GLASS WOOL HEAT INSULATION IN EUROPE

By A. D. Saborsky

Modern heat insulation is a comparatively young art. People who were apt to notice the tiniest leak of live steam, or who would worry about their water bills, when a faucet dripped, felt perfectly at ease and [illegible] about the loss of heat from poorly insulated pipes. We all know that this attitude does not prevail today, and the steady growth of our insulation manufacturing concerns in the past decades is ample proof for it.

When we speak of high grade heat insulation here in U. S. A. we [illegible] involve the so-called asbestos insulations, of which asbestos forms only a small part (15% and less in the best insulations), and merely acts as a fibrous binder for the real insulating material, which is primarily carbonate of magnesia, a very friable and crumbling material. The more asbestos these insulations contain, the heavier they become, and the poorer in insulating value. Of other heat insulations used I may mention mineral wool, slag, some siliceous earth (Kieselguhr), clay, paper preparations, cork, and so on.

The demands made upon an ideal insulating material are so exacting and manifold that the heat insulating materials on the market today are only able to comply with a selected few of these specifications. Glass wool however has proved in practice as well as laboratory tests the closest to being an ideal heat insulator.

The following are the characteristics for an ideal heat insulation material

1. Low conductivity
2. Low specific heat
3. Light weight
4. Withstand vibration
5. Withstand destruction by blows
6. Flexibility to
   - (a) Conform to most any shape
   - (b) Follow a surface, expanding under heat
   - (c) Withstand rough handling without damage
7. Withstand alternate heating and cooling
8. Withstand alternate wetting and drying
9. Easy, clean installation, possible by unskilled labor
10. Installation possible without stopping production
11. Contain a maximum of dead air cells
12. Be non-hygroscopic
13. Withstand extreme temperatures
14. Be proof against damage by steam, water, chemicals, air, rodents, etc.
15. Be comparatively cheap in cost and installation.

The first successful tests with glass wool for insulation purposes were made as early as 1904 in Bohemia (the present Czecho-Slovakia). The high qualities of glass wool as an insulating material were recognized right then, and even though the price, based on manufacturing methods [illegible] in vogue, was almost prohibitive, it sold on its sheer quality for special insulations. Before the advent of the War there were already hundreds of chemical, textile, rubber, paper factories, etc., as well as some power stations and steam ships using and specifying this material in Central and Eastern Europe. The list includes firms as the Okulowska Paper Company of Moscow, which wrote September, 1913 "....We are using glass wool on superheated steam of 680°F, and also on saturated steam lines, as well as on our boilers and vats, and it supersedes all other insulations we used...." In one of their tests with an 8-inch glass wool insulated pipe, carrying superheated steam of 630°F and with a temperature of the surrounding air of 104°F, the drop in temperature per yard of pipe length was only .46°F. The surface temperature of the insulation remained only 9°F higher than the surrounding air. In December, 1910, the Cautchouc Company of Riga, Russia confirm that they were very satisfied with the glass wool insulation on their Diesel engine exhaust pipes, stating that ".....with the motors under full load, the temperature difference between the surface and the surrounding air was only 35°C, and as you guaranteed 50°C, this guarantee has been well met. The thickness of our insulation is 70 mm. (about 2¾ inches)....." The Textile Company of the same town asserts in the same year, that ".....our glass wool insulation, which is steadily exposed to acid and water vapors is still in perfect condition...." Of the German concerns who installed this material before the War, I mention as some of the largest ones Friedrich Bayer & Company, who writes March, 1919, that ".....the insulations installed in 1910 are still in perfect order.....;" the large locomotive works of Orenstein & Koppel, the elevated Railway of Hamburg, the Royal Canning Factories of Spandau, the Wilhelmina Mine and many others.

Fig. 1.—After 12 years' service.

In January, 1921, some steam hammers of the firm of Orenstein & Koppel, whose pipes had been insulated with glass wool way back in August, 1909, were dismantled. Their insulation had been in continuous use for almost 12 years, carrying steam of 470 to 550°F, being exposed all the time to the shocks and vibration, coincident with steam hammer practice, and when this insulation was removed the glass wool was found to have retained all its good insulation qualities and resiliency. Samples of this wool were labeled and attested by notary public (Fig. 1).

In 1914 the War started, and with it an immediate and entire lack of asbestos importations for Central Europe set in, aggravated by a still greater necessity for the preservation of fuel. Glass wool, whose excellent insulation qualities were already recognized, was then called upon irrespective of cost. A firm of ship chandlers in Hamburg, who up to that time had carried a line of asbestos insulations, started to supply the rapidly growing demand for glass wool, at first employing the crude manufacturing methods then available. Gradually as they found themselves unable to comply with the steadily increasing demand, different methods to improve the manufacture were repeatedly tried, put into production and abandoned again, when better ways were discovered. In this way they covered the ground from the semi-manual making of glass wool from glass rods to present day automatic production directly from a vat of molten glass, with scrap glass as the raw material. They finally succeeded in perfecting their machinery to such an extent, that today glass wool insulation is being sold not merely on account of its superiority, but is being offered at competitive prices.

Fig 2.—Locomotive wire net mattress.

Today, only four years since industries started to readjust themselves to peace conditions, there are thousands of factories and power stations specifying and buying glass insulation. Over 10,000 German government locomotives are already carrying glass wool insulation, which is especially desirable for this service, and also countries as Spain, Holland, Denmark, Roumania, Bulgaria, Hungary, Russia, Argentine, Brazil, and others are using it for the same purpose. (Figs. 2 and 3.) Due to its lightness and high qualities this material is absolutely without peer for insulation on shipboard, and I may mention as the latest ships thus equipped the "Resolute" and "Reliance" of the U. S. Line, the "Majestic," the latest and largest (58,000 T.), White Star Liner, the "Hansa" of the Hamburg-American Line, the "Noordam" of the Holland-American Line, four ships of the German-Australian Line, at least six steamers of the South American Line, and many others. (Fig. 4.)

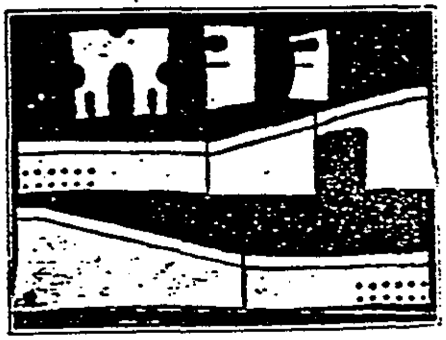

Fig. 3.—Fire box wire net mattresses.

Of the largest manufacturing enterprises using glass wool today I select the following names.

Among Power Stations:
- "Continental Rubber," Hannover
- Reichardt Cocoa, Wandsbeck
- Central Electric Station, Hamburg, etc.

Among Chemical Factories:
- German American Oil Co., Hamburg
- Dessauer Sugar Co., Dessau
- Wolfen Film Co., Bitterfeld, etc.

Among Shipyards:
- Blohm & Voss, Hamburg
- "Vulcan," Hamburg
- "Weser," Bremen
- and every other large German shipyard

On Steam Hammers
- Maschinen Werkstätte Augsburg
- Bismarkhuette, Silesia
- Vulcan Werke, Hamburg; etc.

On Locomotives and Railroads:
- Friedrich Krupp, Essen
- Borsig, Berlin
- Schwartzkopf, Berlin
- and practically all other locomotive builders

In Mining:
- Laurahuette, Silesia
- Koenigshuette
- Bismarkhuette, etc.

[illegible]any laboratory tests were made by independent and unimpeachable [illegible]orities. Professor Oscar Knoblauch of the University of Munich, [illegible]ternational authority on ther[illegible]dynamics, established the heat [illegible]ctivity per cubic meter of [illegible] wool, per one degree C surface [illegible]rence per hour, as follows:

At 0°C	0.030 Calories
At 50°C	0.037 Calories
At 100°C	0.043 Calories
At 200°C	0.056 Calories
At 300°C	0.070 Calories

[illegible] low figures have not been [illegible]ed by any other heat insula[illegible] on the market, and have been [illegible]ed repeatedly by different [illegible] and in different countries, [illegible] Professor Mitchel of the [illegible]ersity of Moscow, by the [illegible] University of Prague, [illegible] number of other high stand[illegible] institutions in Europe. These [illegible] have also been confirmed by a number of private enterprises having [illegible] own laboratories, and using glass wool insulation.

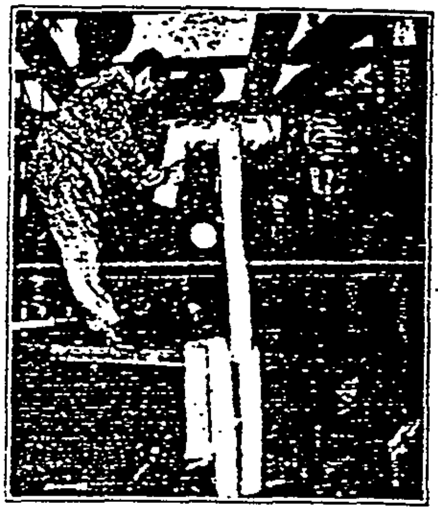

FIG. 4.—Band insulation on shipboard.

The factor of heat conductivity is the only scientific means for just comparisons and a table of curves displaying the conductivity of different materials shows glass wool insulation as the lowest curve. (Fig. 5.)

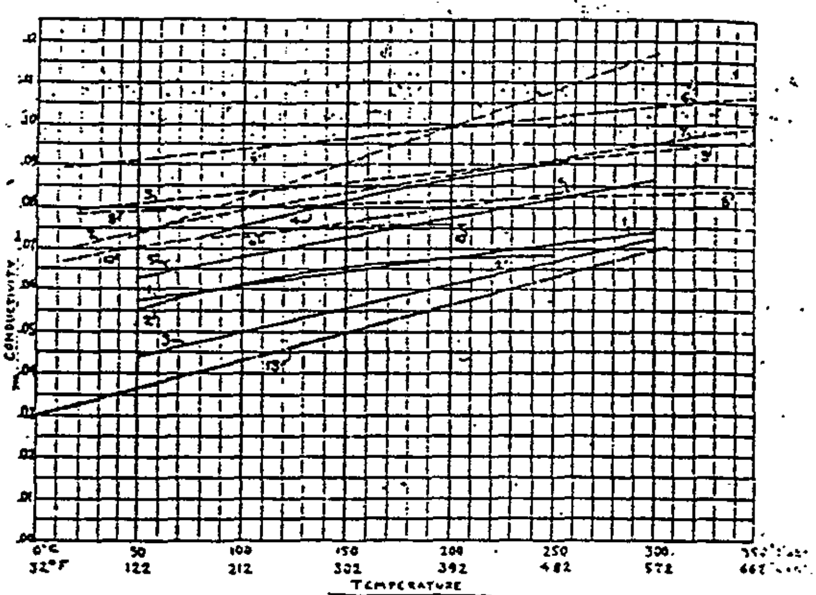

FIG. 5.—Conductivity of different materials [in calories per cubic meter per Centigrade-hour]. Curves 1 to 12 from "Forschungshefte" V.D.I. issue 228, p. 46. Curve 13 as per tests of the University of Munich [Prof. Dr. O. Knoblauch].

		Lbs./ cu. ft.
1.	Asbestos-magnesia—loose mixture,	26.3
2.	Asbestos-magnesia—loose mixture,	22.2
3.	Asbestos-magnesia—loose mixture,	15.3
4.	Asbestos-magnesia—cast slabs,	24.0
5.	Asbestos-magnesia—cast slabs,	17.7
6.	Asbestos-kieselguhr—loose mixture,	41.7
7.	Asbestos-kieselguhr—loose mixture,	39.0
8.	Asbestos-kieselguhr—loose mixture,	35.0
9.	Asbestos-kieselguhr—loose mixture,	34.3
10.	Asbestos-kieselguhr-cork—loose mixture,	20.9
11.	Asbestos-kieselguhr-cork—loose mixture,	20.0
12.	Kieselguhr—baked slab,	20.4
13.	Glass wool—band form,	13.7

Speaking practically and taking the average for the different temperatures, glass wool insulation of about 20% less thickness will replace the best grade asbestos insulations; and glass wool of about one-half the thickness will replace mineral wool. The above figures apply to plane surfaces in insulating pipes or curved surfaces. However, this difference in thick

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[1] Johns Manville Cat
[2] E. R. Weidlein, Che

ness becomes wider and wider as the diameter decreases. Materials whose conductivities stand 1 to 2 for instance, and where double the thickness of the poorer would replace a single thickness of the better insulation on plane surfaces, would differ as much as 1 to 4, even 1 to 6 and more in thickness, to result in the same amount of insulation on a curved or round surface. The above example of 1 to 6 would apply to the extreme case of a $^3/_4$-inch pipe, giving equal insulation with either $1^1/_4$-inch glass wool insulation or 10 inches insulation of the material having a heat conductivity twice as big. The cause for this steadily growing advantage of the higher grade insulating material with the decreasing size of the pipes used, is due to the simple fact, that with the necessary added thickness for the poorer material, the outer circumference, or surface exposed to the surrounding air, also increases, resulting in an additional loss of heat, and requiring again more insulation. As insulation is used more on pipes than anywhere else, the value of a high grade insulating material is obvious.

Next of importance is the lightness of glass wool, whose weight per square foot of 1 inch thickness is only 1.14 lbs., as compared with 1.47 lbs. and more for the best asbestos-magnesia insulations.[1] What this light weight means, and especially for carriers, mainly ships, may be appreciated by considering that ships of the "Sebastopol" class (Russian battleship of the 1914 period), for which I happen to have the figures at hand, could save as much as 348,450 kilograms, or about 380 tons in weight by using glass wool insulation. These 380 tons, corresponding to the combined weight of about 4500 people, mean for this ship of 460 feet length, about 4 inches less draft, which again by reducing the resistance in the water results in a saving of coal.

Glass wool's mechanical strength and flexibility as compared with other insulating materials should not require scientific tests for anybody who ever handled or saw the materials. However it may be stated that 85% magnesia, asbestos claims a crushing strength of 100 lbs. per cubic inch,[2] which means 100 lbs. gradually applied and without shock, and though I have to admit that no laboratory figures are available on the crushing strength of glass wool, it may be comfortably tested by any heavyweight by simply stepping or jumping on it. This test will break a few of the longer fibers into shorter pieces, without impairing the insulating qualities.

Heat is being transmitted in three ways: by conduction, convection and radiation. Glass wool is the only insulator to meet all three. The first by its low conductivity, the second by the millions of dead air cells, preventing circulation, and the third by the reflection of the heat waves by each one of the silvery, smooth and shiny threads of glass.

[1] Johns Manville Catalog.

[2] E. R. Weidlein, *Chem. & Metal Eng.*, vol. 7.

As one cubic foot of glass wool weighs about 13.8 lbs. and as the average glass may weigh about 156 lbs. per cubic foot, about 90% of a given volume of glass wool is taken up by dead air cells.

Glass has been used long enough in chemical industries so that its favorable behavior in this respect does not require further comment. As we also know, it is resistant to moisture and air, and is non-hygroscopic.

Surprising, however, is the resistance of glass wool insulation to temperatures far over the melting temperature of glass, and where other high grade insulating materials deteriorate very quickly. Glass wool when so exposed will bake and even melt for about 1/8 inch and sometimes 1/4 inch right next to the overheated surface, and where it is in direct contact with the red hot iron. The fibers, however, behind this baked wall will remain unaffected and continue to give perfect and permanent insulation. This baking may begin at temperatures as low as 1200° to 1500°F, depending on the hardness of the glass used. A baking of this kind takes place for instance on the exhaust pipes of heavy oil engines, where this material has proved to be the only suitable one. These exhaust pipes are continuously red hot and burn out periodically. Whenever such a pipe had to be replaced, the glass wool was found to be in perfect condition and pliable, with the exception of the thin baked layer right next to the pipe. How confident the manufacturers of this glass insulation are in this resistance to high temperatures is shown by the fact that they are now recommending it for the outside insulation of industrial furnaces for the melting of iron and metal.

649°C

815°C

The early methods of manufacturing glass wool were very crude and simple. The workman melted the tip of a glass rod over a gas flame, seized with another glass rod the forming drop, and threw it, with a quick twist of his hand, over a rotating drum, foot-operated by himself.

The first machines introduced, and those available when the War started, held a number of glass rods clamped in a horizontal position, feeding them gradually into a gas flame, at the same time turning them slowly, to provide for an even heating. (Fig. 6.) The work of the spinner merely consisted of drawing the forming drops over to the continuously revolving drum, by means of a glass rod. He had to renew the tearing threads in the same manner, and also stop the machine to renew rods that had been consumed, except for the short stub remaining inside the clamp.

The biggest advance in spinning was made by the very obvious and long delayed improvement of placing the revolving drum underneath the falling glass drops, thus doing away with the labor of continuously conveying and fastening glass drops to the drum. (Fig. 7.) This simple improvement proved to be so basic in the art, that very strong patents were obtained on this feature. The drops now fell automatically, by gravity, on to the drum, drawing the glass threads after them, and also removed the threads, when any of them broke. The drops themselves were thrown off by the centrifugal force of the turning drum, which retained only the pure and light wool. All the spinner had to do was to renew the glass rods, when consumed, and regulate the flames. One spinner was now able to watch three or four times the number of threads as before, with the drum ahead of him.

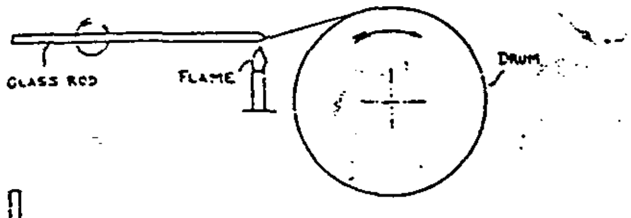

FIG. 6

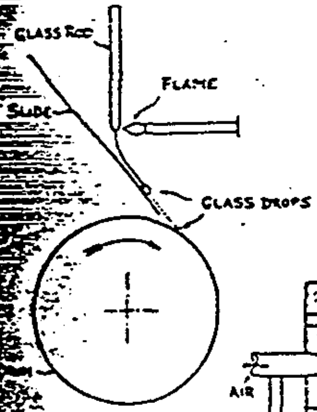

FIG. 7

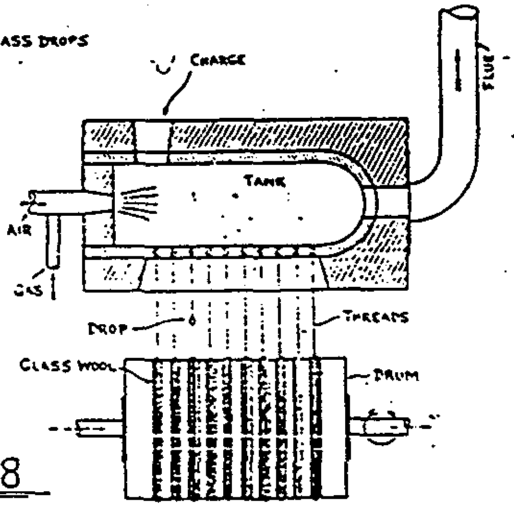

FIG. 8

As the cost of thin glass rods in Europe in pre-war times was about [illegible] cents per lb. whereas scrap glass had a market price of about $1\frac{1}{2}$ c., it was attempted very early to make glass wool directly from the molten glass, without the necessity to produce or buy glass rods first. Many methods were tried and abandoned, until at last the present way of using vats, containing the molten scrap glass, and provided with small openings at the bottom end was successful. From these openings the glass drops emerge, falling on to the drum below, and drawing the threads after them. (Fig. 8.)

Sometimes these openings are separately heated by an electric coil or gas flame, and sometimes air pressure is put above the molten mass. There are still smaller improvements possible no doubt, but these machines are working now and producing continuously, and the making of glass wool from rods has been abandoned entirely about a year. The factories, though they can not be called large establishments according to our standards, are now producing an average of more than 8 lbs. of wool per employee-hour, mostly girl labor being employed.

When one drum is loaded with glass wool, it is stopped and the wool cut off and removed. The product is then carded and loosened up, a very simple process, but still performed by hand in a country where the necessity of economizing with labor has not quite reached our standards. (Fig. 9.)

Fig. 9.—"Carding."

Quite manifold are the ways in which glass wool is applied as insulation. The most commonly used form is in the shape of bands about $^3/_8$ inch to $^1/_2$ inch in thickness and a width of from two to ten inches. This insulation weighs about three to four pounds per square yard. The loose and carded glass wool is put upon a table, mostly upon a sub-foundation of paper, burlap, or wire mesh, and run through sewing machines, which sew rows of stitches about $1^1/_2$ inches to 2 inches apart into the wool sheet. The glass mattress is then run through cutting machines, cutting the bands to the desired width. In applying this insulation, these bands are simply wound spirally around the pipes in one or more layers. (Fig. 4.) The insulation may be finished off on the outside by bandaging and painting in customary manner, if so desired. When larger surfaces and not pipes are to be insulated by this method, the mattresses are not cut into bands but trimmed to the size required. (Fig. 10.)

Larger pipe lines and objects are often insulated by first surrounding them with coarse wire mesh, distant from the object, to represent the outer line of the finished insulation. The glass wool is then simply stuffed in between the wire mesh and the body to be insulated. (Fig. 11.)

The highest grade insulation, and the one used exclusively on locomotives, boilers and other objects, where the insulation has to be removed at intervals to make inspection and repairs on the machinery or boilers, is made in the following way. From a drawing or sketch two templates are cut out of wire mesh of the weave of narrow chicken wire. Next these two templates reach an operator, to whom also a certain amount of glass wool, figured in so many pounds to the square inch, is allotted. In the above process about 1 to 2½ lbs. per square yard are figured, depending on the quality of insulation desired. The girl distributes the glass wool received evenly over one of the templates, covers the whole with the other template, and crimps the edges. On large surfaces she may crimp a few wire staples through the center. The mattress is now ready to be fastened to the object to be insulated, can be removed whenever required, and will stand all kinds of rough usage. (Figs. 2 and 3.)

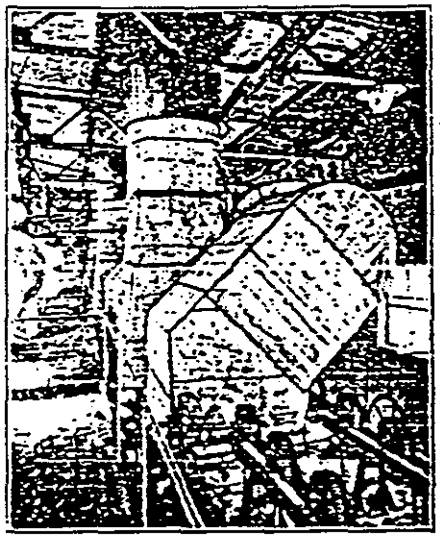

FIG. 10.—Sewed mattresses.

Glass wool is now being manufactured in considerable quantities and economically. The German factories in Hamburg, which have enlarged to several times their original size, have been working on three 8-hour shifts since 1918. A large new factory for the production of glass wool is under construction in Dresden, Saxony, where every furnace will feed three vats of two hundred openings each. It is estimated from present production figures that about 6300 lbs. of wool would be produced in 24 hours working time. The help required would be two spinners, one melter and one helper per furnace, which would result in an output of almost 70 lbs. per man per hour.

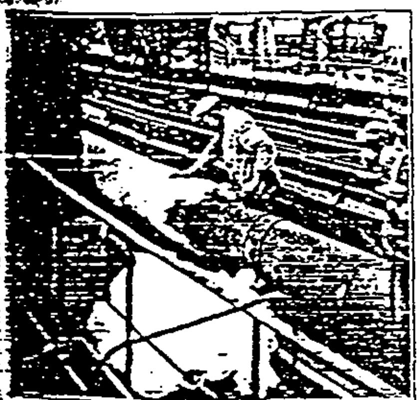

FIG. 11.—"Stuffing" glass wool.

It would be preposterous for me as a layman in glass generally, to attempt estimating the American costs for the manufacture of glass wool. The more so as the German costs, with the constant rise and fall of the mark, and the daily changing wages, can hardly be used as a base. The fact is that the German manufacturers themselves can not establish their present costs, nor can it be established for them by any accounting method in captivity. The amount of labor required to produce a pound of wool has been stated above. The fuel consumption is 32 cubic feet of artificial gas per one pound of glass wool. The wastage of material in the shape of drops, etc., amounts to about 10%, which waste is remelted in the next load or in a smaller furnace. The manufacturers of glass wool, setting their material as the most important item at 100 units, figure their labor at 40 units, and their overhead again at 40 units of their total cost. Translated into our usage this means 100% overhead, based on labor. Faced by the impossibility of establishing his exact cost, the German manufacturer plays safe by fixing his selling price in foreign exchange, preferably *dollars*, and based on this dollar price makes his quotations in marks, according to the exchange value on the day of sale, or still better, the day of delivery. Glass wool insulation is selling for 12 cents per lb. in competition with the highest grade imported insulations. From what I have seen and heard I would reservedly place the manufacturing cost today at about $2^1/_2$ to $3^1/_2$ cents per pound.

Several patents were obtained during the development of the manifold processes and machines. All thinkable possibilities were tried, out of which the present machines finally crystallized. This process of producing glass wool directly from a molten mass of glass is new, and has been well protected in all civilized countries. The number of the American patent covering this feature is 1,427,014.

European glass manufacture of the type produced by machinery has never been able to gain a strong foothold in our country. As far as glass wool is concerned, the German manufacturers realize that introducing a new line like theirs into the vast field of heat insulation could not be done in a small way in U. S. A., and establishing branches, advertising and paying for these and other incidentals of pioneering in foreign currency constitutes an utter impossibility for them.

Born under the pressure of the past War, glass wool heat insulation is one of the very few inventions and substitutes of war times, which have proved valuable, and therefore have survived peace. Now that glass wool is available in quantities and cheaply, new fields besides insulation will probably be opened to this product as the years go by. But as far as insulation is concerned, there is no doubt to my mind, from what I have seen, heard and investigated as an engineer, that glass wool is the coming heat insulation, and coming fast.

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