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Mineral Wool and Vermiculite as Insulation

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The relationship of thermal insulation to air-conditioning is discussed. The contributions of the newer types of insulating materials (developed during the past five years) to better the art of living are shown. The characteristics of various insulation materials for both domestic and industrial insulating purposes are described and their physical properties compared.

INTEREST in thermal insulations should be universal, whether from a domestic standpoint, which involves one's comforts throughout the year, or from an industrial standpoint, since every one engaged in industry is decidedly concerned with the control of temperature and heat flow. The obvious reason for domestic insulation is that of comfort and a saving of money in the heating of our homes. From an industrial standpoint the use of thermal insulations is to prevent the escape of heat, which is a direct loss in dollars. A reason which is less obvious, but is often of as great importance, is the fact that a well-operated plant depends to a large extent on the accurate control of temperature, since the tendency is toward chemical processes where definite temperature control is required. Where conditions are such that temperature fluctuations are due to the cooling of heated surfaces, proper steps must be taken to reduce such heat variations to a minimum.

The insulation industry has been particularly active throughout the depression in not only developing new thermal insulations, but likewise in improving those materials which had been used in the saving of heat loss prior to that time.

Air-conditioning has come to the front rapidly. One of the most important needs in proper air-conditioning is that of thermal insulation. The insulation industry has kept pace with the needs of air-conditioning so that even now it is in an advanced state both in the building industry and in general industrial work. Today the training of a graduate in chemical engineering must include a study of thermal insulation since that subject is of as great importance to the chemical engineer as evaporation and distillation.

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Insulation in Air-Conditioning

Percy Walker of the Bureau of Standards has stated that the greatest single development which will come out of the depression will be air-conditioning: "Air-conditioning at the present time is in its infancy and there will be as much improvement in the next century in purifying the air we breathe as has been accomplished within the last century in purifying the water we drink." In other words, he believes "that the inhabitant of our cities a hundred years hence will demand clean air not only in his house but on the streets just as we demand clean, wholesome water delivered in our houses, whereas our ancestors of a hundred years ago used any water that was available without any real care to see that it was wholesome."

Faced with a situation where the public is definitely becoming more insulation-minded, both from a domestic and an industrial standpoint, it is only proper to follow some of the advances which have been made during the past five years on this important engineering subject. The art of living has been materially bettered since thermal insulations have begun to play such an important part in the comfort of homes, offices, and places of entertainment. It is today almost an economic impossibility to operate a theater or restaurant during the summer months unless it is air-conditioned and properly insulated.

The American Iron and Steel Institute estimates that the installations of air-conditioning equipment in 1934 required 28,000 tons of steel and it was the forecast that the 1935 demand would be double that amount. The demand within the next 10 years was estimated by the institute as 450,000 tons of steel annually.[2]

Domestic insulations can be divided into three divisions:

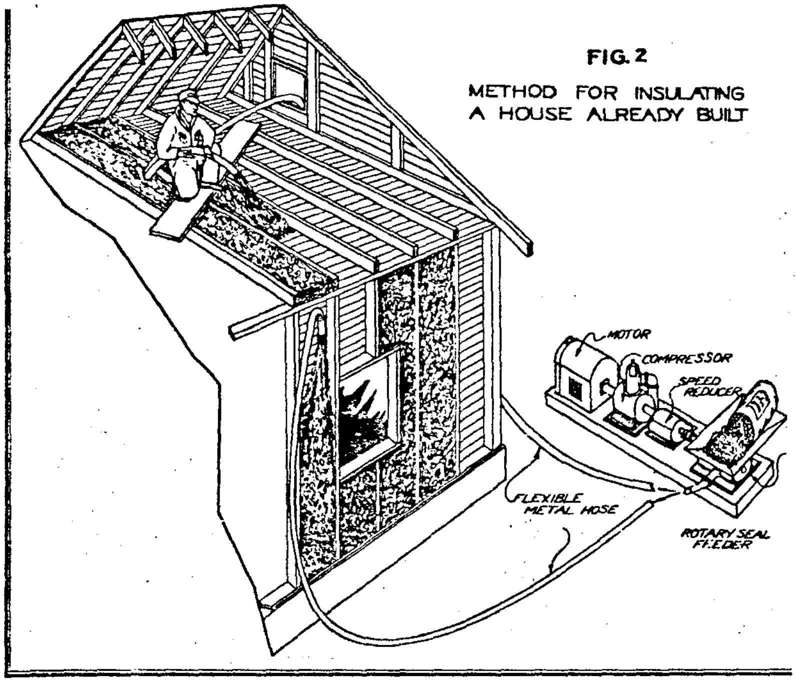
1. The application of loose-fill insulation materials to buildings already erected.
2. The installation of insulation material in the form of bats between the studding in the walls of new houses or buildings which are being erected.
3. The use of insulation board, applied either while the house is being built or after it has been built.

Although several different types of loose-fill insulation materials have been employed for insulating buildings which are already standing, the greatest advance has been made in the use of mineral wool for such purposes.

[2] Data obtained from the St. Louis *Globe Democrat*, February 20, 1935.

A. Loose: Used as loose fill on boiler and furnace walls, fireless cookers, ovens, and home insulation.
B. Granulated: used as loose fill for home insulation, ovens, and furnace walls.

FIGURE 1. MINERAL WOOLS: WEIGHT, 8 POUNDS PER CUBIC FOOT; THERMAL CONDUCTIVITY, 0.27



Mineral Wool Insulation

Chemically, mineral wools are calcium silicates or calcium-iron silicates. They are made by melting the silicates in a short cupola furnace, using coke as the fuel with the addition of lime or iron in proper proportion to yield a fusion which is easily fusible. The molten material issues from a small hole at the bottom of the furnace. The stream of molten material is blown into fibers by a jet of high-pressure steam. These fine fibers are collected by settling in large chambers from which they are periodically removed for further processing. When the silicates are derived from native rock, the wool produced is designated as rock wool (calcium-magnesium silicates) with properties similar to mineral wool.

The properties which make mineral wool (Figure 1A) unique in the field of domestic insulations are its low conductivity (0.27 at room temperature), its ability to withstand high temperatures, and its stability. This material is practically unattacked by dilute mineral acids or alkalies. Sulfur dioxide and other corrosive gases have but little effect on it. It retains its original form and has good insulating value up to its fusion point of 1800° F. This material is probably the only insulating material which combines low conductivity with ability to withstand elevated temperatures. Basic magnesium carbonate dehydrates and calcines when heated. Asbestos, which has a rather high conductivity, decomposes because of dehydration upon heating. The animal and vegetable products cannot withstand high temperatures, since they burn and are completely destroyed.

The problem of using this desirable insulating material in buildings already erected developed slowly but in such a way as to be highly efficient. For domestic insulation, mineral wool is nodulized by shredding the loose mineral wool and rolling the shreds into small pellets. In the nodulized or granulated form (Figure 1B), mineral wool is well adapted for blowing into the space between the studding in buildings which are already erected. Figure 2 shows the method of using nodulized or granulated mineral wool in insulating a building. The nodulized mineral wool is fed into a blowing machine and is then carried by compressed air to the place to be insulated. The mineral wool settles to its natural density with a thickness of 4 inches. The attic of a dwelling is insulated in the same manner. Because of the very low conductivity of mineral wool, a 4-inch layer is ample for proper insulation.

Figure 3 shows the difference in the physical characteristics of glass wool and mineral wool. The glass wool consists of long, comparatively thick fibers, whereas the mineral wool contains very fine threads admixed with larger fibers, scarcely any of which has the diameter size of glass wool. Glass wool is also rather brittle and tends to break on handling.

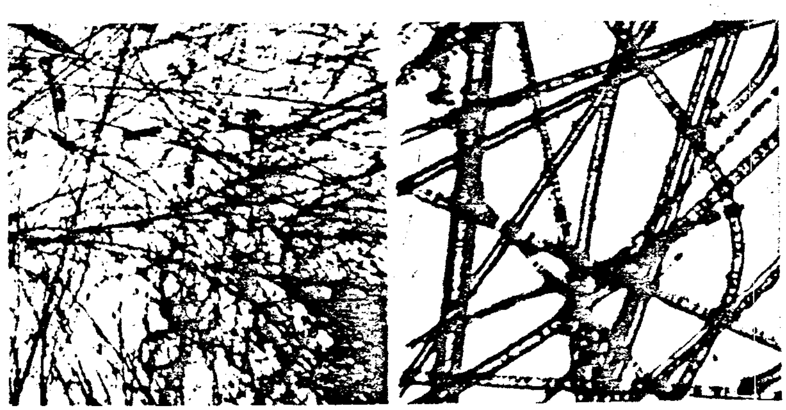
In insulating buildings during their construction, a different procedure is followed. Here it is far more satisfactory to use mineral wool formed into a bat (Figure 4) of the proper size, usually 15 inches × 18 inches × wall thickness and weighing 8.0 pounds per cubic foot. The insulation bats are placed in the space between the studding before the lath and plaster are applied. This gives a perfectly insulated wall.

The same practice is used in insulating the attic, which is of great importance. A house so treated is cooler in summer, warmer in winter, and sound-proof to a certain extent, and can be maintained at a comfortable temperature in winter with an actual saving of 20 per cent in fuel. Its greatest convenience is in the summer months, since buildings can be kept warm in winter but cannot so successfully be kept cool in summer. The attic is the worst offender because in the daytime it stores up a large supply of heat which it dissipates to the rooms below during the night.

The use of insulation board, either applied after a building has been erected or during the process of erection, is not considered as highly efficient as the other methods of insulation. It is difficult to obtain a proper thickness of requisite insulation when insulation board is used. Certain insulation boards, however, have a rather low heat conductivity; for example, vegetable fiber board has a conductivity of only 0.33.

It has been predicted that within five years practically no modern homes will be erected which are not insulated, if not entirely air-conditioned. The same will also hold true for office buildings.

While we find mineral wool being most largely used in the insulation of buildings, it has other important applications. Mineral wool serves as the raw material for the manufacture



A. Mineral wool *B.* Glass wool

Figure 3. Photomicrographs of Fiber (× 52)

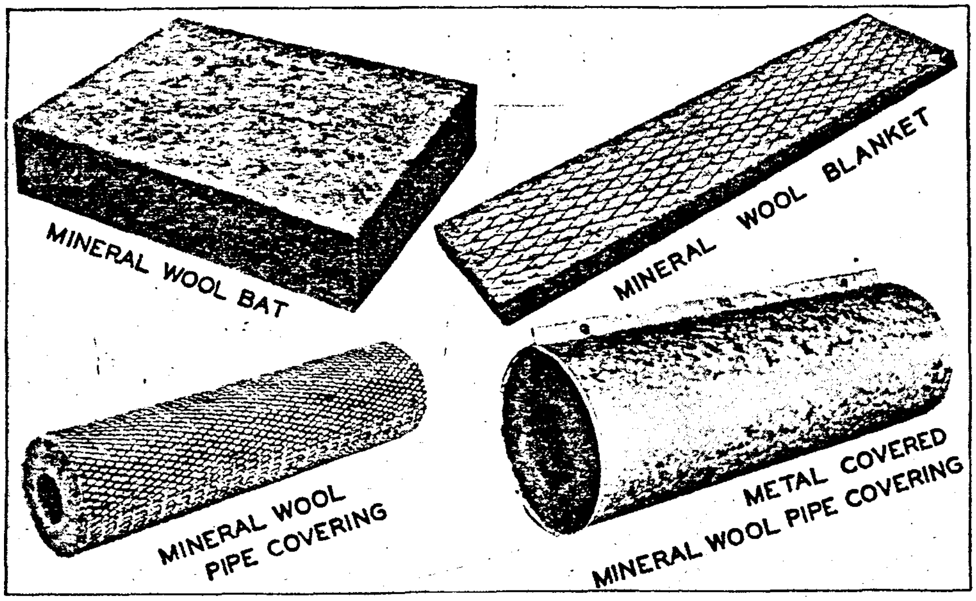


FIGURE 4. FORMS OF MINERAL WOOD INSULATION

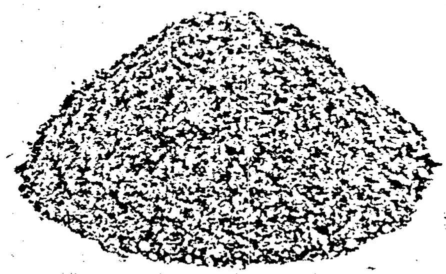


FIGURE 5. MINERAL WOOL CEMENT

of blankets (Figure 4), used to insulate furnace and boiler walls, bubble or clay refinery towers, and any flat or slightly curved surface. Pipe covers (Figure 4) consist essentially of mineral wool felted between various metal fabrics, and are used for insulating pipe lines exposed to weather. The important feature of such fabrication is the fact that, since no binding agents are added, the low conductivity of the wool is not impaired. Such fabricated products are used extensively in insulating high-pressure steam lines, oil refinery lines, furnace and boiler lines, and many flat or curved surfaces. They have the added advantage of being rather light in weight and of successfully withstanding moderately high temperatures. For these uses, mineral wool blankets and pipe covering are superior to 85 per cent magnesia blocks and pipe covering because they are able to withstand much higher service temperatures, and at the same time have lower thermal conductivity.

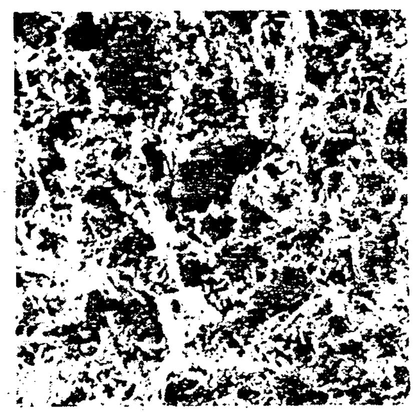


FIGURE 6. PHOTOMICROGRAPH OF MINERAL WOOL CEMENT (× 2.2)

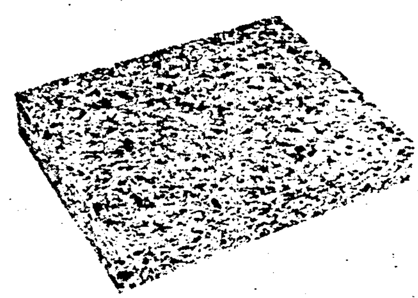


FIGURE 7. MONOLITHIC MINERAL WOOL CEMENT USED FOR INSULATING IRREGULAR SURFACES, FURNACE AND BOILER WALLS, PIPE LINES, AND PRESSURE KETTLES

Mineral Wool Cement

Another important use for mineral wool is that of serving as the basic raw material for the manufacture of mineral wool cement (Figure 5). Such cement has as its base granulated or nodulated mineral wool, mixed with long-fiber asbestos and bonded with a suitable binder, usually clay. When mixed with water to the proper consistency, it can be readily applied to either hot or cold surfaces. Its greatest advantage is its convenient form since it can be readily applied to any irregular-shaped body, such as furnace and boiler walls and will dry to a monolithic coating. The cement consists of small nodules of wool fiber surrounded by a binder. None of the binder appears to penetrate the wool nodules so that the original good properties of the wool are preserved in the dried cement. Such insulating cement has a weight per cubic foot of 35 pounds, yet has a thermal conductivity value of 0.6. There is quite a tendency towards the use of such cements for monolithic insulations. As its name implies, it gives one continuous coating and thereby eliminates the escape of heat through joints such as would be found in an insulation built up of blocks and similar forms.

The illustrations, showing the structure of the cement itself after application (Figure 6) with a magnification of 2.2 diameters and (Figure 7) as a dried block, clearly reveal the character of the cement after it has been dried.

A definite method has been worked out for the application of highly efficient insulating materials where insulations must be applied where exposed to the weather. The proper method of insulating such equipment is to use first a mineral wool blanket and then to apply a thin layer of mineral wool insulating cement. This insulating cement is in turn protected from the weather by an asphaltic weather-proofed material which yields a permanent installation. Figure 8 shows a cross section of such an installation. This method of insulation is highly efficient, for the heat is retained by the original mineral wool application (with a thermal conductivity of 0.27) and the insulating cement aids in preventing heat loss and provides a base for the final weather-proofed layer.

Vermiculite

A new type of insulation material has come to the front rapidly during the past five years. This material, which is used as a base for many insulation products, is the mineral vermiculite. It is a micaceous, alteration product of biotite, which is found rather widely distributed throughout the United States, and has the peculiar property of expanding rapidly when subjected quickly to high heat, because of an almost immediate expulsion of water of constitution. Figure 9 shows the volume increase upon heating (the two quantities shown have the same weight). It is not unusual to find vermiculite which will expand from fifteen to eighteen times its original size. The insulating value of vermiculite depends largely upon the degree of exfoliation which will take place upon furnacing. Such expanded vermiculite adapts itself well to the manufacture of insulation products. It has a thermal conductivity of 0.48. Its weight per cubic foot of a medium sized product is between 6 and 8 pounds. It does not decompose readily when exposed to heat and is suitable for use as a base material in products which must withstand temperatures up to 2000° F. While used as a raw material for the insulation of dwellings, it is not quite as effective as mineral wool because of its higher thermal conductivity. It serves well as a base for the manufacture of insulating pipe coverings for high-pressure and oil refinery lines, and insulating blocks (Figure 10), particularly those subjected to a high temperature, such as insulation for furnaces, oil towers, and other flat or slightly curved surfaces. Such blocks and pipe coverings are made with vermiculite as the base material, asbestos fiber, and a suitable binder. They have a thermal conductivity of 0.65.

Insulating bricks made from vermiculite are used extensively in industrial operations. The bricks are of two types. The light-weight type is made purposely to obtain the lowest possible conductivity by sacrificing structural strength (Figure 10). Such brick are used largely in open-hearth furnaces over arches where no structural strength is required, particularly where the brick must be used repeatedly. The weight per standard brick is 24 ounces, and the thermal conductivity is 0.7. Where strength is needed in a vermiculite brick, it is always necessary that heat conductivity be sacrificed since it is impossible to maintain low heat conductivity with high structural strength. To produce such high-strength brick (Figure 10) a binder has to be added. These brick can be used for building purposes, such as insulation for furnace walls where structural strength and fairly low conductivity are required to replace ordinary brick which have a rather high heat conductivity. The weight per standard brick is 33 ounces and the thermal conductivity is 0.80.

Another type of insulating brick (Figure 11) has only recently been developed. The principle involved is to create voids in the brick itself, thereby lowering conductivity without great loss of strength. The same ordinary materials are used as are utilized in the manufacture of fire brick, and are admixed with certain organic substances which volatilize at moderate temperatures. After the brick are made, through the process of firing, the volatile constituents disappear and leave voids in the brick. Because the base for making such brick is highly refractory material, the brick will withstand as high temperatures as are found in fire brick of the ordinary type (up to 2600° F.). Here again structural strength is sacrificed to gain lower heat conductivity, but the brick is sufficiently strong for industrial purposes.

Table I gives data from standard authorities to show the density and conductivity of certain insulating and building materials.

Figure 12 shows the value K (thermal conductivity factor) for a number of building materials which are used today for both insulating and building purposes. Figure 13 shows the density of various insulating materials in pounds per cubic foot. Comparison of Figures 12 and 13 shows that certain materials of low conductivity have a high density. This comparison is of interest since it has been the general conception that low density per cubic foot is always accompanied by low conductivity.

Figure 14 is a three-dimensional chart based on mineral wool where the thermal conductivity is a function of density and temperature. The conductivity of insulating materials

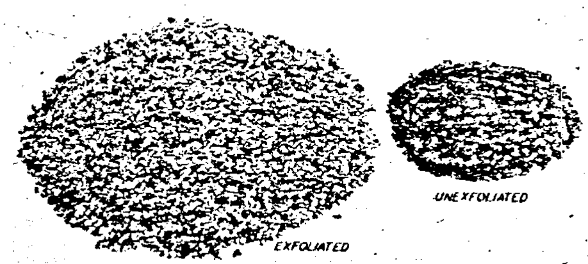


FIGURE 9. VOLUME INCREASE OF VERMICULITE UPON HEATING

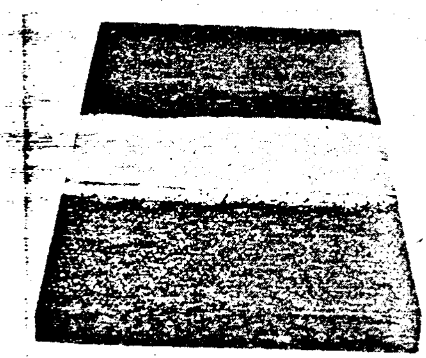


FIGURE 8. TYPICAL INDUSTRIAL APPLICATION OF MINERAL WOOL INSULATION

Bottom layer, blanket insulation; center layer monolithic wool cement; top layer, asphaltic weather-proof coating

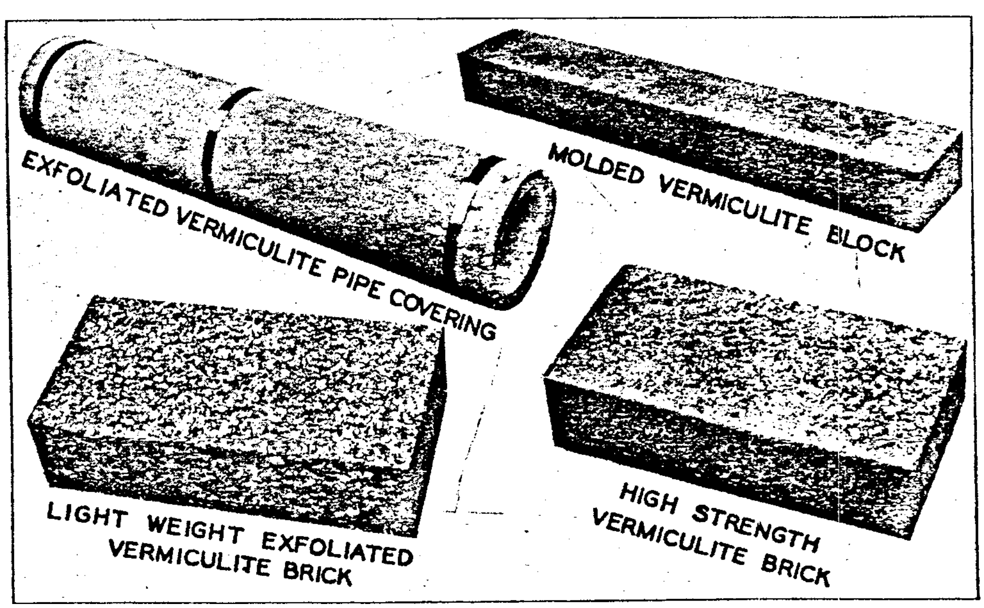


FIGURE 10. FORMS OF VERMICULITE INSULATION

is naturally affected by the density of the product as well as the temperature at which the thermal conductivity determination is made. On such a three-dimensional graph the conductivity of mineral wool can be plotted packed to any given density and dependent upon any given temperature; the optimum packing required to obtain the minimum conductivity for a given temperature can be determined.

A three-dimensional graph of this type can be used for comparative purposes in determining the thermal conductivity as a function of the density and mean temperature; Figure 15 shows the relationship between mineral wool and glass wool. The upper surface is the three-dimensional graph for glass wool, and the lower surface is that for mineral wool.

Table I. Density and Conductivity of Insulating and Building Materials

Material	Density	Mean Temp.	Conductivity, K	Authority
	Lb./cu. ft.	*° F.*	*B.t.u./hr./sq. ft./° F./in.*	
Balsam wool	3	...	0.255	Weiss[a]
Felted cattle hair	11	90	0.26	Bur. Standards[b]
Loose mineral wool	8	103	0.27	Bur. Standards[c]
Rock wool (fibrous material made from rock)	10	90	0.27	Bur. Standards[b]
Diatomite, in powder form	10.6	86	0.308	Bur. Standards[d]
Cork, regranulated	8.1	90	0.31	Bur. Standards[b]
Fiber board, from sugar cane	13.5	70	0.33	Peebles[e]
Vermiculite, exfoliated	8	100	0.48	Research Lab., Eagle-Picher Lead Co.
Corrugated asbestos board	20.4	110	0.48	Willard, Litchy, Harding[f]
85% magnesia–15% asbestos board	19.3	86	0.51	Bur. Standards[b]
Wood (white pine)	31.2	86	0.78	Bur. Standards[b]
Brick, common	..	...	5.00	A. S. H. V. E. Guide, 1935[g]
Concrete, typical	..	...	12.00	A. S. H. V. E. Guide, 1935[g]

[a] *Chem. & Met. Eng.*, **29**, 534–7 (1923).
[b] Tests based on samples submitted by manufacturers as shown in American Society of Heating and Ventilating Engineers Guide, 1935.
[c] Direct communication.
[d] Report of the American Society of Refrigerating Engineers Insulation Committee A. S. R. E. Circular No. 1.
[e] Tests conducted at Armour Institute of Technology, based on samples submitted by manufacturers.
[f] Tests conducted at University of Illinois.
[g] Recommended conductivity for computing heat transmission coefficients.

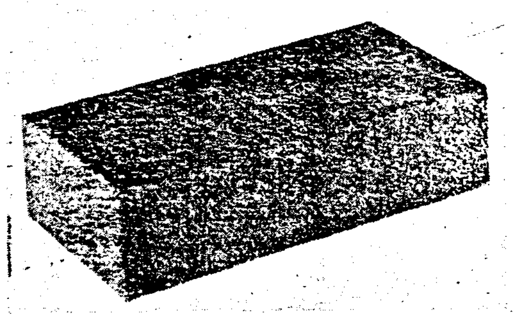


Figure 11. High-Refractory Insulating Brick

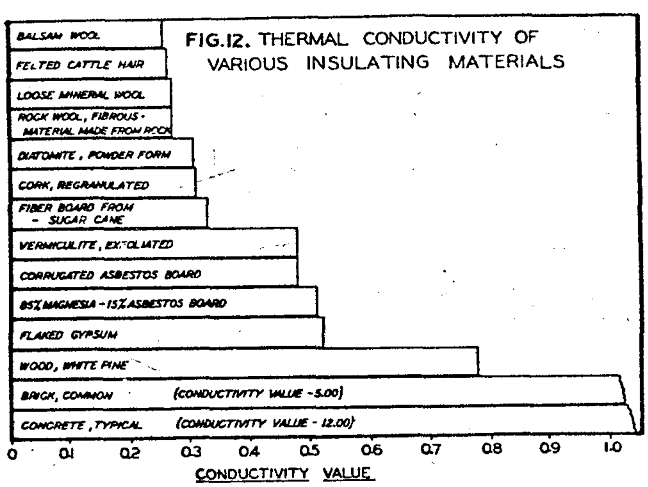


FIG. 12. THERMAL CONDUCTIVITY OF VARIOUS INSULATING MATERIALS

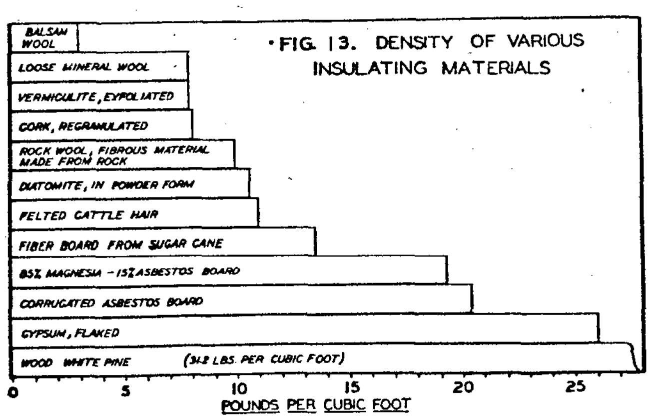


FIG. 13. DENSITY OF VARIOUS INSULATING MATERIALS

The photomicrographs of Figure 3 show that because of the larger fiber size of glass wool, larger air cells are present than are found in the smaller fibered mineral wool. This characteristic is also exemplified in Figure 13 where the coarser fibered glass wool, even at a lower density, shows a higher conductivity than mineral wool. It is particularly noticeable that conductivity increases rapidly with increase in temperature in the case of the glass wool. The reason is that convection within the air cells plays an important part as the conveyor of heat through the material, particularly at elevated temperatures.

By taking a given density of 5 pounds per cubic foot and a mean temperature of 220° F. in both the case of glass wool and mineral wool, Figure 13 shows that the thermal conductivity of the glass wool will be approximately 0.5, whereas in the case of mineral wool at the same density and mean temperature a thermal conductivity of approximately 0.4 is obtained.

Using the same densities with a mean temperature of 420° F., the mineral wool will have a thermal conductivity of approximately 0.63 as compared to approximately 0.97 for glass

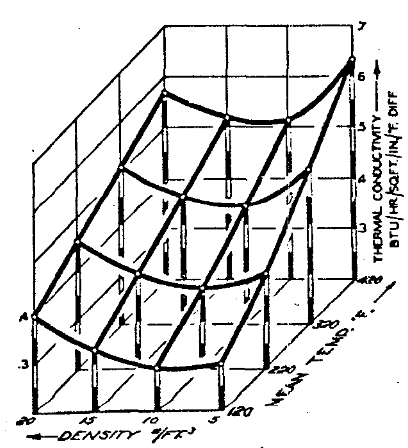


Figure 14. Three-Dimensional Chart Showing Conductivity of Mineral Wool as a Function of Density and Mean Temperature

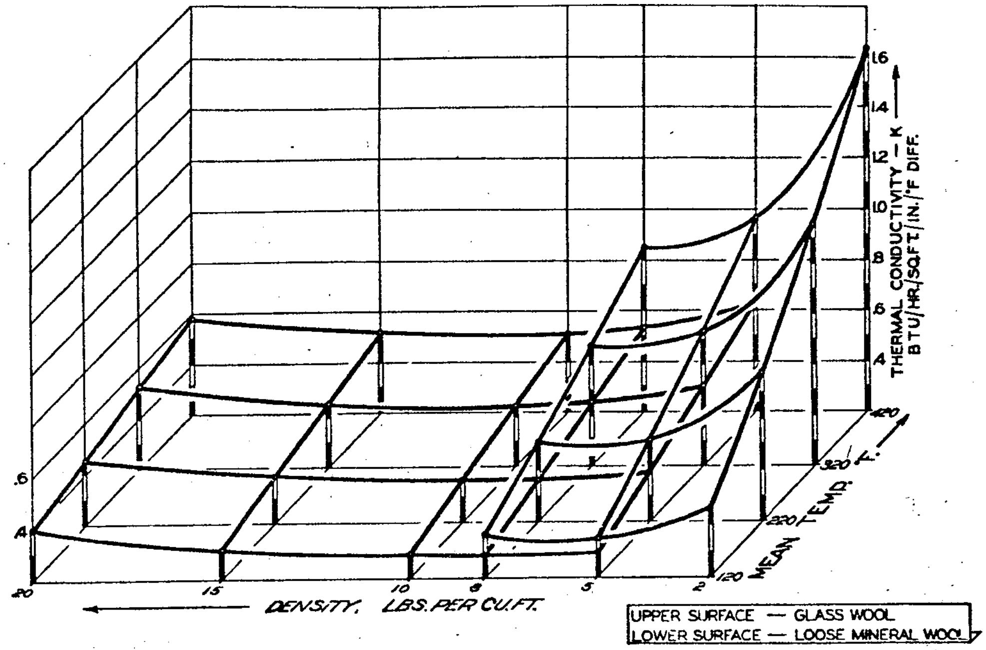


FIGURE 15. THREE-DIMENSIONAL CHART COMPARING MINERAL WOOL WITH GLASS WOOL AND SHOWING CONDUCTIVITY AS A FUNCTION OF DENSITY AND MEAN TEMPERATURE

wool. This clearly illustrates the effect of convection in the larger air cells found in glass wool.

It is difficult to cover even partially the field of thermal insulations in a paper of this length. All that can be done is to stimulate interest in thermal insulations as a necessary adjunct to the building industry, both from a domestic and an industrial standpoint. The fact that these industries are growing so rapidly makes it imperative that engineers and architects be familiar with this field. So many data have been published on the subject of thermal insulations that it can be called a definite branch of engineering.

RECEIVED April 27, 1935.

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Preservatives and Antitermite Protection of Timber

C. DEMERE

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Some new wood preservatives and a new method of applying these preservatives to the wood have resulted from recent research and development work. These new preservatives are designed to meet the requirements of those phases of building which are not satisfactorily served by other preservatives and methods of application. This brief summary has not attempted a detailed treatment of the numerous considerations involved in the development of improved wood preservatives but has endeavored to show what one group of investigators is doing to solve the problems involved.

A NUMBER of wood preservatives, such as creosote and zinc chloride, are excellent for outside use for treatment of crossties, bridge timbers, poles, etc., since they are cheap and effective. The field for new preservatives has its basis in the limitations of these old types. Creosote's limitations are its persistent and sometimes objectional odor, the fact that its fumes under certain conditions may be injurious to human health, its discoloration of the wood, and the difficulty of painting wood after treatment with creosote. Zinc chloride and other preservatives of the same general type use water as a carrying agent. The application of water causes wood to expand and become distorted and, when it is dried to the moisture content satisfactory for use, the grain tends to raise, the wood tends to check and warp, and some woods become discolored.

The need for new preservatives for use in the building industry is most clearly recognized in the field of home construction and for certain uses in other building construction, packing houses, dairy buildings, farm buildings, textile plants where the humidity is high, and refrigerator, box car, and automobile construction, etc.

A program of research, which has resulted in the development of a series of new preservatives, was begun by the laboratories of the E. L. Bruce Company in 1927. After careful study it was decided that a preservative to meet the