 Btu-in/ft ² hr°F (extruded) 0.23-0.26 Btu-in/ft ² hr°F (molded)
Thermal resistance (R-value) per 1" of thickness at 75° F.	5 (extruded) 3.85-4.35 (molded)
Water vapor permeability	0.6 perm-in extruded 1.2 to 3.0 perm-in molded
Water absorption.	C 0.7% by volume extruded < (.020/0 by volume extruded < 4% by volume molded < 2% by volume molded
Capillarity	none
Fire resistance.	combustible
Flame spread	5-25
Fuel contributed	5-80
Smoke developed.	10-400
Toxicity.	develops CO when burned
Effect of age	
Dimensional stability.	none
Thermal performance	k increases to .20 after 5 yrs.
Fire resistance.	extruded none molded none
Degradation due to	
Temperature.	above 165° F
Cycling	none
Animal.	none
Moisture	none
Fungal/bacterial.	does not support growth
Weathering.	direct exposure to UV light degrades polystyrene
Corrosiveness	none
Odor.	none

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No BNL-50862, June 1978, p. 86

ulating properties, however, are not affected by short-term exposure to UV **light**. **Polystyrene** foam can tolerate temperatures up to 1650 F, but higher temperatures may cause it to soften. Polystyrene does not promote fungal or bacterial growth, and is odorless and non-corrosive.⁴

Polyurethane

Polyurethanes are plastics produced through the reaction of isocyanates and alcohols. Either rigid or flexible foam can be produced. For example, slab stock is produced by **mixing the necessary components and metering the mixture onto a moving conveyor**. The mixture forms a continuous foam that can be cut to predetermined lengths. Foamed-in-place

⁴ *ibid.*, p. 85

Table A-7.—Polyurethane/Polyisocyanurate Foams

Material property	Value
Density	2.0 lbs/ft ³
Closed cell content	90%
Thermal conductivity (k factor) at 75° F.	0.16-0.17 Btu-in/ft ² hr°F (aged & unfaced or spray applied) 0.13-0.14 Btu-in/ft ² hr°F (impermeable skin faced)
Thermal resistance (R-value) per 1" of thickness at 75° F.	6.2-5.8 (aged unfaced or spray applied) 7.7-7.1 (impermeable skin faced)
Water vapor permeability	2-3 perm-in
Water absorption	Negligible
Capillarity	none
Fire resistance.	combustible
Flame spread	30-50 polyurethane 25 polyisocyanurate
Fuel contributed	10-25 polyurethane 5 polyisocyanurate
Smoke developed.	155-500 polyurethane 55-200 polyisocyanurate
Toxicity	produces CO when burned
Effect of age	
Dimensional stability.	0-120/ change 0.11 new
Thermal performance	0.17 aged 300 days
Fire resistance	none
Degradation due to	
Temperature.	above 250 °F
Cycling	not known
Animal.	none
Moisture	limited information available
Fungal/bacterial.	does not promote growth
Weathering.	none
Corrosiveness	none
Odor.	none

SOURCE U.S. Department of Energy, *An Assessment of Thermal Insulation Mater/a/s and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No. BNL-50862, June 1978 p 89

polyurethane are prepared by mixing or metering the components and manually or automatically dispensing them. Specially designed units are now available for spray-on applications.

The R-value for polyurethane is around 6. Because of the closed cell structure of this material, water absorption and permeability are very low. In curing and aging, polyurethane foam is reported to demonstrate a dimensional change. The degree to which this foam expands or shrinks is related to conditions of temperature and humidity and the duration of exposure to extreme conditions.⁵ One American Society for Testing of Materials (ASTM) test procedure indicated a change in volume

⁵ *ibid.*

Table A-8.—Urea-Formaldehyde and Urea-Based Foams

Material property	Value
Density	Wet - approximately 2.5 lb/ft ³ Dry -0.6 to 0.9 lb/ft ³
Thermal conductivity (k factor) at 75° F.	0.24 Btu-in/ft ² hr°F
Thermal resistance (R-value) per 1" of thickness at 75° F.	4.2
Water vapor permeability . . .	4.5 to 100 perm-in at 50% rh 73° F
Water absorption	32% by weight (0.35% volume) 95% rh 18% by weight (0.27% volume) 60% rh 68° F 180 = 3,800% by weight (2-42% volume) immersion
Capillarity.	slight
Fire resistance.	combustible
Flame spread	0-25
Fuel contributed	0-30
Smoke developed.	0-10
Toxicity.	no more toxic than burning wood
Effect of age	
Dimensional stability.	1 to 4% shrinkage in 28 days due to curing 4.6 to 10% shrinkage at 100" F 100% rh for 1 week 30 to 45% shrinkage and 158° F 90 to 100% rh-10 days
Thermal performance	No change
Fire resistance	
Degradation due to	
Temperature.	decomposes at 415° F
Cycling	no damage after 25 freeze-thaw cycles
Animal.	not a feed for vermin
Moisture	not established
Fungal/bacterial.	does not support growth
Weathering.	none
Corrosiveness	none
Odor.	may exude formaldehyde until cured

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No. BNL-50862, June 1978, p. 91.

of up to 12 percent after 14 days. This material will begin to decompose at temperatures above **2500** F. Polyurethane foam is resistant to fungal and bacterial growth, and is odorless and noncorrosive.

Urea-Formaldehyde Foam

Urea-formaldehyde foam is produced at the site of application "by the combination of an aqueous solution of a urea-formaldehyde based resin, an aqueous solution foaming agent which includes a surfactant and acid

Table A-9.—Perlite

Material property	Value	
	Loose fill	Perlite concrete
Density	2-11 lb/ft ³	20-40 lb/ft ³
K app at 75° F	0.27-0.40	0.50-0.93
Thermal resistance (R-value) per 1" of thickness at 75° F.	3.7-2.5	2.0-1.08
Water vapor permeability	high	high
Water absorption	low	
Capillarity.	none	none
Fire resistance.	noncombustible	noncombustible
Flame spread	0	0
Fuel contributed	0	0
Smoke developed	0	0
Toxicity.	not toxic	not toxic
Effect of age		
Dimensional stability	none	none
Thermal performance	none	none
Fire resistance	none	none
Degradation due to		
Temperature.	none under 1,200" F	none under 500" F
Cycling	none	none
Animal.	none	none
Moisture	none	none
Fungal/bacterial.	does not promote growth	does not promote growth
Weathering.	none	none
Corrosiveness	none	none
Odor.	none	none

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No. BNL-50862, June 1978, p. 94.

catalyst (or hardening agent), and air. In the mixing or foaming gun, compressed air is mixed with the foaming agent to produce small bubbles which are expanded and coated with the urea-formaldehyde resin. The foam is delivered at about 75 percent water by weight and immediately begins to cure."⁶

Urea-formaldehyde has an R-value of 4.2. According to a National Bureau of Standards (NBS) study, shrinkage and resistance to high temperature and humidity may be a problem. The magnitude of the shrinkage and the time period over which it occurs are subjects of debate. The study presented some data on material that had been installed in a wall of a test house. Periodic inspections were made of the insulated wall and in about 20 months the foam had undergone an average linear shrinkage of 7.3 percent. ⁷The NBS data are only preliminary; until more studies are concluded on the inservice performance of this material, the question of durability will remain unanswered.

⁶Ibid., p. 23,

⁷*Urea-Based Foam Insulations: An Assessment of Their Thermal Properties and Performance, Technical Note 946 (National Bureau of Standards, July 1977), p. 34.*

Table A-10.—Vermiculite

Material property	Value	
	Loose fill	Vermiculite concrete
Density.....	4-10 lb/ft ³	20-60 lb/ft ³
K app at 75 °F.....	0.33-0.41	0.59-0.96
Thermal resistance (R-value) per 1" of thickness at 75 °F ..	3.0-2.4	1.7-1.0
Water vapor permeability.....	high	high
Water absorption.....	none	none
Capillarity.....	none	none
Fire resistance.....	noncombustible	noncombustible
Flame spread.....	0	0
Fuel contributed.....	0	0
Smoke developed.....	0	0
Toxicity.....	none	none
Effect of age		
Dimensional stability.....	none	none
Thermal performance.....	none	none
Fire resistance.....	none	none
Degradation due to		
Temperature.....	none below 1,000 °F	none below 1,000 °F
Cycling.....	none	none
Animal.....	none	none
Moisture.....	none	none
Fungal/bacterial.....	does not pro- mote growth	does not pro- mote growth
Weathering.....	none	none
Corrosiveness.....	none	none
Odor.....	none	none

SOURCE: U.S. Department of Energy, *An Assessment of Thermal Insulation Materials and Systems for Building Applications*, prepared by Brookhaven National Laboratory, Publication No. BNL-50862, June 1978, p. 96.

An odor of formaldehyde may occur during the application of ureaformaldehyde-based foam insulation. Under normal circumstances, the odor should dissipate quickly and linger for only a few days. According to one major manufacturer, "formaldehyde gas is emitted from the foam, in the part per million range, during the drying and curing process, which will be over in 2 weeks."⁸

Perlite

Perlite is a glossy volcanic rock mineral, indigenous to the western United States. It contains between 2 and 5 percent water by weight. Perlite ore is composed primarily of aluminum silicate. When heated to a suitable point (1,000 °C), the crushed ore particles expand to between 4 and 20 times their original volume and contain numerous cavities. It is then treated with nonflammable silicone to become

⁸ *ibid.*, p. 58.

highly resistant to water and to moisture. The R-value of perlite is between 3.7 and 2.5. As an inorganic material it resists rot, vermin, and termites. Perlite is noncorrosive and odorless. It is primarily used as loose-fill insulation, or as aggregate in insulating concrete.

Vermiculite

Vermiculite is a generic name for micalike minerals. When subjected to high temperatures it expands to a corklike consistency. The R-value for this material is 3.0 to 2.4. Vermiculite is water repellent and noncombustible. As an inorganic material it is resistant to vermin, rot, and termites and is not affected by age, temperature, or humidity. Vermiculite is noncorrosive and does not exude an odor. Like perlite, it is primarily used as loose-fill insulation, or as aggregate in insulating concretes.

Aluminum Multifoil

Aluminum multifoil insulation consists of several sheets of aluminum foil separated by air spaces. The outer layers of the foil sandwich are usually backed with kraft paper for strength. The foil reflects infrared heat radiation, and the air spaces add to the insulation value. The R-value of this material depends on specific location. Three layers of foil with 4 air spaces can have an R-value of 29 under the floor, **14 in a wall, and 9.8 in the ceiling** in winter. In summer, the same ceiling insulation can have an R-value of 29 for keeping the air-conditioned house cool.⁹ Foil insulation weighs less and is less expensive than fiberglass.

Glass Foam

Glass foam insulation is a rigid, closed-cell foam that is entirely resistant to water, fire, decay, vermin, and chemicals. [It can be made from recycled glass. Its R-value is 2.6 per inch. Present costs are about 20 times as high

⁹ J R Schwartz, President, Foil Pleat Inc., personal communication, January 1979.

¹⁰ *Foamglass Insulation* (Baltimore, Md.: Pittsburgh Corning Product Literature, Publication No F1-132 (rev.), April 1975)

as the more common insulation materials. Therefore, it is limited to specialized applica-

tions requiring its noncompressibility, moisture resistance, or chemical inertness.

PRODUCTION CAPACITY OF THE U.S. INSULATION INDUSTRY

This section attempts to summarize the present production capacity of the insulation industry, the leadtime for new insulation manufacturing facilities, and any roadblocks to large increases in production capacity. Table A-11 summarizes the data. Various projections of future insulation production capacity are not included here because they are so dependent on what manufacturers decide to do in the

future. Decisions will depend on their perceptions of the market at a given time, and those perceptions will depend to a large extent on Government actions to encourage energy conservation and other future events. As an alternative to existing projections, this section gives leadtimes and constraints to capacity increases to illustrate just how flexible the future can be.

Table A-11.—Production Capacity of Insulation Industry and Leadtime for New Capacity

Insulation type	Number of manufacturers	R-value assumed for calculation of capacity	Annual production capacity (billion Rxt ²)	Leadtime for new capacity (months)
Rock & slag wool	10 ^a	—	19.4 (1/77) ^a	12-30 ^e
Fiberglass	4 ^a	—	98-160 (1/77) ^a	12-36 ^c
Cellulose	> 700 (6/78) ^c	3.7	28 (6/77) ^a	1 ^d
Polyurethane & polyisocyanurate foams	~ 35 ^a	6.25	6.1 (1/77) ^a	6-12 ^e
Polystyrene foam	100 ^a	4	4 (1/77) ^a	6-12 ^e
Urea-formaldehyde foam	4 Major ^a	4.2	3.2 (1/77) ^b	10-20 ^d
Perlite	> 30 ^b	2.7	2.1 (1/77) ^b	6-12 ^e
Vermiculite	> 16 ^b	2.27	3.2 (1/77) ^b	6-12 ^e
Aluminum multifoil	5 ^b	19	(loose fill only) 16 (1/77) ^b	6-12 ^e

^aAn Assessment of Thermal Insulation Materials and Systems for Building Applications, BNL-50862, prepared by Brookhaven National Laboratory for U.S. Department of Energy, June 1978, pp. 31-37.

^bW. Penoyar and F. E. Williams (U.S. Department of Commerce), "Survey of U.S. Residential Insulation Capacity and Projections for Retrofitting U.S. Housing Inventory," *Construction Review* (U.S. Department of Commerce), August/September 1977, pp. 4-14.

^cU.S. Interagency Task Force Report reviewing the supply and demand of insulation, preliminary draft, 1978.

^dSee text.

^eH. Majors (Department of Energy, Conservation, and Solar Applications), personal communication, February 1979.

The "present capacity" figures presented here must be regarded with some caution since the references did not always distinguish between the amount of insulation produced in a year and the amount that could be produced if the factory were running at full capacity. Since insulation has been in short supply recently, factories have probably been operating close to full capacity, and any differences are probably not very great. Production capacities given include all the material produced, not just that sold for residential use. This gives a better idea of actual capacity for making the material. In several cases, the references did not make clear whether they were presenting

total production or just residential insulation, so some figures in table A-11 may be less than full production capacity. Finally, most of these figures are for capacity in January 1977, and capacity has been growing steadily since that time

Fiberglass

Fiberglass insulation production is a high-technology, capital-intensive industry. The four manufacturers are Owens-Corning Fiber-

—
"Porter-Hayden Company, personal communication, January 1979.

glas Corporation, Johns-Manville Corporation, Certain Teed Corporation, and Gebr. Knaut Westdeutsche Gipswerke.¹² Owens-Corning has about half of the fiberglass insulation market, and Johns-Manville has about a quarter. Even for an established firm, an additional fiberglass plant can cost about **\$25 million**.¹³ "Industry estimates of the time required for adding an additional line to an existing plant is about 12 to 18 months. A new plant would require **24** to 36 months to become fully operational once ground breaking has occurred."¹⁴

Cellulose

It is fairly easy to get into the cellulose insulation manufacturing business, and many people are doing it. Between 70 and 100 new manufacturing companies were started in 1977¹⁵ and by mid-1978 there were over 700 companies in business. Most of these are very small businesses.¹⁶ It is possible to get into business for less than \$10,000 with a small machine on the back of a truck, but some larger manufacturers claim that it takes at least \$300,000 to set up a factory capable of producing cellulose that can meet safety standards consistently.¹⁷

Concern is frequently expressed that short supplies of borax and boric acid, used as fire retardants, could constrain rapid growth in the capacity of cellulose production. However, if shortfalls are met with imports, capacity could grow rapidly. Furthermore, "several chemical companies . . . are in the process of investigat-

¹²An Assessment of Thermal Insulation Materials, *op. cit.*, p. 32.

¹³R. Kurtz, U.S. Consumer Product Safety Commission, memorandum to H. Cohen, CPSC, on "Potential Effects of CPSC Regulations Upon Supply, Demand, and Utility of Home Insulation: Initial Speculation," Dec. 29, 1977, p. 4.

"Report on Insulation: Supply, Demand, and Related Issues, Office of Conservation and Solar Applications, preliminary draft, prepared by the Task Force on Insulation (U.S. Department of Energy, May 1978), ch. 6, p. 6.

¹⁴"Home Insulation Sales are Almost Too Hot," *Business Week*, September 1977, p. 88

"Report on Insulation," *op. cit.*, p. 5

¹⁵R. Kurtz memo on "Potential Effects of CPSC Regulations," pp. 3-4.

ing different formulations requiring less boric acid." ¹⁸

Urea-Formaldehyde Foam

Urea-formaldehyde foam is produced at the house using a specially designed foam gun. Considerable **skill is required to apply the foam properly**. Poorly installed urea-formaldehyde foam can shrink and crack within a few months, and can release formaldehyde fumes for many months. The limited number of trained installers could limit rapid expansion of the near-term market.¹⁹

Most of the chemicals are produced by four companies, and one of them, Rapperswill Corporation, reportedly has 80 percent of the U.S. market for urea-formaldehyde insulation.²⁰ The other major producers are Borden Chemical, Brekke Enterprises, and C. P. Chemical Company.²¹ Based on a projected tenfold increase in production within 2 years,²² it appears that the leadtime for new capacity "is roughly a year.

Boric Acid and Borax

Boric acid and borax are used in the manufacture of both cellulose and fiberglass insulation. In the manufacture of fiberglass, borax is used to reduce the drawing temperature of the fibers to less than 1,000 C as well as to strengthen the fibers. In the production of cellulose, borax improves the fire-retardant capabilities of boric acid and reduces its acidity. Both chemicals have recently been reported to be in short supply nationally. Therefore, prices may go up as more is imported.

Total U.S. boric acid production capacity in 1978 was around 180,000 metric tons, of which U.S. Borax and Chemical Corporation was responsible for about 65 percent.²³ **Kerr-McGee Chemical Corporation and Stauffer Chemical**

¹⁸An Assessment of Thermal Insulation Materials, *op. cit.*, p. 34

"Report on Insulation," *op. cit.*, p. 6.

²⁰Energy Users Report, Aug. 18, 1977, 210:16,

²¹An Assessment of Thermal Insulation Materials, *op. cit.*, p. 36

²²*Ibid*

²³*Ibid*, p. 34.

Corporation share the remainder of the production. The major foreign producers are France, U. S. S. R., Turkey, Chile, and Italy. In 1977, the United States exported 33,000 metric tons and imported 13,000 metric tons.²⁴

Boric acid has been used as an important fire retardent chemical in cellulose insulation. Some cellulose manufacturers and chemical companies are investigating fire-retardant formulae [as that use less boric acid and borax].²⁵

During 1977, U.S. production of boron minerals and compounds was estimated to be 1.3 million metric tons. Exports were 241,000 tons and imports about 46,000 tons. The three U.S. producers of borax are U.S. Borax and Chemical Corporation, American Borate Corporation, and Kerr-McGee Chemical Corporation.²⁶

Since 1975 there has been a growth in demand for borax and other borates attributable to increased demand for fiberglass, mineral wool, and cellulosic insulation. Current data is not available on how much borax is used in the manufacture of these products. However, the Bureau of Mines (BOM) **estimates 35,000 tons of borax and other borates** were used to manufacture cellulosic insulation in 1976.²⁷ Current-

ly, BOM is surveying the three borax producers to obtain specific end-use data on their sales to manufacturers. Domestic shortages of borax may occur **in the future** "if a producer alters its process to consume borax and produce additional boric acid by using the borax it otherwise would have produced."²⁸

Concern over the possibility of a boric acid shortage led to the formation of an Inter-agency Task Force which pointed out four obvious options for increasing supply. The amount of minerals mined could be increased. This would not necessarily solve the problem as large amounts of borates are presently used for other products. A second option would be to increase refinery capacity and expand production of boric acid. This is seen as an unlikely response since long-term demand for borates is uncertain and boric acid refineries are not easily convertible to other uses. Some of the borates now going elsewhere in the market could be reallocated to boric acid production, or more boric acid could be imported.²⁹ At present, market forces are responding adequately to meet boric acid demand, so Federal intervention does not appear necessary.

HEALTH HAZARDS

The real and potential health hazards associated with various types of insulation materials have attracted much attention. This section addresses some of the major health-related problems.

Fiberglass and Mineral Wool

It has been known for a long time that fiberglass can produce eye and skin irritation. It is classified by the Occupational Health and Safety Administration (OSHA) as a nuisance dust. Furthermore, fiberglass workers sometimes experience respiratory tract irritation

characterized by bronchitis, rhinitis, sinusitis, pharyngitis, and/or laryngitis. These irritations are caused by mechanical injury to the skin and mucous membranes by small glass fibers and are "considered to be transitory since symptoms disappear without treatment when exposure to fiberglass is ended."³⁰

As there is a fairly well-established link between asbestos and several types of cancer,³¹ a number of researchers have been attempting

²⁸Ibid.

²⁹Ibid., pp. 4-5.

³⁰"Memorandum by Dr. Rita Orzel, Acting Director, Division of Human Toxicology and Pharmacology, Office of the Medical Director, Consumer Product Safety Commission, Dec. 2, 1976, p. 1.

³¹National Cancer Institute, *Asbestos: An Information Resource*, ed. by R. J. Levine, prepared by SRI International, Publication No. NIH 79-1681, May 1978, p. 1,

²⁴Report on *Insulation*, op. cit., ch. 5, p. 1.

²⁵Ibid., p. 3.

²⁶Ibid., p. 1.

²⁷Ibid., p. 4.

to determine if other inorganic fibers act like asbestos fibers in contributing to cancer. Studies of the relationship between fiberglass or rock wool and cancer have produced mixed results. Glass fibers surgically implanted in the lungs of rats have produced cancers, but the implantation process is artificial and does not allow the natural cleansing actions of the lung to remove the fibers.³² Several early studies found that workers in glass wool plants did not have any higher cancer rates than similar persons who did not work with fiberglass.³³ To date there is no evidence that fiberglass as normally manufactured and used is related to the occurrence of cancer in humans.

However, over the years, the average diameter of manufactured glass fibers has been decreasing. In the case of the implanted fibers, it is the small diameter fibers (**0.5 to 5** microns) that have caused the most concern.³⁴ In the 1930's, the average fiber diameter of insulating rock and slag wool and fiberglass was 15 microns or more. Today, the average diameter is 6 microns with a fraction of the fibers falling below 3.³⁵ Over the years, manufacturers have been changing the composition of the binders and lubricants coating the fibers,³⁶ so the fiberglass handled by workers 30 years ago was not the same material that is manufactured today.

³²M. F. Stanton, "Fiber Carcinogenesis: Is Asbestos the Only Hazard?" *Journal of the National Cancer Institute*, 51:633-636. Cited by J. Milne, "Are Glass Fibers Carcinogenic to Man? A Critical Appraisal," *British Journal of Industrial Medicine*, 33:47.

³³*Criteria for a Recommended Standard . . . Occupational Exposure to Fibrous Glass*, prepared by Tabershaw-Cooper Associates, Inc., Publication No. NIOSH-77-152 (National Institute for Occupational Safety and Health, April 1977), pp. 30-40.

³⁴M. F. Stanton, "Some Etiological Considerations of Fiber Carcinogenesis," *Biological Effects of Asbestos, Proceedings of a Working Conference*, published by the International Agency for Research on Cancer, Lyon, France, IARC Scientific Publication No. 8, October 1972, ed. by P. Bogovski, et al., pp. 289-294 Cited by J. T. Maddock, et al., *Small Fiber Inhalation*, Publication No. AA I-238 3I2384-100-TR-2 (U.S. Consumer Product Safety Commission, December 1976), p. 9.

³⁵J. W. Hill, "Health Aspects of Man-Made Mineral Fibres, A Review," *Ann. Occup. Hyg.*, 20:1 61-162

³⁶*ibid.*, p. 162.

Because the latency period for cancer can be 20 to 50 years, there has been insufficient time to assess fully the effects of exposure to small glass fibers and the newer resin systems. Several American studies are underway, but the results **are not in.**³⁷

Until more studies and tests are completed, it seems prudent to minimize exposure to fiberglass, especially where small particles are prevalent. Areas calling for special care include:

- factories where fiberglass and fiberglass products are produced,
- handling during installation,
- air ducts that could bring fiberglass particles into the house, and
- unwanted materials and debris from demolition or renovation of buildings.

Cellulose

Cellulose fiber appears to present no significant health problems. However, the borate salts that are used to impart flame retardancy to the shredded paper can be toxic if ingested. The estimated lethal dose is 15 to 20 grams **for adults and 5 to 6 grams for infants**; young infants are particularly susceptible. Acute borate exposure can affect the central nervous system and cause persistent vomiting and diarrhea, followed by profound shock and coma. Borate salts can be absorbed through the skin.

Investigators have so far determined cellulose dust to be a nuisance. That is, it does not have the potential to produce pathologic changes However, as the handling of cellulosic material can generate considerable amounts of dust, the user is advised to wear gloves, cover up, and wear a mask.

³⁷M Sloan, *personal* communication, January 1979.

Cellulose Plastics

Polystyrene

According to the Consumer Product Safety Commission (CPSC), finished foam resins such as polystyrene generally do not produce adverse health effects.³⁸ Although Sax classifies polystyrene as a “suspected carcinogen” when in the body,³⁹ there appears to be no hazard from normal use.

Polyurethane

Polyurethane foam is an isocyanate-polyol-resin blend to which flame-retardant chemicals are usually added. As the isocyanates are toxic, extreme caution must be exercised during application. Application must be performed by qualified persons using appropriate safety equipment such as goggles, gloves, head covers, and respirators.

It appears that the health hazards associated with polyurethane foam are in the handling, mixing, spraying, and other application procedures encountered in occupational situations. Sax classifies polyurethane as a “suspected carcinogen.”⁴⁰

Urea-Formaldehyde

Formaldehyde is a strong irritant. Exposure to its vapors can cause irritation of the mucous

membranes of the eyes, nose, and upper respiratory tract. The level of irritation is a function of the formaldehyde concentration and of individual sensitivity. With increased concentrations, these irritations become more pronounced and tolerable for only a few minutes.

Repeated exposure may increase sensitivity to formaldehyde. Skin problems have also been reported after exposure to even small amounts in the air.

After the curing process, odor normally disappears, but it has been known to recur—in some cases persisting for 10 to 12 months. Some consumers have complained of formaldehyde released from wallboard, particle board, or fiberboard bonded with urea-formaldehyde resin. The continued odor has required that the wallboards be removed from the interiors of homes in some cases.

The safe application of this material requires a qualified person who knows how to handle, mix, and use the chemicals involved.

Perlite and Vermiculite

No potential health hazards have been associated with the use of perlite or vermiculite as an **insulation material**. A DOE study indicates **that both are nontoxic and odorless.** ”

FIRE HAZARDS

Data on the fire hazards associated with various insulation materials are plentiful but sketchy. Most fire data identify only the first material ignited and do not indicate those instances where insulation may play a significant role in the growth of a fire started by another material.

Fiberglass

Fiberglass itself is considered nonflammable until subjected to very high temperatures. In flammability test procedures, however, flammable backing or vapor barrier materials are often not included. In the manufacturing of fiberglass, flammable oils and resins are introduced to reduce dust and solidify the insulation material. But often the flammability tests are performed on fiberglass that doesn't contain these organic materials. Additionally,

⁴¹*An Assessment of Thermal Insulation Materials*, o.p. cit., p 92.

³⁸Memorandum by Dr. Rita Orzel, P. 3.

³⁹N.I. Sax, *Dangerous Properties of Industrial Materials*, fourth ed., Van Nostrand Reinhold Co., 1975, pp. 1037-1038.

⁴⁰*Ibid.*, p. 1038.

the absence of appropriate practices in the manufacture and installation of this material can increase the risk of fire and resulting smoke inhalation.

CPSC has discussed the potential flammability and organic burden of fiberglass insulation with representatives of Owens-Corning, Johns Manville, Certain Teed, and NBS and has concluded:⁴²

1. Most paperbacking (foil and kraft) on the market today is flammable.
2. Most paperbacking is situated underneath batts or blankets of fiberglass insulation and is unexposed to likely ignition sources. But NBS has indicated that if fiberglass is improperly installed (e.g., faceup in an attic space) or left exposed (e.g., in a garage beneath the second story of a house), it might be exposed to an ignition source.
3. There **is** currently no requirement to test fiberglass insulation with paperbacking intact. Some manufacturers do test fiberglass insulation with paperbacking intact and measure a higher flame spread than fiberglass insulation alone.
4. Phenolic binder, although combustible, does not promote flame spread in fiberglass insulation.

Cellulose

According to a petition filed by the Denver District Attorney's Consumer Office with CPSC, several fires have been observed and related to cellulosic insulation. Factors believed

⁴²Paul Lancer, U.S. Consumer Product Safety Commission, memorandum to Bernard Schwartz, CPSC, on "Home Insulation," Jan. 31,1977

by the petitioner to be related to the fires include:⁴³

1. **Poor** quality control, which contributes to wide fluctuations in fire retardancy.
2. inadequate knowledge about levels of fire retardancy necessary for proper protection.
3. Uncertainty about the permanency of the flame-retardant chemicals.
4. Certain fire retardants utilized and the extent to which sublimation and moisture affect the permanency of these fire retardants as the insulation ages.
5. Failure to add proper amounts of fire retardants at the manufacturing or installation stages, coupled with the absence of onsite testing.
6. Variance of flame spread requirements and, the lack of smoldering-resistance requirements.
7. Lack of uniform test methods, hence unsatisfactory flame spread and smoldering readings.

This petition was rejected by CPSC on March 5,1979.

Improper installation of cellulose insulation on or near electrical wiring, recessed lighting fixtures, attic furnaces, heating ducts, and other heat-bearing and heat-producing elements can cause fires. The absence of regulations by industry or Government is to be noted. There are no standard test methods used for determining the toxicity of combustible products.

Other Materials

Polystyrene and polyurethane foams are combustible; rock wool, vermiculite, and perlite are not.

⁴³Petition filed by the Denver District Attorney's Office of Consumer Affairs with the U.S. Consumer Product Safety Commission, Oct. 8,1976, pp. 3-4

MATERIAL STANDARDS AND ENFORCEMENT

Testimony before Congress, the Federal Trade Commission, and the CPSC has demonstrated a great need for new and improved materials standards and test procedures to ensure the efficacy, durability, and safety of residential insulation materials.

The General Services Administration (GSA) and the ASTM are the principal bodies responsible for the testing of insulation materials and the promulgation of materials standards. With one exception, however, these standards are not mandatory for residential insulation.

GSA Standards and Specifications

GSA sets standards and specifications for goods purchased directly by the Federal Government. This program encompasses 4,500 Federal specifications and 1,500 standards. Included in this program are specifications for cellulosic or wood fiber loose-fill insulation (HH-I-515C), mineral fiber loose-fill insulation (H H-I-1030), and mineral fiber blankets and batts (H H-I-521).

These specifications, however, do not have a direct application to thermal insulation purchased by consumers. They apply only to Federal procurement of thermal insulation for Government-owned buildings, etc. Nevertheless, it is the practice of many manufacturers of insulation for residential use to claim that their products meet current GSA specifications. There is no enforcement mechanism to discourage false claims.

GSA began in 1976 to upgrade its insulation specifications. In November 1977 it issued its proposed new standards for insulation purchased by the Federal Government.

Some of the most important changes proposed by GSA were contained in its proposed specifications for loose-fill cellulose insulation (H H-I-515 D). For example, the new specifications include a requirement concerning fungal growth, as it is now recognized "that this condition could cause the degrading of the thermal properties of the insulation by destroying

the structure of the fibers. It could provide a source of fungal spores which might penetrate the living area and cause health problems. It could increase the corrosive action of the insulation material through the accumulation of metabolic products."⁴⁴

Other changes include a requirement that all "cellulose tests be conducted at the product's settled density, i.e., the density of the product that would be expected to be found in the field sometime after installation."⁴⁵ This would eliminate the current practice of some cellulose manufacturers of having their products tested at an arbitrary density to enhance their chances of passing the corrosion test or to obtain a better fire safety test result. The new standard for cellulose also includes a smoldering test that is not included in the HH-1-515C specifications. This test is to determine whether cellulose will continue to smolder beyond the area of an initial heat source, such as a hot electrical wire or a recessed lighting fixture.

Further revisions to the existing HH-I-515C specifications for cellulose insulation include new tests for flammability. The GSA based its decision to switch to a radiant panel flammability test and to adopt a smoldering test on a number of factors:

1. The poor relationship between the Steinen tunnel flammability test and an actual attic situation.
2. Failure of the Steinen tunnel test to address a small open flame or a smoldering ignition source.
3. Unsuitability of the Steinen tunnel test for low-density materials such as cellulose.
4. **NBS fire data that demonstrate that** covered electrical or heating devices or wiring hot spots may cause ignition of exposed insulation, factors which are not simulated in the Steinen tunnel test.

⁴⁴U.S. Congress, House Committee on Interstate and Foreign Commerce, Subcommittee on Oversight and Investigations, *Home Insulation*, 95th Cong., 2d sess., Apr. 26, 1978, p. 24.

⁴⁵*Id.*,

DOE estimates that while 80 percent of the manufacturers can pass the existing GSA C specifications, perhaps only 10 to 30 percent can pass the new version. The president of the Society for the International Cellulose Insulation Manufacturers (SICIM) disagrees. It was reported that most of the SICIM member companies recently passed both the radiant panel and smoldering tests performed by Certified Laboratories of Dalton, Ga. However, these tests appear to be silent on the manufacturers' ability to meet the D standard if the fire-retardant formulae were changed.⁴⁶

In June 1978, GSA issued the new HH-I-515D specifications for loose-fill cellulose insulation. They reflect only slight alterations to the originally proposed specifications. The proposed specifications for mineral wool, which include similar testing requirements, have been resubmitted for additional comments.

Enforcement of GSA Standard HH-I-515C for Residential Application

As discussed earlier, there are almost no mandatory performance standards for residential insulation. One exception, **however**, applies to the most recent enforcement of the "C" standard for cellulose insulation.

The Interim Consumer Product Safety Rule Act of 1978, which establishes an interim consumer product safety standard, went into effect September 8, 1978. Under this Act, CPSC will adopt the requirements for flame resistance and corrosiveness as set forth in GSA's HH-I-515C specifications for cellulose insulation. The "C" standard is to be enforced in the same manner as any other consumer product safety standard.

Accordingly, any cellulose insulation material that is produced or distributed for sale to the consumer is to have a flame spread rating of 1 to 25, as such rating is set forth in GSA's specification HH-I-515C. Each manufacturer or private labeler of cellulose insulation is required to include on any container of cellulose insulation a statement indicating that

the material meets the applicable minimum Federal flammability standard. The statement must also indicate that the standard is based on laboratory tests that do not reflect actual conditions in the home.

Until a final consumer product safety standard takes effect, CPSC will incorporate into the interim safety standard for cellulose insulation each revision superseding the requirements for flame resistance and corrosiveness as promulgated by GSA.

The adoption of the "C" standard by CPSC thus marks the first federally supported initiative to protect the consumer against various hazards associated with cellulose insulation. At this writing, however, it is difficult to determine whether other thermal insulation materials will be covered by the Interim Consumer Safety **Rule Act of 1978**.

Problem Areas in Materials Testing and Standards

One of the major bodies responsible for the development of materials testing and standards is ASTM Committee C16 on Thermal and Cryogenic Insulation Materials. The committee was established by the American Manufacturing Industry about 40 years ago. The development of ASTM standards is based on "consensus" documents, which reflect the views of the "manufacturer," "user," and "general interest members." After a standard is produced, it is usually reviewed every 5 years and revised as current technology and knowledge dictates. One criticism of this process is that the gestation period for a standard is at times too long.

Many testing methods are currently being revised or discarded in light of the critical problems now appearing. Given the number and variety of testing methods and standards, only general comments will be offered in this discussion.

Although a number of adequate testing methods do exist for determining the mechanical, thermal, and physical performance characteristics of a material under laboratory conditions, there is an immediate need for the extension of this knowledge to real life condi-

⁴⁶*Ibid.*, pp. 25-26

tions and for complete systems. That is, the interrelationships between materials and overall system performance must be investigated.

The development of new test methods or technical revisions to existing methods is lengthy and expensive and until recently has been beyond the means of any organization outside of the major manufacturers and Government bodies. Given the existence of new testing needs, it is argued by some that increases in public funding will be necessary to support the level of effort that is needed in a short time (5 to 10 years), and to develop test methods that can be used **in actual field conditions**.

Another problem has been the absence of a general set of testing procedures that pertain to all materials. As is often the case, materials are compared with each other based on the results of different test methods used to evaluate their properties. It becomes important, therefore, that material standards contain the correct and relevant test methods and specifications.

Two of the immediate concerns about materials testing are the adequacy of organizations

currently available to undertake the volume of testing and evaluation that will be required in the future, and the reliability of the results that such organizations can obtain. There appears to be great dissatisfaction in the insulation field over these factors.

Widely divergent claims are made about material properties, such as thermal performance. In some cases, it has been found that such claims are made with no physical basis. In general, however, the common view is that the test methods are not at fault; rather, some organizations make unsubstantiated performance claims. Moreover, equipment or apparatus for testing has been designed that does not meet specified guidelines. In other cases, the testing technique employed is often not the appropriate technique for the material. In view of these concerns, the CI 6 Committee in mid-1976 recommended to the Department of Commerce that a voluntary laboratory accreditation program be established in order to resolve some of the current problems of materials testing and standards.