Mineral Wool—the Mining Industry's Fastest Growing Product

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IN five years mineral wool has grown to a thirty-million-dollar industry from one whose output was valued, in 1933, at $1,700,000. Ten years ago, in 1928, there were only seven producing companies, with an annual output of but 50,000 tons. By 1936 fifty or more companies were producing half a million tons. The industry is still growing vigorously and will profit from the expected activity in building in 1339, for two-thirds of this material is used for building insulation and to assist in fire-retarding, in both new and old homes. It is as useful in the South, to protect against heat, as in the North, to keep out the cold, if one may speak nontechnically. It is a concomitant of air conditioning, that new addition to the American standard of living that began in theatres, department stores, and railroad dining cars, and is rapidly progressing down to small homes. Here, then, is an industry that is only beginning to have a present, and one with an almost certain important future; one that depends upon mining and the by-products of mining for all of its raw materials; one that every progressive mining man should know something about.

Courtesy Eagle-Picher Sales Co.

Mineral wool insulation makes houses cooler in summer, warmer in winter. Here it is being blown between joists in an unfinished attic.

Man has searched for comfort in his dwellings ever since his primitive ancestors built their first windbreaks. The thick-walled homes of colonial days gave way to thin pervious walls of modern construction because of their cheaper cost. Now comes mineral wool insulation to enable us to regain and even to add to the comfort of our immediate ancestors' dwellings.

Sometime in 1788 a group of scientists sent out by the United States Government visited the crater of Kilauea in Hawaii. As they climbed the side of the volcano, they noticed a soft, woolly substance floating in the air that caught on foliage or rock fragments. The folklore of the native Hawaiian accounted for the material by the story that when the Goddess Pele became angry she pulled out her hair by the handful and threw it out of the crater. Hence, the fine fluffy stuff was known as Pele's hair. Investigation showed that Pele's hair was formed in the crater of Kilauea by jets of steam blowing up through molten lava. Samples of the material were brought back to Washington and tested in various ways. As a result a process was devised for its commercial manufacture, but it apparently got little attention. Then in 1840 mineral wool was reported produced in Wales, and in Germany later. *Stone* magazine, in its issue of November, 1888, published an article describing the manufacture and use of rock wool near Cleveland. A dress made from silica wool fibers was exhibited at the World's Fair in Chicago in 1893 and is still on display in the Toledo Art Museum. The first successful and continuous manufacture of rock wool as a commercial venture is credited to C. C. Hall in Alexandria, Ind., in 1897.

Mineral wool is a substance composed of fine, interlaced mineral fibers having the appearance of loose wool or cotton. It is a fibrous, glasslike material composed principally of silicates of calcium and aluminum, with other minor constituents. Mineral wool is a generic term covering a number of similar products differentiated chiefly by the raw materials from which they are made, as rock wool, slag wool, and glass wool or glass silk. Rock wool, as its name implies, utilizes as raw materials limestone, dolomite, shale, and clay, combined with silica in the form of sandstone, or quartz, or as an ingredient of the other rocks. Slag wool is made from slags resulting from the reduction of iron, lead, or copper ores. Other materials, such as limestone or silica, may have to be added depending on the chemical analysis of the original slag. Glass wool is made from the same materials that are required for making glass. Basically, these are soda ash, limestone, and silica. The addition or partial substitution of other

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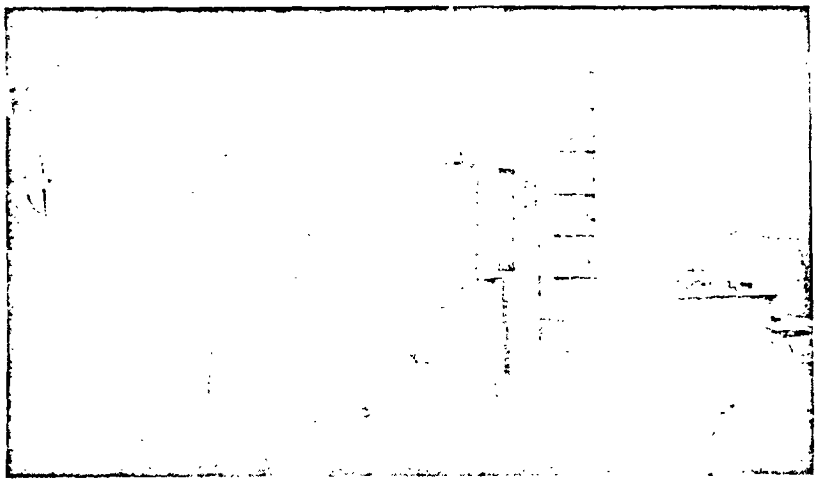


Courtesy Rock Products

Charging floor of a rock wool cupola.

ingredients changes the characteristics of the glass; similar substitutions in the raw mix enable the manufacturer to alter the character of the wool blown.

Just as the jets of steam issuing from the crater at Kilauea picked up bits of molten lava and blew them into the substance called Pele's hair so the manufacturer of today directs a stream of molten rock, slag, or glass to a jet of either steam or air and blows it into wool. Technically, however, the process is not so simple, since many factors enter into the process, all of which must be under rigid control to assure a commercial product. Merely projecting a molten stream of rock into a jet of steam does not always produce wool. Chemical constituents of the raw material, degree of viscosity, and temperature of the slag, size of slag stream, length of fall, and the pressure of the steam or air are only a few of the many variables that must not only be controlled individually but co-ordinated to make the process successful in producing the kind of wool desired.

THE usual process consists of mixing raw materials with coke in alternate layers in a water-jacketed steel cupola, igniting the coke, melting the rock or slag ingredients to a fluid molten slag, tapping the slag through a small aperture, allowing the slag stream to drop to a steam jet, and blowing the slag in tiny droplets through the air, whereby friction elongates the droplet to a fine thread before it has time to solidify. These fine silicate threads form the wool and are then collected and fabricated into many forms of insulating products.

The cupolas are double-walled steel cylinders with open ends. They range from 26 to 72 in. in diameter and from 7 to 16 ft. in length. The thickness between the double walls, or water jacket, ranges from 3 to 6 in. These cylinders or cupolas are set on end on brick or concrete foundations. The lower end is closed with a sheet-iron plate and the upper end housed in a firebrick hood containing the charging opening and surmounted by a metal stack. Surrounding the lower portion of the cupola is a hollow, concentric metal ring from which several hollow arms or tuyères extend radially to and through the cupola wall through which air is forced into the cupola.

In starting operations, a few inches of sand or clay is placed on the bottom plate. The cupola is then filled with coke to a point above where the tuyères enter the walls. The coke is ignited, and when burning briskly, rock or slag is added to a depth of several inches. The cupola is then filled with alternate layers of fuel and raw materials to the charging door and the air is turned on at the tuyères. The materials charged are in lump form to allow free passage of air and combustion gases; briquetting may be necessary for fine material.

At one point near the base of the cupola a round or square opening is provided through the wall and filled at the start with firebrick or clay. When the charged material has been melted to a fluid slag, a hole is punched in this opening, permitting the slag to escape in a small stream. It falls only a few inches before it is intercepted by steam or air issuing under high pressure from a trough-shaped orifice. This shears the falling slag stream into myriads of tiny globules and propels them through the air at high speed. As each globule rushes along, air friction forces its outer shell or surface layer into a long, fine, threadlike tail which cools and solidifies to form wool fiber.

One manufacturer of rock wool has introduced a spinning disk in place of the steam jet, which is revolved at high speed on a vertical axis. The molten stream issuing from the furnace falls to the outer section of the disk, whence it is violently propelled through the air in a manner similar to the action of the steam jet.

If conditions are not exactly right, part of the original globule will be cooled and solidified before it is drawn into fiber. Examination of most raw wools will show fibers still fastened to what is left of the original particle of molten slag. These solidified globules are known in the industry as "shot," a waste product.

The fine fibers, with their unfiberized particles, or shot, are either packed for shipment as loose wool or prepared for other types of fabrication.

Recently other types of melting furnaces have been introduced successfully. One manufacturer uses a flat, reverberatory-type furnace fired with fuel oil. With this type of furnace, raw materials are first crushed and fed continuously. Another plant is reported to be using a similar type of furnace fired with natural gas. At still another plant, an electric furnace is used, with the electrodes immersed in the molten mass.

Loose wool is not suitable for some forms of insulation. For example, wool used to insulate structures already built must be blown into the walls by air pressure. For this purpose loose wool is "granulated," which involves passing it through one of several types of equipment ranging from small swing hammer mills to rapidly revolving ensilage cutters to break up the fibers and separate them from the attached shot. This granulated wool is then passed to an ordinary revolving trommel or inclined shaking screen where the shot passes through the wire mesh and the freed fibers are collected and rolled up into small pellets or balls. In this form, the wool is an ideal product for blowing into house walls.

Glass wool is made in regenerative-type glass tanks fired with natural gas. The molten glass flows over a perforated forehearth, and the fine streams of glass passing through the perforations are attenuated by steam pressure and blown into wool.

MANY factors must be more or less rigidly controlled to assure a finished product that will meet the rapidly narrowing limits of consumer requirements. The first of these is the chemical composition of the raw materials, which exhibit a wide range. It has been proved experimentally that a combination of pure calcium carbonate and silica without other ingredients can be blown into wool. However, all manufacturing plants use alumina in some form, and in most mixtures some magnesia is present. Some operators attempt to achieve and maintain a chemical balance between acids and bases. Others contend that this is not necessary and that better wool results when there are more acids than bases, or vice versa. It is sufficient here to point out that similar chemical compositions in the furnace charge may be obtained by combining two, three, four, or more of a large number of natural or waste materials and that the chemical composition of the charge is reflected in the chemical composition of the wool.

The next variable is the temperature of melting and blowing. This, however, is directly coupled with the viscosity or fluidity of the molten material and to a large extent may be influenced by the chemical composition of the charge. Melting temperatures range from 2300° to 3400° F. Blowing temperatures, or the temperatures of the molten stream when cut by the steam jet, are somewhat lower, ranging from 2000° to 2850° F. A greater amount of heat is required to melt some minerals than others, so one combination of raw materials will need a greater amount of fuel and must be raised to a higher temperature than another mixture, to obtain the same fluidity or viscosity. Viscosity alone, however, is not the only controlling factor. The furnace charges of different composition, when brought to the same viscosity at the same or different temperatures, may produce entirely different wools, or it may even be impossible to blow one into wool. No published results covering the relationship between chemical composition, temperature, viscosity, and ability to produce wool have appeared as yet, so the manufacturer must rely on his own research to determine the best procedure with his particular raw materials. For various reasons, this combination of variables can be controlled more accurately in the manufacture of glass wool, so the characteristics of the wool itself can be varied to a considerable extent at will.

Another variable is the diameter of the molten stream when cut by the steam jet and the length of fall from draw hole to steam jet. Obviously the greater the length of fall the smaller will be the diameter of the stream. There will probably also be a corresponding change in temperature which in turn may change viscosity. Whatever effect a change in length or diameter may have, operators have found that wool blown from a stream 6 in. long will have different characteristics from that blown with the steam jet cutting the stream 3 in. or 9 in. from the taphole. In fact, some manufacturers are using this difference in length of stream to blow wool to meet different specifications.

Production of shot seems to be a necessary evil. Shot itself has no insulating value so the wool with the lowest percentage is the best insulator, other conditions being equal. Therefore, the constant aim of the manufacturer is to produce wool with as little shot as possible. A change in any one of the previously discussed variables may be directly reflected in the amount of shot. Various schemes have been devised to remove all the shot from the wool, and some promise success. Granulation is the process generally applied. This, however, breaks the wool fiber into short pieces thus destroying the binding effect of long fiber. The process of spinning wool seems to produce long-fibered wool singularly free from shot but whether this is attributable directly to spinning or to other elements in the process is difficult to determine from casual observation. Glass wool ordinarily is free from shot but frequently has enlarged fibers with hooked ends instead. Production of shot in wool blown from a cupola is an industrial waste, since the shot cannot be returned to the cupola for remelting for it would restrict the flow of combustion gases. Shot can, however, be remelted in the reverberatory furnace but even so, its production is a waste because of the extra heat and fuel required to remelt it.

The diameter of the wool fibers is another variable that requires constant control. The value of mineral wool as an insulator lies in the great number of minute air spaces confined within the interlaced fibers. Obviously the finer the fiber the greater in number and smaller in size these little air spaces will be. A change in chemical composition, temperature, viscosity, or possibly steam pressure may be reflected by a change in diameter of the fiber. Ordinarily manufacturers try to hold fiber diameter between 4 and 10 microns, or 0.00016 and 0.0004 in. but this is not easy. Random samples that I have taken and measured under the microscope showed fibers in one sample ranging from 2 to 25 microns, though in another no fiber was under 4 and none over 8 microns in diameter.

A LONG-FIBERED wool is preferable because of the greater strength of its interlaced fibers. For reasons previously mentioned it seems to be difficult, by the customary methods, to obtain long-fibered wool which at the same time is shot-free. However, greater knowledge and improved processes will undoubtedly yield such a product. The manufacturers of glass wool and spun-rock wools already seem to have approached a solution of this problem.

There are other less obvious variables, the effect of which may or may not be serious, for example, the shape of orifice from which the blowing steam issues. Ordinarily this is V-shaped, but the shape or dimension of the V is seldom the same in different plants, and in some plants the customary V has been discarded in preference for some other shape. Indicative of how the shape of the steam orifice affects the product is the assertion by one operator that the molten slag stream must fall in the exact center of the V for best results; another is equally emphatic that better shearing effect is obtained by cutting the slag stream by one side of the steam trough.

Fabrication Methods

PROBABLY the first step in fabrication is the application of a light, high-flash-point paraffin oil to the wool. This serves two purposes: it keeps the extremely fine fibers from flying around the plant as dust and acts as a lubricant between fibers, reducing internal friction and making the wool more resilient. This oil is applied in various ways. In some plants it is added in the steam line. In others the oil is sprayed or allowed to drip slowly into the wool stream a short distance beyond the steam jet. This application of oil should not be confused with the waterproofing process. Other types of oil or other materials are used for waterproofing, but the materials used and methods of application for waterproofing are trade secrets.

In most plants the wool is blown into wool rooms as it leaves the steam jet. These rooms vary greatly in size and construction. Modern practice, however, requires a moving conveyor-type floor. Some wool rooms have elaborate ventilating systems, whereas others have no such provision. The wool collects on the moving floor and is carried out of the room in a blanket of quite uniform thickness, the latter being regulated by the rate of blowing and the speed of the conveyor. As the blanket emerges, it usually passes under a heavy idler roll which further compacts it to uniform thickness. In some plants the blanket, as it emerges, is sprayed with a liquid binder to increase its structural strength or to promote ease in handling the various shapes into which it may be cut.

Blankets intended for immediate fabrication are cut both longitudinally and transversely by knives or revolving disks into the sizes required for batts to be used in wall insulation between studding. These may be covered on one or both sides with plain or moisture-proofed paper.

TABLE 1. DENSITY AND CONDUCTIVITY OF INSULATING AND BUILDING MATERIALS

Material	*Density lb. per cu.ft.*	*Mean temperature, deg. F.*	*Conductivity, K, B.T.U. per hr. per sq.ft. per deg. F. per in.*	*Authority*
Balsam wool	3	..	0.255	Weiss[1]
Felted cattle hair	11	90	0.26	Bur. Standards[2]
Loose mineral wool	8	103	0.27[8]	Bur. Standards[2]
Rock wool	10	90	0.27	Bur. Standards[2]
Diatomite in powder form	10.6	86	0.308	Bur. Standards[4]
Cork, regranulated	8.1	90	0.31	Bur. Standards[2]
Fiber board, from sugar cane	13.5	70	0.33	Pebbles[5]
Vermiculite, exfoliated	8	100	0.48	Research lab., Eagle-Picher Lead Co.
Corrugated asbestos board	20.4	110	0.48	Willard, Litchy, Harding[6]
85% magnesia, 15% asbestos board	19.3	86	0.51	Bur. Standards[2]
Wood (white pine)	31.2	86	0.78	Bur. Standards[2]
Brick, common		.	5.00	A.S.H.V.E. Guide, 1935[7]
Concrete, typical		..	12.00	A.S.H.V.E. Guide, 1935[7]

[1] Chem. & Met. Eng., 29, 534-7 (1923).
[2] Tests based on samples submitted by manufacturers as shown in American Society of Heating and Ventilating Engineers Guide, 1935.
[3] Direct communication.
[4] Report of the American Society of Refrigerating Engineers Insulating Committee, A.S.R.E. Circular No. 1.
[5] Tests conducted at Armour Institute of Technology, based on samples submitted by manufacturers.
[6] Tests conducted at University of Illinois.
[7] Recommended conductivity for computing heat-transmission coefficients.
[8] Since 1935, glass and rock wool have been reported having a "K" value as low as 0.22.

They are then packed in cartons for shipment. Wool intended for other types of products is usually gathered from the conveyor and sent to the granulator, after which the shot is removed. These fine, shot-free fibers are bagged for shipment as granulated wool for blowing into the walls of houses already constructed.

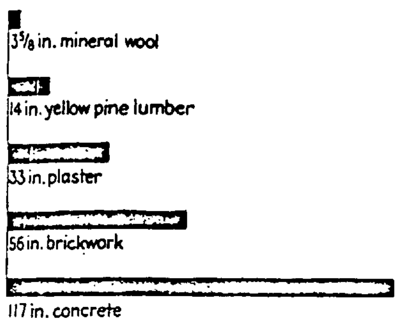
Granulated or loose wool is also mixed with suitable binders and pressed or molded into insulating board, pipe covering, or other shapes. Mixed with clay or bentonite and asbestos, loose or granulated wool is sold as insulation cement. Mixed with water to form a paste, it can be formed around irregularly-shaped objects as an insulating cover. Loose wool as taken from the conveyor is frequently placed between chicken wire or steel lath and sold in blanket form as insulation for steam generating units in furnace walls and on ducts and bridgings, and in petroleum refining for insulating process vessels and heat exchangers. Railway cars and annealing ovens offer other outlets. Insulating board or blocks are made up to any specification size and thickness for stove or refrigerator insulation.

In the manufacture of glass wool, the operators have greatly reduced the size of the wool rooms, and the wool is literally deposited by the blowing process on a moving conveyor which delivers it to the fabricating rooms. Rock wool made by the spinning process is thrown across the end of a large sheet-metal pipe, into which it is drawn by an exhaust fan and blown to the fabricating rooms. The shot made in the spinning process are thrown beyond the pipe orifice and collect in the spinning room.

House Insulation

INSULATION of houses against excessive summer heat or the escape of internal heat during the winter provides the greatest market for mineral wool. The best insulator of all is empty space, as illustrated by the vacuum bottle. The next best, practically, is still air. In modern frame construction, the walls of houses contain a dead air space between the outside sheathing and inside plaster separated into vertical panels by the studding. In masonry or brick construction similar dead air is found in the furring spaces. Even if all these dead air spaces were hermetically sealed movement of air within each panel would occur, thus reducing its insulating value. But when filled with mineral wool, the original space is converted into millions of tiny air pockets entrapped by the interlaced wool fibers. The fibers thus prevent air currents or, in fact, any air movement. Mineral wool thus converts the dead-air spaces of house construction to still-air spaces.

Table 1 presents the relative insulating values of various materials as published in 1935 in *Industrial & Engineering Chemistry.* The "K" value or measure of conductivity is the inverse of insulating value, hence a higher figure in that column represents a lower insulating value.



Thickness of various building materials required to give equal insulating values.

The increasing demand for house insulation and the application of air conditioning to residences have concentrated the attention of architects and builders on proper design for the best use of insulation. There were numerous complaints from early installations of mineral wool because walls so insulated absorbed moisture and either caused construction materials to rot or resulted in unsightly walls or ceilings because of condensation. These complaints led to extensive research, the results of which have been published. That conducted by Frank B. Rowley, of the University of Minnesota, to determine the best type of insulation construction developed the following points:

(1) Moisture is produced indoors by several means, including cooking, washing, and operation of humidifiers.

(2) This internal moisture can pass as vapor through almost all building materials, including wood, plaster, brick, and ordinary building papers. The vapor will pass through materials that prevent air movement.

(3) Since internal moisture can penetrate the walls of ordinary house construction, it will accumulate in the wall unless the outer covering is such as to allow it to pass on through to the outdoors. Moisture-proof paper on the outer wall, as is commonly used in building construction in the North, will tend to trap the moisture in the wall.

(4) To prevent condensation in the walls, provision must be made to prevent moisture moving into the wall at all. If this is impossible, then provision must be made to allow easier egress of moisture to the outer air than from the interior of the house to the wall.

(5) To prevent moisture entering the wall it is necessary to use a moisture barrier on the *warm side* of the wall. This is accomplished by stretching moisture-proof paper on the studding *before* the lath and plaster are applied. Several moisture-proof papers have been developed and are on the market.

(6) To remove any moisture in the wall which may get past the inner barrier it is only necessary to be sure that the outer paper covering is of such nature that it will allow moisture to pass through. Ordinary slater's felt is such a material.

(7) In houses already constructed and insulated and which have experienced wall condensation, this trouble can be corrected by removing some of the siding and replacing a strip of the waterproof paper with a windproof but porous paper.

(8) The same type of moisture-proof barrier should be installed on the underside of the rafters when the roof is insulated or on the underside of the attic floor joists when the attic floor is insulated.

(9) The moisture movement in summer in a hot, humid climate in the reverse direction through an insulated wall is not objectionable because the temperature differential between the house interior and the inside of the wall is not sufficient to cause condensation in the wall.

(10) Some mineral wools are treated on one side by a moisture-proofing process. This is good practice but insufficient to prevent the passage of moisture. The inner moisture-proof barrier should be used, as with untreated wools.

TABLE 3. HEAT LOSS FROM A TYPICAL HOUSE

House with	*Heat Loss, B.T.U.*	*Equivalent Tons of Coal*
No insulation	38,000,000	1.6
1-in. rock wool	18,700,000	0.8
3⅝-in. rock wool	8,600,000	0.4

Heat loss calculated through 1000 sq. ft. of wall consisting of clapboard on sheathing with building paper between, 2 by 4 studs set at 16-in. intervals, and an inner wall of wire lath and plaster. The calculation was made for a 15-m.p.h. wind velocity, 200 days' heating season, 30° average temperature difference, and 24-hr. load.

Even with the best type of insulation, properly applied, all possible heat losses are, however, not stopped. Assuming the total possible heat loss of any building as 100 per cent, about one-third occurs through walls and roof; another third is due to air leakage around windows and doors; and the rest escapes through the glass of doors and windows. These proportions, of course, depend upon the type of construction and will vary widely.

TABLE 2. FUEL SAVING UNDER VARIOUS CONDITIONS.

Building with	*Fuel Saving, Per Cent*
No insulation but weather-stripped	15 to 20
Same as above but fitted with double windows	25 to 30
1-in. insulation, not weather-stripped	30 to 40
1-in. insulation, weather-stripped	50
1-in. insulation, with double windows	60

The National Bureau of Standards has estimated the fuel savings due to proper prevention of heat losses as shown in Table 2. On this basis, it is apparent that about one-third of the heat losses occur from air leakage around doors and windows, which can be reduced by weather-stripping. Loss through window glass accounts for one-sixth and is reduced by adding winter or storm sash. At least one-half of the heat loss is then accounted for through walls and roof, which can be reduced by insulation.

Another set of tests, the results of which are shown in Table 3, showed that in a certain case use of 3⅝-in. (wall thickness) of rock wool would reduce the heat loss 75 per cent.

About two-thirds of the heat entering a house comes in through the roof. The importance of attic-floor insulation, coupled with adequate attic ventilation, is thus apparent in providing a cooler house interior during a hot summer.