UNITED STATES DEPARTMENT OF LABOR
L. B. Schwellenbach, *Secretary*
BUREAU OF LABOR STATISTICS
Ewan Clague, *Commissioner*

Labor Requirements to Produce Home Insulation

Bulletin No. 919

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1947

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 10 cents

Letter of Transmittal

UNITED STATES DEPARTMENT OF LABOR,
BUREAU OF LABOR STATISTICS,
Washington, D. C., July 28, 1947.

The SECRETARY OF LABOR:

I have the honor to transmit herewith a study on labor requirements in the production of certain types of nonrigid home insulation. This study is the fifth in a series conducted by the Bureau's Construction Statistics Division to determine the amount of labor needed to produce the more important construction materials; it was prepared by Carl R. Taylor and Benjamin Levine, under the direction of Thomas M. Flanagan. The Bureau wishes to acknowledge the cooperation of the companies which provided data for the survey, and of their trade associations.

EWAN CLAGUE, *Commisioner.*

Hon. L. B. SCHWELLENBACH,
Secretary of Labor.

The photographs reproduced in this bulletin are by courtesy of Johns-Manville Corp., the Vermiculite Research Institute, and the U. S. Department of Agriculture.

Contents

Bulletin No. 919 of the
United States Bureau of Labor Statistics

Labor Requirements to Produce Home Insulation

Mineral Wool, Cotton and Expanded Vermiculite

Characteristics of Industry's Products

This study is the fifth in a series[1] which the Bureau of Labor Statistics has been conducting to determine the amount of labor needed to produce the more important construction materials for the present housing program or for other construction activity.

The present survey analyzes the amount of labor required to produce 3 important types of nonrigid home insulation material: mineral wool, cotton, and expanded vermiculite. It describes the processes involved in the manufacture of these materials, and analyzes the man-hours required per unit of product at each production level, from mining or growing the raw material to transporting the finished product.

The use of insulation in new residential construction has increased rapidly in recent years and, during the war, insulation of existing buildings became especially important as a fuel-conservation measure. Savings in fuel costs are estimated at around 30 percent for insulated, as compared with uninsulated homes.[2]

[1] This survey, covering three important nonrigid insulation materials, is the first of two studies of the labor required to produce home insulation. The second will cover labor requirements for fiber insulating board, a rigid type of insulation material. Building materials for which results will be reported in future articles include hardwood and hardwood flooring, and plumbing and heating supplies. Previous studies covered labor requirements in cement production, summarized in the September 1946 Monthly Labor Review (p. 355); labor requirements in the production and distribution of concrete masonry products and concrete pipe, summarized in the November 1946 Monthly Labor Review (p. 681); in southern pine lumber production, summarized in the December 1946 Monthly Labor Review (p. 941); and in softwood plywood production, summarized in the January 1947 Monthly Labor Review (p. 67).

[2] Bowles, Oliver; Home Insulation With Mineral Products, in Information Circular Number 7388 (U. S. Department of Interior), October 1946, p. 7.

Nonrigid insulating materials usually consist of interlaced wool-like fibers or hollow or stratified granules, providing millions of minute spaces in which dead air is enclosed and, thus, having especially low heat conductivity. Their function is to reduce the transfer of heat from one side of a wall, ceiling, or roof to the other, irrespective of the side on which the heat is generated. In winter, the use of insulation reduces the escape of heat from the inside of a dwelling, maintaining a higher indoor temperature with decreased fuel consumption. In summer, the reverse occurs, and insulation reduces the penetration of the heat of the sun through walls and ceilings to the interior of the house.

There are many types of insulating materials, but in general they fall into two categories: the rigid, such as fiber board, used in new construction or in remodeling in place of lathing or wall sheathing; and the nonrigid, varieties of which are discussed in this report. Nonrigid insulation has no structural value, but is placed in the hollow spaces of walls, between floor joists, or between roof and rafters. It is used effectively to insulate existing buildings and is also installed in new construction. Most types are fire resistant or flameproofed, and it has been found that even in frame dwellings the spread of fires is hindered by the use of insulation in ceiling and roof, as well as by filling the hollow spaces of walls and partitions.

Of the three types of nonrigid insulation covered in this survey, mineral wool is the most important in terms of tons produced and sold each year. (See table 1.) The processed mineral wool is a fibrous, intermeshing material, resembling natural wool. It is composed principally of silicates of calcium and aluminum and is produced from three principal types of raw material: natural rock or combinations of various natural minerals or rocks, such as limestone and shale; iron, copper, or lead blast-furnace slag; and such glass materials as silica sand, soda ash, and limestone. The mineral wool is named rock wool, slag wool, or glass wool, according to the raw materials from which it is made. Mineral wool is sold commercially for home insulation in three forms: loose, granulated, or as batts and blankets.

Loose wool is the initial product after the first processing operation and it is from loose wool that the other mineral wool products are prepared. Loose wool is sold by the bag and installed by hand.

Granulated wool is by far the most widely used of the three forms. It is the only product from which the shot, or grains of slag have been removed. Because the granules are formed into small pellets and can be blown between the framing of buildings with an air hose, granulated wool is used chiefly for the insulation of existing buildings. Like loose wool, it is usually sold by the bag.

Blankets and batts of mineral wool have been fashioned into soft flexible quilts, usually surfaced on one or both sides by specially treated vapor-proof paper. Batts are similar to blankets except that they are usually smaller in size. Batt and blanket wool are sold by the roll or carton and installed by hand.

Processed flameproofed cotton is a comparatively new product, dating from 1940. It is sold only in the batt or blanket form, by the roll or carton. Expanded vermiculite, granular in form, is marketed by the bag, as a fill type of home insulation material. It is prepared from vermiculite ore, which closely resembles mica in appearance and is characterized by its extraordinary quality of expansion when heated.

TABLE 1.—*Estimated production of mineral wool, cotton, and expanded vermiculite home insulation, 1942 and 1946*

Type of insulation	Tons produced	
	1942	1946
Total (all types)	411, 450	681, 295
Mineral wool [1]	377, 603	631, 611
Loose wool	58, 586	56, 213
Granulated wool	183, 107	408, 021
Blanket or batt wool	135, 910	167, 377
Cotton [2]	873	9, 050
Expanded vermiculite [3]	32, 974	40, 634

[1] For 1942 production figures, see Minerals Yearbook, 1943, p. 1583. Production figures for 1946 for all mineral wool of the types shown are based on the production estimate for 1945 furnished the U. S. Bureau of Mines by the Mineral Wool Association, and increased by 12 percent—the Bureau of Mines estimate of the rise in mineral wool production in 1946 compared with 1945. Production in 1946 was distributed by type of mineral wool in the same ratio as found in the production of the plants covered in the Bureau of Labor Statistics' survey during 1946.

[2] For 1942 production figures, see E. H. Omohundro and N. B. Salant, Cotton Insulation. Washington, D. C., U. S. Department of Agriculture, et al., December 1944, p. 2. The 1946 figure is an estimate furnished by the U. S. Department of Agriculture. Production of cotton insulation not covered in the Department of Agriculture incentive program is excluded, but this is believed to be very small.

[3] For 1942 production figure, see Minerals Yearbook, 1943 p. 1588. It is estimated that 60 percent of the total production is used in home insulation. The 1946 figure is an estimate provided by the U. S. Bureau of Mines.

Scope and Method of Survey

The mineral wool survey covers 10 plants representing about one-third of 1946 production. The studies of labor requirements to produce flameproofed cotton and expanded vermiculite were made by analyzing the records of four and six plants, respectively, accounting for something over 50 percent of 1946 production in each of these industries.

The companies and plants to be included in the survey were selected after consultation with appropriate trade associations, government officials, and industry members. Small, medium, and large plants in each branch of the insulation field, were selected in approximately the same ratio in which they are distributed in the industry. Figures on unit man-hours for each plant were weighted by the plant's estimated 1946 production in order to arrive at estimated average man-hours required per unit of output in each of the three insulation industries surveyed.

Data were collected in the latter part of 1946 and, in each case, a period was selected for survey that plant officials considered typical of their 1946 operations. Field representatives of the Bureau of Labor Statistics, working with plant officials, derived the information on total man-hours spent on each manufacturing process and in administration, from plant records. Man-hour requirements were estimated for extracting and transporting the raw materials, for power, and for transporting the finished product to local dealers and users on the basis of the following: (1) plant information on quantities consumed and produced; (2) labor requirements information obtained from various sources, including the extraction and utility industries represented; and (3) earlier surveys of the Bureau of Labor Statistics. No attempt has been made in this study to include the man-hours expended by distributors, jobbers, or retailers in selling the finished product.

Summary of Man-Hour Requirements

An average of 9.1 man-hours was required in 1946 to manufacture a ton of mineral wool home insulation, according to the Bureau's survey. Loose wool, because of the simplicity of its manufacture, required only 6.7 man-hours per ton to produce in the factory; granulated wool required somewhat more labor (8.2 man-hours) as a result of an added processing step, and batt or blanket wool still more (12.2 man-hours) reflecting primarily the process of fashioning the wool into the blanket-type product and affixing the vapor-proof backing. About 5.6 man-hours may be added on the average for producing and transporting the raw materials, fuel, and other products used in making mineral wool, and for transporting the finished wool to dealers.

Flameproofed cotton insulation is measured by the thousand square feet. The Bureau's survey shows that while only 4.2 man-hours were required to produce a thousand square feet of cotton insulation in the plant in 1946, 85.8 per thousand square feet were needed for the outside activities of making the cotton and other materials available, and shipping the finished product. Of the 85.8 man-hours, 84 were required just for growing and preparing the cotton for delivery to the insulation plant, according to estimates of the Department of Agriculture.

In the case of expanded vermiculite, also, man-hour requirements for processing are not as high as those for producing and transporting the raw materials, fuel, and other products used and for shipping the finished insulation. Expanded vermiculite is measured by the thousand cubic feet. An average of 25.2 man-hours was found to be needed in 1946 to manufacture a thousand cubic feet of expanded vermiculite, compared with 35.9 man-hours for the out-of-plant activities, making a total of 61.1 man-hours per thousand cubic feet from mine to dealer. A large part of the man-hour requirements for producing vermiculite insulation (19.4 man-hours) was expended in transporting the vermiculite ore from the mines, which are situated in a very few States, to the scattered processing plants. Since the cubic footage of vermiculite expands considerably during processing, the manufacturing plants are located near distributing centers and often quite distant from the source of raw materials, to save transportation costs.

It is clear from the above discussion that the production man-hour requirements vary considerably per unit of product between the three home-insulation materials discussed in this report, when each industry's customary unit of measurement is used. Using a common unit of measurement with reference to the use to which the material is put (i. e., the amount of insulation material 3 inches thick required to cover a thousand square feet of space), the Bureau has computed roughly that labor requirements in the factory vary little by type of product, ranging from a little over 4 to something over 6 man-hours per unit. Variations are much greater when nonmanufacturing labor needs are considered, because of the differences in raw materials used and in transportation problems, as described briefly above.

Mineral Wool

HISTORY AND ANNUAL PRODUCTION

Production of mineral or rock wool was first reported in 1840 in Wales.[3] Commercial production in this country is believed to have started at Alexandria, Ind., in 1897 when C. C. Hall established a plant for the production of rock wool to utilize the slag produced as waste in the operation of a steel plant. Annual production in 1900 was estimated to be 6,002 short tons, increasing to 11,626 tons in 1909 and dropping to 7,514 tons in 1911. Production in 1928 was estimated at around 50,000 tons [4] increasing to 500,000 tons in 1936 and decreasing to approximately 400,000 tons in 1938.[5]

The centennial celebration of the mineral wool industry was held in Chicago in 1940.[6] Only estimates rather than actual production figures are available for most other years prior to 1942, although the Bureau of Census has released some data on dollar value of mineral wool produced for certain earlier years. Recent data on mineral wool production are shown in table 2.

---

[3] The Origin of Rock Wool, in Stone, vol. 57. No. 12, December 1936, p. 448.

[4] Mineral Wool, by J. R. Thoenen, Bureau of Mines Information Circular 6142, June 1929, pp. 2 and 13.

[5] Mineral Wool, by J. R. Thoenen, Bureau of Mines Information Circular 6948R, June 1939, p. 4.

[6] Minerals Yearbook, 1940, p. 1420.

748937°—47——2

TABLE 2.—*Annual production of loose, granulated, and batt or blanket mineral wool used in home insulation, 1942–46*

Year	Short tons of mineral wool produced			
	Total	Loose	Granulated	Batt or blanket
1942 [1]	377,603	58,586	183,107	135,910
1943 [1]	409,067	63,978	277,833	67,256
1944 [2]	426,600	59,787	308,411	58,402
1945 [3]	563,939	78,952	406,036	78,951
1946 [4]	631,611	56,213	408,021	167,377

[1] Minerals Yearbook 1943, p. 1583.
[2] Op. cit. 1944, p. 1541.
[3] Estimate for the total was provided to the U. S. Bureau of Mines by the Mineral Wool Association. Production by type of mineral wool was estimated by the Bureau of Labor Statistics, using the same ratio to the total as in 1944.
[4] Figure for the total was based on the production estimate for 1945, increased by 12 percent—the Bureau of Mines estimate of the rise in mineral wool production in 1946 compared with 1945. Production by type of mineral wool was distributed in the same ratio as found in the production of the plants covered in the Bureau of Labor Statistics' survey during 1946.

PRODUCTION PROCESS

Though variations in the technique of manufacturing mineral wool occur from plant to plant, the process may be described generally as follows: Different combinations of coke with slag, rock, shale, dolomite or limestone, among others, are fed into a cupola—a furnace used in melting minerals. Automatic scales are usually used to weigh the amount of each raw material to be put into each charge. The charge is heated to a melting temperature of from 2,500° F. to around 3,500° F. and is then drawn off from the cupola in a thin stream. The stream of melted slag, about the size of a lead pencil, drops from a few inches to something over a foot. It is then intercepted by a blast of steam which catches it and blows it into the adjacent blowing or wool room. The blowing temperature is usually 300 to 500° F. lower than the melting temperature.

As the slag droplets are traveling at high speed through the air, each tails out into fibers or strands. The minute amount of each droplet of slag that does not strand out or form fibers, but remains as a tiny ball or knot of slag, is called "shot." A single piece of shot is about the size of a grain of sand. As shot has no insulation value, its elimination in the production process is highly desirable, and the degree of efficiency of the blowing process is in part measured by the small shot content of the loose wool. To reduce the dust, an oil spray is mixed with the steam, or strikes the wool after it has been blown a few inches.

The blowing rooms are enclosed and are narrow and high and usually from 20 to 50 feet in length. A conveyer belt ordinarily forms the floor and removes the blown wool from the wool room through a small opening. In some plants the wool is removed by hand. At this point the processing of loose wool is completed and it may be bagged and shipped.

In the case of granulated wool, the conveyer may move the wool out of the wool room onto a belt through a series of grinders that break up the fibers. The wool then passes into a rotary screen which causes the formation of small round pellets or nodules, producing granulated, often called nodulated wool. The shot drops through the screening to be returned to the furnace and remelted. There is about a 17-percent loss in pounds between the raw slag used and the loose wool produced. If the loose wool is further processed into granulated wool, an additional loss of 25 percent is incurred, making an average loss of about 42 percent in processing granulated wool.

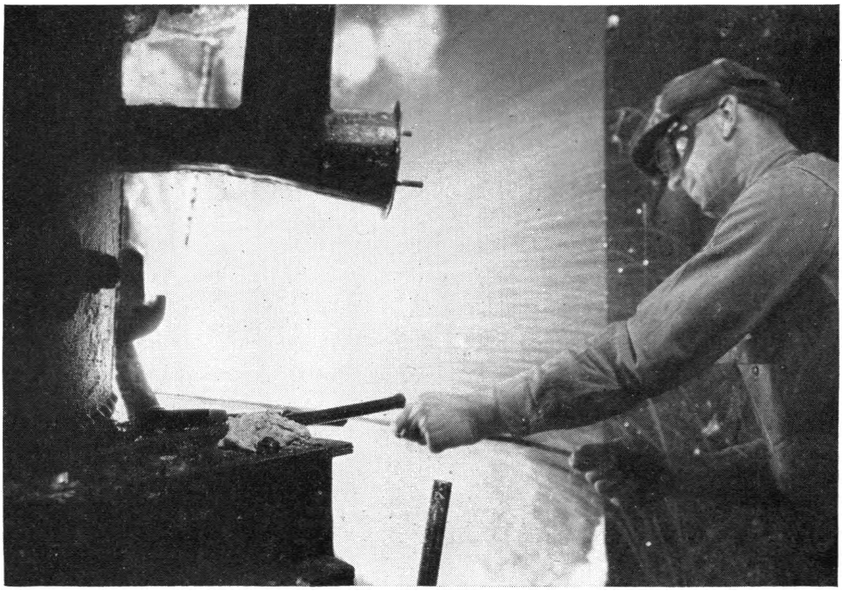

FIGURE 1. Blowing mineral wool: As the molten slag leaves the cupola in a thin stream, it is intercepted by a blast of steam and blown into the wool room, thus forming loose mineral wool.

To make batt or blanket wool, the loose wool is removed from the wool room, usually on a conveyer belt, and sprayed with resin or some other binder. It then passes through rollers which compress the wool with the binder and set it into a continuous mineral wool blanket. Following this, the blanket passes through ovens which complete the process of binding and setting the blanket in permanent form. Blankets are made from 1 to 4 inches thick to suit various insulation purposes. The conveyer moves the newly formed blanket along to the point where the moisture-proof vapor-barrier paper is added as backing, though batt or blanket wool is sometimes made without paper backing. The mineral blanket is then cut and trimmed automatically to batt or blanket sizes, automatically rolled, and then hand packed for shipment. The wool clippings from the trimming operation are salvaged and made into granulated wool.

In some of the larger plants, there is a separate production line for each type of wool, but in smaller plants one cupola produces the loose wool used to make granulated and batt or blanket wool.

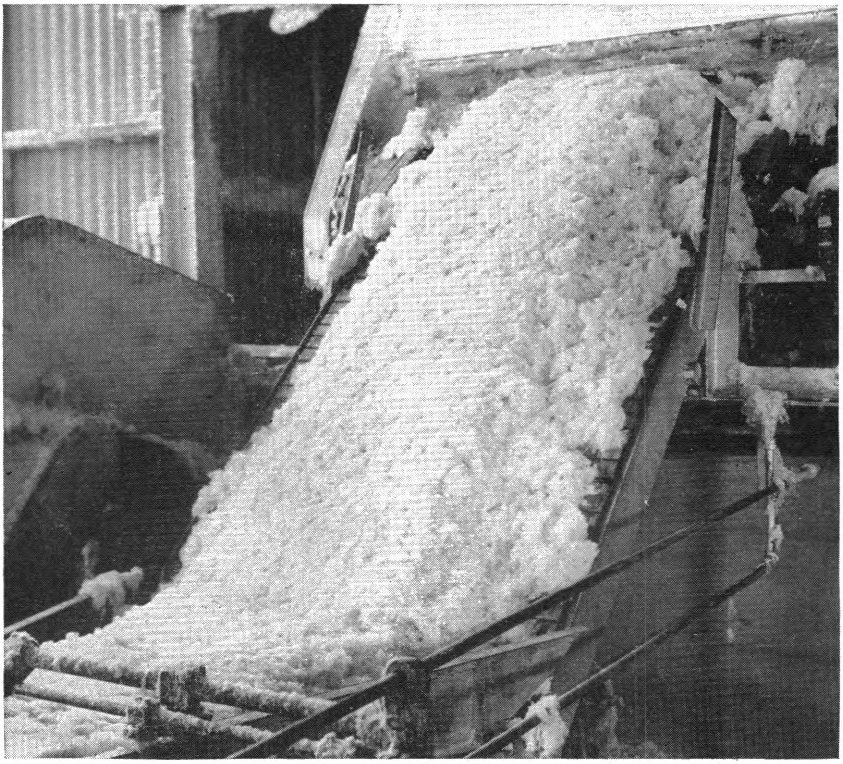

FIGURE 2. Loose mineral wool: An endless belt conveys the blown wool from the wool room for bagging or further processing into granulated or batt and blanket wool.

LABOR REQUIREMENTS IN MANUFACTURING

The labor requirements to manufacture a ton of mineral wool for all processes combined have already been quoted (p. 6). Figures showing detail by department or process are presented in table 3.

It will be noted that the processing of granulated wool requires more labor than loose wool chiefly in the maintenance department, as a result of the additional machinery required for nodulating or granulating the wool, removing the shot, and then bagging the wool automatically.

Also, more labor is required to make granulated wool than loose wool, because of the loss or waste in raw materials caused by removal of the shot. This necessitates handling and heating more raw material to produce a ton of the granulated mineral-wool product.

While granulated wool is bagged automatically, loose wool must be bagged by hand, as the fibers tend to cling together to form large masses or lumps. Man-hours required for packing loose wool, in fact, exceed those for processing. In contrast, the pellets of granulated wool are easily bagged by machine.

Most of the additional labor required to produce batt or blanket wool as compared with granulated wool is employed in the manufacturing and packing department where additional machine operations require a larger number of machine tenders. In addition, batt or blanket wool is hand packed in contrast with the automatic bagging of granulated wool. Machine maintenance and labor supervision also are more extensive in making batts or blankets.

TABLE 3.—*Man-hour requirements per ton to manufacture mineral wool home insulation in 1946, by type of mineral wool product*

Major department or process	Average man-hours required per ton of mineral wool for—			
	All types (weighted average)	Loose wool	Granulated wool	Batt or blanket wool
All departments	9.1	6.7	8.2	12.2
Handling raw materials	.3	.1	.3	.4
Cupola	2.4	2.2	2.4	2.4
Manufacturing and packing	3.4	2.5	2.5	5.6
Loading and shipping	.7	.7	.8	.7
Administration, clerical, and sales	.6	.3	.6	.7
Maintenance	1.3	.6	1.3	1.9
Superintendent and foreman	.4	.3	.3	.5

A relationship can be seen between production level and average man-hour requirements per ton in the mineral wool plants surveyed. The greater the plant's production, the lower the average man-hour requirements to produce each ton. The relationship appears to affect practically every processing department, as shown in table 4.

TABLE 4.—*Average labor requirements per ton of mineral wool produced in 10 plants in 1946, by estimated monthly production and by major department*

Major department	Man-hours required per ton in plants with monthly production of—		
	Less than 1,000 tons	1,000 to 2,000 tons	More than 2,000 tons
All departments	17.6	10.8	8.3
Handling raw materials	.6	.5	.2
Cupola	4.1	2.7	2.2
Manufacturing and packing	4.7	3.9	3.1
Loading and shipping	2.1	1.3	.6
Administration, clerical, and sales	1.5	.7	.5
Maintenance	2.2	1.2	1.5
Superintendent and foreman	2.4	.5	.2

OUTSIDE LABOR REQUIREMENTS

To follow the employment needs for producing mineral wool from mine to dealer, it was necessary to study how much labor was required to produce and transport the raw materials, fuel, and other major products needed to make this type of home insulation and it was necessary to compute, also, the labor required to transport the finished product from the plant. Estimates of these labor needs are, at most, approximate and could be prepared only for loose wool.

Labor needs for all these activities averaged 5.6 man-hours per ton of loose wool produced. When added to manufacturing man-hours (6.7 per ton), a total of 12.3 man-hours per ton is derived for the labor needs from extraction of the raw materials to delivery of the finished product. The nonmanufacturing labor requirements undoubtedly vary somewhat for the granulated and batt or blanket types as compared with loose wool. On the average, however, it is safe to say that about 15 man-hours (9.1 for manufacturing and 5.6 to produce the material used, etc.) are required to produce one ton of all type mineral wool home insulation, from mine or slag pile to dealer.

The method by which these totals were derived may be described briefly as follows: An average cupola charge contains about 2,400 pounds of blast furnace slag, 40 pounds of gravel, and 400 pounds of coke. It is estimated from information of the National Slag Association and previous studies of the Bureau of Labor Statistics,[7] that an average of 1.3 man-hours is needed to produce these raw materials at their source, distributed as follows: 0.24 man-hour for the slag, 0.01 for the gravel, and 1.07 for the coke. Using earlier Bureau figures on labor needs in transporting raw materials to the site of manufacture,[8] it is estimated that a total of 0.5 man-hour was required to deliver the raw materials to the mineral wool plants—0.26 man-hour for the slag, 0.01 for the gravel, and 0.20 for the coke.

The fuel used at the plant—about 280 lbs. of coal and 39 kw.-hr. of electricity per ton of loose wool—is estimated to require 0.18 [9] and 0.10 [10] man-hour, respectively, and other materials (principally the

[7] For studies covering man-hour requirements to produce coke and gravel, see Monthly Labor Review, May 1935, Man-Hours of Labor per Unit of Output in Steel Manufacture (also reprinted as Serial No. R. 240), and Monthly Labor Review, July 1939, Labor Requirements in Production and Distribution of Sand and Gravel (also reprinted as Serial No. R. 944).

[8] See Monthly Labor Review, October 1937, Labor Requirements in Rail Transportation of Construction Materials (also reprinted as Serial No. R. 637), and see also Monthly Labor Review, June 1938 (p. 11), Labor Requirements in Production and Distribution of Plumbing and Heating Supplies (also reprinted as Serial No. R. 733).

[9] See U. S. Bureau of Census, Mineral Industries, Vol. 1, 1939, p. 224.

[10] See Bureau of Labor Statistics Bulletin No. 888–1, Labor Requirements in Cement Production, pp. 16–18.

57 bags required for a ton of loose wool) about 0.5 man-hour. The transportation of the coal requires 0.21 man-hour, making an approximate total of 1 man-hour for fuel and materials used.

The rail haul of the finished wool is estimated to average 375 miles, requiring 2.8 man-hours per ton of wool transported.[11] An estimated average of 13 tons of mineral wool is carried per car.

Cotton Insulation

Cotton insulation is made from sound, staple, well-cleaned, and firmly matted material. The matting of the individual hollow tubular fibers, each of which contains tiny dead air spaces, forms additional air spaces, thus providing an exceedingly effective natural barrier to the passage of heat.[12]

Cotton insulation was first produced commercially in 1940. It was developed under a United States Department of Agriculture program to create a new outlet for the grades of cotton which are usually surplus. This surplus cotton is made available under incentive payments enabling the producers of cotton insulation to compete successfully with other types of nonrigid home insulation. The acceptance of cotton insulation and the commercial development of the industry since 1940 has been rapid. (See table 5.)

In general, the machinery used to make cotton insulation was adapted from existing types of textile machinery. With the assistance of the Department of Agriculture, methods of flameproofing and mildew-proofing the raw cotton were devised. The firms in the industry now have individual formulas for flameproofing, which they regard as trade secrets.

TABLE 5.—*Production of cotton insulation under the U. S. Department of Agriculture incentive program 1940–46* [1]

Year	Annual production in thousands of pounds
1940	55
1941	769
1942	1,746
1943	7,447
1944	8,544
1945	9,351
1946	18,100

[1] U. S. Department of Agriculture. Excludes small amount of production outside the Department of Agriculture program for which data are not available.

[11] See Monthly Labor Review, October 1937 (pp. 846–853), Labor Requirements in Rail Transportation of Construction Materials.

[12] Cotton Insulation by E. H. Omohundro and N. B. Salant, Washington (U. S. Department of Agriculture), December 1944, p. 5.

PRODUCTION PROCESS

Although the methods and machinery for making cotton insulation vary somewhat from plant to plant, the operations are basically the same in all plants.

The baled raw cotton is unloaded from the freight cars or trucks and stored in a warehouse. As the cotton is needed it is moved by conveyor or hand cart to the beginning of the production line.

The raw cotton is fed into the opener or willower machine which loosens and fluffs it up. The fluffed cotton is then blown through tubes or conveyed on belts to the dipping or soaking vats, which are fed automatically by means of weighing machines. The vats are filled with a combination flameproofing and mildew-proofing chemical.

The cotton moves slowly from one end of the vat to the other, being mechanically agitated all the time so that it is thoroughly soaked with the chemicals. In some cases, the soaking vats are variations of wool washing machines. The soaking process may require as long as 1 hour to complete.

Dry cotton is being continuously fed into one end of the vat while soaked cotton is removed from the other end by a conveyor belt. The belt carries the wet cotton through large rubber squeeze rolls which operate under hydraulic pressure and remove most of the moisture. The conveyor belt continues into a battery of drying ovens where a combination of heat and circulating air thoroughly dries the cotton.

The processed cotton is then fed by blower or conveyor into the blanket-forming machine, sometimes called a batting or spider web machine. Its function is to process the loose cotton into a continuous thin blanket. This is done by a series of carders or combs moving at high speed.

As the cotton leaves the batting machine, it is in the form of a thin blanket. It is then fed layer on layer to the final conveyor belt until the desired thickness of blanket is formed. The blankets are produced in rolls up to 50 feet in length, in widths of 12, 16, 20, and 24 inches, and in thickness from ¾-inch to 4 inches.

The final processes of cutting the cotton blanket to proper width, applying moisture-proof paper backing, and rolling for packing are usually accomplished in one automatic operation. At the end of the batting machine the newly formed blanket is moving along a conveyor belt about 4 feet wide. Slitting knives at the end of the conveyor cut the blanket to the desired 12, 16, 20 or 24-inch width. From under the conveyor belt the special kraft paper, wax coated on one side and asphalt coated on the other, is heated on the asphalt-coated side and fed to the underside of the blanket roll. The entire conveyor moves through a roller which laminates the paper to the blanket and compresses the blanket for packing. At the end of the line the completed blanket is formed automatically into rolls of predetermined size. The rolls are cut automatically to the proper length and are then removed

FIGURE 3. Installing cotton insulation: The cotton blankets are installed between the framing structure of the walls in the new house. Other types of batt and blanket insulation are installed in the same manner.

by hand and hand-packed into corrugated boxes. A sample from at least every 2,000 square yards of finished insulation is subjected to certain minimum specification tests as outlined by the Department of Agriculture.

LABOR REQUIREMENTS

Most of the operations performed in processing cotton insulation are automatic, so that manufacturing labor requirements per unit of product are at a minimum. Of the 4.2 man-hours required per 1,000 square feet to process cotton insulation in 1946, half were in the flame-proofing and drying, and blanket-forming and cutting departments where most of the processing takes place under the supervision of machine tenders (table 6).

In contrast, the growing, picking, and ginning of the 210 pounds of cotton used per 1,000 square feet is estimated to require 84 man-hours.[13] The material used in producing cotton insulation is lint (virgin) cotton not less than ¾-inch staple and of at least certain minimum quality as required by the Department of Agriculture for participation in the cotton-insulation incentive program. It is shipped to the manufacturers of cotton insulation from various points in the southern cotton belt in 500-pound bales.

TABLE 6.—*Man-hours required to produce and distribute 1,000 square feet of 3-inch-thick cotton insulation in 1946*

Major department or operation	Man-hours per 1,000 square feet of 3″ cotton insulation
Total, all operations	90.0
Production of raw materials	84.5
Transportation of raw materials	.5
Manufacturing	4.2
Handling raw materials	.3
Flameproofing and drying	.7
Blanket forming and cutting	1.7
Packing	.4
Shipping	.5
Administrative, clerical, and sales	.4
Maintenance	.1
Superintendent and foreman	.1
Transportation of finished product	.8

The rail haul from cotton gin to insulation plant is estimated from factory records to average 900 miles for which 0.5 man-hours would be required for the 210 pounds of cotton used per 1,000 square feet of finished product.[14] Another 0.5 man-hours are needed, according to industry sources, to produce the 30.3 pounds of paper used in making 1,000 square feet of insulation. The average rail haul of 300 miles to the plant, as indicated in plant records, is estimated to require only the fractional sum of less than 0.1 man-hours.

Since the amounts and kinds of chemicals used in flameproofing and mildewproofing the cotton are trade secrets, no information on

[13] Based on estimates for 1946 furnished by the Bureau of Agricultural Economics of the U. S. Department of Agriculture.

[14] Based on an average haul of 25 tons of cotton per car. See Monthly Labor Review, October 1937, Labor Requirements in Rail Transportation of Construction Materials.

labor requirements could be obtained for these materials, but the labor needed per unit of product is believed to be very small.

The average rail haul of the finished insulation was estimated at 500 miles in 1946, requiring 0.8 man-hours per 1,000 feet of insulation, compared with 0.5 man-hours for the average of 900 miles that the raw baled cotton was hauled. The difference is in the fact that 25 tons of baled cotton can be carried per car, as compared with but 5 tons of the finished cotton insulation.

Expanded Vermiculite

When vermiculite ore is subjected to heat of 1,400° F. to 2,000° F., it expands 8 to 15 times its original size and the resulting porous substance has especially high insulating properties. Exfoliation is the term used in the industry to describe the expansion process. Dead air cells within the granules, as well as between the granules of the expanded ore, act as nonconductors of heat, thus giving vermiculite its insulating value. Vermiculite is also incombustible.

It is estimated that about 60 percent of all vermiculite ore mined is used for home insulation. In 1946, this resulted in the production of something over 13 million cubic feet of expanded vermiculite with an estimated value of over 3 million dollars.[15] The exfoliated ore leaves the furnace in various sizes of feather light, resilient pellets ranging from powder or dust to granules about three-quarters of an inch square. The medium granular sizes are used as a loose fill type of home insulation. Other sizes of expanded vermiculite are used to make precast concrete slabs for roof, floor, and wall construction. Because of the light weight of vermiculite, these slabs weigh as little as 25 pounds per cubic foot. Compressed vermiculite wall board also is being manufactured, and in increasing quantities. The powder and smallest granule sizes of the expanded vermiculite are used as concrete or plaster aggregate in place of sand. They are also added to garden soil to make the soil more porous and easy to work.

PROCESS OF MINING AND EXFOLIATING

Vermiculite ore was originally discovered in this country in 1824 near Worcester, Mass., by Thomas H. Webb.[16] At present most of the ore comes from Montana, with a few small mines operating in Colorado, North Carolina, South Carolina, and Wyoming. At least one company has also begun to import ore from South Africa. Raw unexpanded vermiculite ore is composed of minute laminations of

[15] Expanded vermiculite was priced at about $75 per ton, f. o. b. plant, in 1946. See U. S. Bureau of Mines Information Circular 7388, October 1946, p. 11.

[16] G. R. Gwinn, Marketing Vermiculite, Bureau of Mines Information Circular 7270, January 1944, p. 1.

mineral ore which have a glossy surface similar to isinglass; as mentioned earlier, the ore is like mica in appearance.

Most vermiculite ore comes from open pit mines. A small percentage of gangue [17] or mineral rock containing the ore is mined along with the vermiculite. The raw ore is first crushed into smaller flakes. The oversize gangue is eliminated by a screening operation and the partly crushed vermiculite goes into a rotary or conical type drier. Here it is subjected for a short time to a heat of 200° F. to 300° F. to eliminate part of the free moisture content of the ore. The vermiculite is then graded by screening it into four sizes. Each size is shipped separately in freight cars of 42 to 50 tons capacity. Exfoliating plants order the raw ore by size depending on the ultimate use to which the expanded ore is to be put. This screening, grading, and drying operation is usually done at the mine site, but may be performed at the exfoliation plant when it is located near the mine. While expanded vermiculite has been in continuous commercial use since the early 1920's, production has increased considerably in recent years, and more than tripled between 1940 and 1946. (See table 7.)

TABLE 7.—*Amount and value of screened and cleaned raw vermiculite ore sold or used in the United States, 1935–46* [1]

Year	Short tons	Value	Year	Short tons	Value
1935	7,068	$88,445	1941	23,438	$125,444
1936	16,933	185,787	1942	57,848	319,931
1937	26,556	260,664	1943	46,645	471,595
1938	20,700	192,000	1944	54,116	541,744
1939	21,174	174,587	1945	64,808	648,077
1940	22,299	137,698	1946	71,289	712,890

[1] Data for 1935–42 from U. S. Bureau of Mines Circular 7270, January 1944, p. 6; data for 1943–45 are from U. S. Bureau of Mines Circular 7388, October 1946, p. 11. Figures for 1946 are estimated on the basis of information from the Bureau of Mines that production increased 10 percent over 1945 with the price per ton of vermiculite remaining about the same. (All data are for unexpanded ore.)

When the freight cars of raw ore arrive at the exfoliation plant siding, they are usually unloaded by hand. The ore is hauled and dumped or shovelled into a bucket-type conveyor which lifts it overhead into storage hoppers, from which it moves automatically by conveyor belt to the top of the furnace.

The various plants use different types of furnaces for the exfoliation process. Each is designed to produce the expanded ore by subjecting it to a heat of 1400° F. to 2000° F. for a few seconds. The furnaces are usually heated by forced-air oil burners. Some plants use baffles to delay the fall of the ore through the furnace, while others have the furnace set at an angle so that the ore flows rather than falls through the furnace. As the expanded flakes come out of the

[17] The mineral or rock material accompanying the ore in a vein.

bottom of the furnace they are again picked up by conveyor belt or bucket elevator. The flakes, now expanded some 8 to 15 times, are tough and pliable.

The expansion process occurs as the result of a minute amount of water between the laminations in the granules of the raw ore, which, when subjected to the heat of the exfoliation furnace, expands and turns to gas, forcing the laminations apart to form expanded vermiculite. Excessive heating drives out all the moisture content and renders the flakes permanently brittle.

When the expanded ore is picked up from the furnace it is ready for grading and bagging. The plants have different methods of grading, depending on the uses to which the product is to be put.

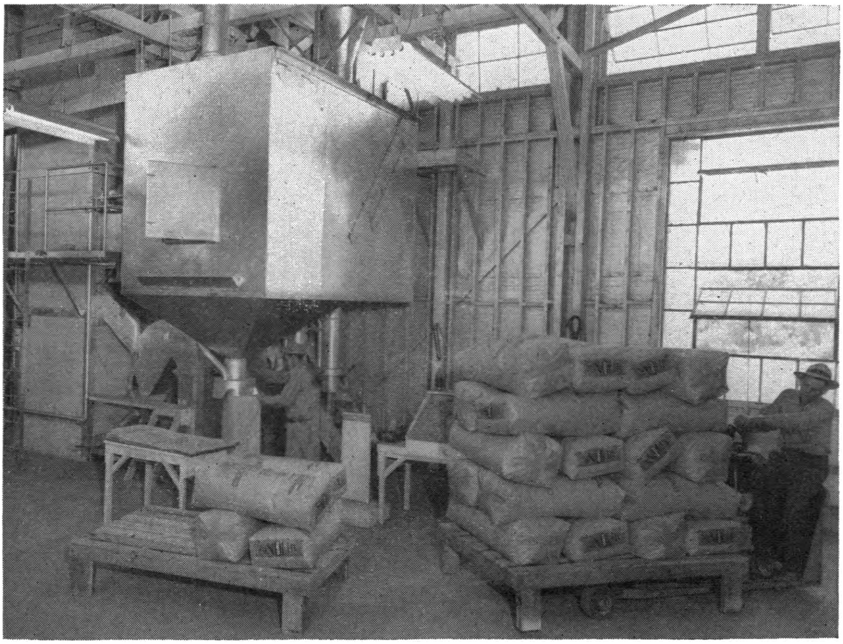

FIGURE 4. Processing and bagging vermiculite: On the left is the furnace used to expand vermiculite ore. The expanded ore is then elevated overhead into the loading hopper (center) below which the bags are filled and sealed.

One method is to lift the expanded ore to a long mesh screen set over the bagging hoppers. As the ore slides down the tilted screen, it passes over meshes of various sizes. The powder or very fine flakes drop through the fine mesh into the first hopper, larger flakes through the second size of mesh into another hopper, etc. Thus the expanded flakes can be graded into several sizes.

A second method of grading is by the use of forced air. As the granules leave the furnace and are elevated overhead, a fan drives the lighter and finer material across an opening into a hopper while the unwanted heavier granules and unexpanded gangue drop through the opening. This method is used when very fine ore is being fed into the furnace, thus producing little of the larger and heavier material after exfoliation. The average loss by this method is estimated to be about 5 percent.

Until the flakes reach the bagging hoppers the process is entirely automatic, except for furnace and machine tenders. Bagging, however, requires some hand labor. A 4-cubic-foot bag is placed under the spout extending from the bagging hopper. When the bag is filled it is removed by hand and sealed with gum tape or tie wires. One 4-cubic-foot bag of home insulation weighs approximately 25 pounds.

Since the exfoliating of vermiculite is a relatively simple operation, one or two foremen generally supervise the entire plant.

LABOR REQUIREMENTS

Three-fifths of the 19.2 man-hours required to process 1,000 cubic feet of expanded vermiculite in 1946 were needed for the most important operations of heating, grading, and bagging. An average of 25.2 man-hours was needed for all production operations, including the 6 man-hours for plant administration, clerical, and selling functions. Between individual plants, man-hour requirements for processing and administration ranged from 20.5 to 29.4 man-hours. This range was found to depend in large part on the degree to which the plants approached capacity operations. For example, plants operating on a three-shift basis required an average of 24 man-hours per 1,000 cubic feet of production, compared with the average of 29 man-hours required by plants operating fewer than three shifts.

It will be noted from table 8, that as much labor was needed to transport from mine to plant the 3.3 tons of ore used per 1,000 cubic feet of expanded vermiculite (19.4 man-hours), as was needed to process the ore (19.2 man-hours) when it arrived. The reason for this is the long haul, averaging 1,500 miles, from mine to the widely scattered plants, which are situated near their markets rather than near the few mine locations. Because of its light weight and consequent bulk, it is impracticable to ship the finished product any great distance. An average of only 13 tons, in fact, constitutes a fully loaded car. The average rail haul for the finished product is 200 miles, for which an estimated 4.7 man-hours [18] are required per 1,000 cubic feet of insulation.

[18] See footnote 11.

TABLE 8.—*Labor requirements for all operations in production and distribution of 1,000 cubic feet of vermiculite home insulation in 1946*

Operation	Man-hours per 1,000 cubic feet of the final product
Total—all operations	61.1
Extraction of ore [1]	8.9
Transportation of ore	19.4
Processing	19.2
Unloading raw materials	2.1
Heating, grading, and bagging	11.6
Loading	5.5
Administration, clerical and sales	6.0
Production of fuel used [2]	.7
Production of paper bags used [3]	2.2
Transportation of final product	4.7

[1] About 3.29 tons of ore are needed to produce 1,000 cubic feet of vermiculite home insulation.
[2] About 8.9 gallons of fuel oil at mine, 16.3 gallons of fuel oil at plant, and 25 kilowatt-hours of electric-power were required per 1,000 cubic feet of expanded vermiculite, taking, respectively, an estimated 0.2, 0.4, and 0.1 man-hours to produce.
[3] An estimated 250 paper bags were used per 1,000 cubic feet of expanded vermiculite produced. The estimate shown does not include the labor required to produce the paper used in the bags.

Nearly 9 man-hours are expended in producing 3.3 tons of ore in the mine, covering administration requirements as well as the mining, cleaning, screening, grading, and loading operations. Over a third of the mining man-hours are needed in mining the ore, and in preliminary crushing and sorting. Cleaning, screening, and grading the ore require nearly half the total man-hours. The remaining labor is needed for maintenance, clerical, and supervisory labor.