Sept. 3, 1946. T. M. ELFVING 2,406,815

MULTILAYER INSULATION

Filed July 9, 1943

Fig. 1.

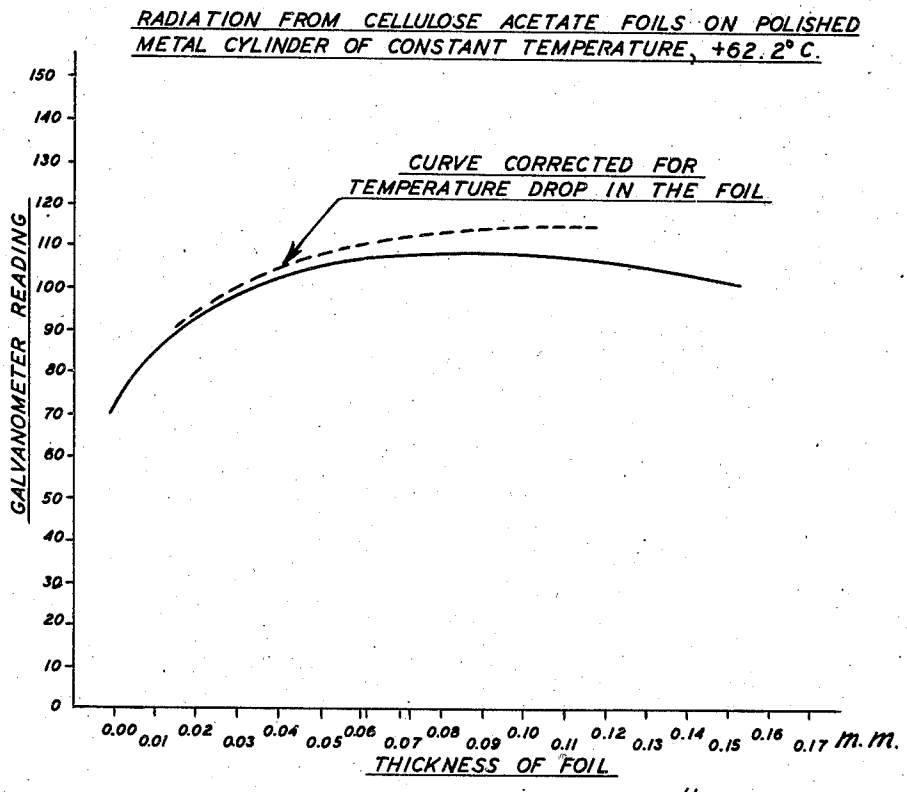
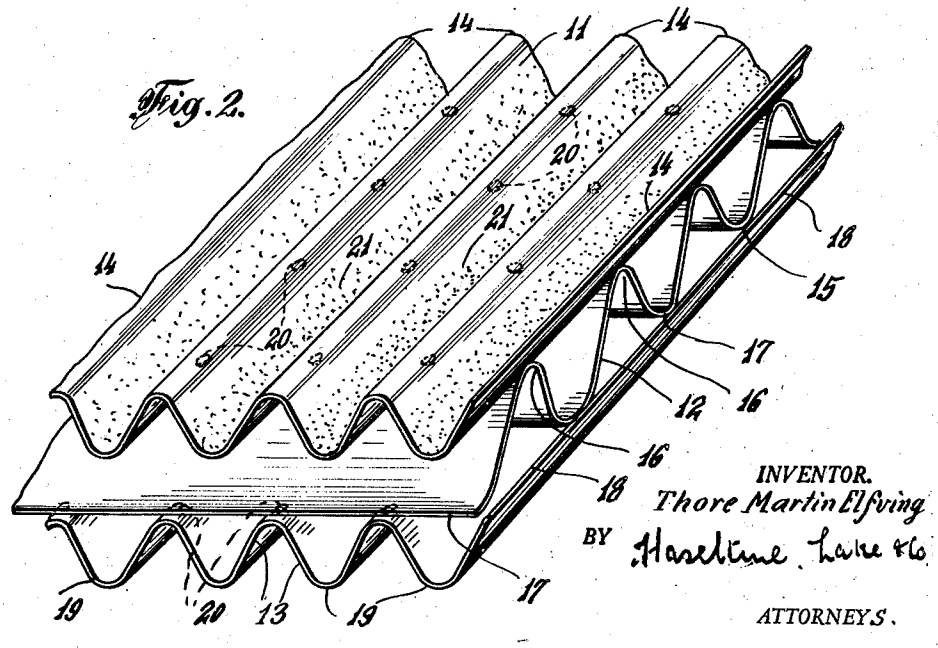


Fig. 2.



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MULTILAYER INSULATION

Thore Martin Elfving, Nockeby, Sweden

Application July 9, 1943, Serial No. 494,013
In Sweden January 10, 1938

6 Claims. (Cl. 154—45)

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This application constitutes a continuation-in-part of my application, Serial No. 204,603, filed April 27, 1938.

The present invention relates to heat insulations in the form of boards composed of foils separated by air intermediate spaces. The boards are made either of plane foils which by being fixed in frames or in some other way are held at a suitable distance from one another, or of corrugated foils superimposed one upon the other with the backs of the corrugations crossing one another, and preferably pasted together at the contact points.

In order to reduce as far as possible the conduction of heat by radiation foils with great reflecting power such as metal foils have been used in such multilayer insulations. In using foils of cellulose esters, such as cellulose acetate which on account of its low hygroscopicity is very suitable for insulating purposes the radiation from the foils has been reduced by mixing a metallic powder for instance aluminium powder into the foil mass. Such intermingling of metallic powder is, however, connected with certain great drawbacks. Cellulose acetate, which in itself is very difficultly ignitable and easily can be made practically non-ignitable, when intermingled with aluminium powder becomes easily ignitable due to the great combustibility of the finely divided aluminium powder.

In using foils with small heat reflecting power the insulating power may be increased by using a relatively large number of layers, that is to say a large number of foils spaced apart by intermediate air spaces per centimetre of cross section. It is, however, to be observed that the conduction of heat from one foil to another foil increases as the distance between the foils decreases. To that must be added that an increased number of foils involves a greater quantity of material. When using for instance cellulose acetate foils, the cost of the material is of very great importance.

By making the foils thinner in the multi-layer insulations in question one reduces the heat transmission by direct conduction which inevitably occurs for the reason that the various foils separating the air spaces in the insulation are in a direct heat conducting connection with one another, this being particularly the case when the insulation is built up of foils provided with corrugations or elevations. Moreover, if thinner foils are used it is possible to obtain a greater number of layers with the same quantity of material.

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Very thin foils of cellulose esters alone without heat reflecting substances could not be used for heat insulating purposes since no satisfactory results could be obtained.

It is therefore an object of this invention to impart to thin cellulose ester foils such characteristics which will make them excellent heat insulators.

It has been shown that all heat radiation, and especially long wave heat radiation, has a certain power of penetrating into a solid body, that is to say the absorption of the nonreflected portion of the radiation is complete only at a certain depth below the surface of the body. In accordance therewith it has been found that a thickness of 0.01–0.1 mm. for a foil material consisting of cellulose esters is less than the layer thickness required for complete absorption. In cellulose acetate foils, for example, wave lengths between 7 and 15 microns, that is to say heat radiation at the usually occurring temperatures, will not be completely absorbed unless the foil is more than 0.1 mm. thick.

The penetration of heat rays at a certain depth in cellulose acetate foils can be established by measuring the radiation from a polished metal cylinder held at constant temperature when cellulose acetate foils of various thickness are placed on the surface of the metal cylinder. The radiation can be measured by means of a thermopile, which in its turn sends an electric current to a galvanometer. The galvanometer reading will be a measure of the radiation. The appended curve sheet, Fig. 1 of the drawing, shows the results of such tests when different thicknesses of cellulose acetate foils are used which cover a polished cylindrical container of brass. According to the curve the galvanometer readings increase up to a foil thickness of 0.1 mm., from which it is to be concluded that when the foil thickness is less than 0.1 mm., the metal surface underneath the foil will affect the heat radiation, which means that at the wave length in question, which in the stated tests corresponded to a temperature of 62.2° C., the cellulose acetate lets through rays to a depth of about 0.1 mm. The curve shows that the heat radiation permeability of the cellulose acetate foils above this thickness is very small, but that the penetration strongly increases as the thickness of the foils decreases. According to the curve, between 15 and 20% of the heat radiation will thus penetrate a foil with a thickness of 0.02 mm.

The indicated test shows that a multi-layer insulation should not be built up by cellulose es-

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ter foils without ascertaining that the foil thickness corresponds to what is required for total absorption. Otherwise there will be extra losses due to an exchange of radiation not only between adjacent but also between more remote layers.

I have now found that when using such foil materials for multi-layer insulations I may, by intermingling with the material of the foils substances which absorb the heat radiation, obtain complete absorption even though the thickness of the foils be less than would be required for complete absorption if only the basic mass would be used. A thin layer of such material thus gives the same insulating effect with respect to the heat radiation as a thick layer of cellulose esters when used alone without admixture of heat absorbing substances. According to the invention I employ an exceedingly thin type of foils made completely or substantially of cellulose esters of a thickness below 0.1 mm. preferably not exceeding 0.06 mm., which normally should actually be permeable to the heat rays and I obtain the surprising result that such foils may be rendered completely impermeable to heat rays by having embedded in their substance, in a proportion ranging from 2 to 25 percent by weight, finely comminuted particles of a nonmetallic and substantially non-reflecting material which blocks heat radiation. This comminuted material forms part and parcel of the foils and compensates for the permeability of the foils by blocking and absorbing the remaining portion of the heat rays which would pass through said thin foils, if they were clear. An embodiment of the invention is illustrated by way of example on Fig. 2 of the annexed drawing which forms part of this specification.

The figure is a perspective which illustrates rather diagrammatically an insulation board of this invention.

The board as illustrated consists of three corrugated foils **11**, **12** and **13**, the corrugations of which cross one another. The angle of crossing in the embodiment shown is 90°. This angle however is arbitrary, likewise the number of corrugated foils of which the board is composed.

The upper crests or ridges of the three foils respectively are **14**, **16**, **18** the lower ridges of troughs respectively **15**, **17**, **19**. At the points **20** where the crossing troughs and ridges contact each other, the corrugated sheets are welded, cemented, or glued together in any conventional or convenient way.

The thickness of the sheets has been shown on an enlarged scale. As set forth hereinbefore the thickness is below 0.1 mm.

The basic material of the foil may be of any plastic, for instance of a cellulose ester such as cellulose acetate. With the basic mass very small non-metallic particles are intermingled, as indicated by **21** for the purpose of illustration. In fact, these minute particles are not visible to the naked eye; they rather impart to the foil the aspect of a uniform tint or tone. Various substances which due to their molecular structure are practically impermeable to the heat radiation are suitable for use as a material to be admixed with the foil substance. The colour of such material is of no importance, as it is not certain that the absorption is greater in dark than in light materials. A particularly suitable material of that kind is graphite powder which can be obtained in very finely comminuted form, and the permeability of which to heat rays is practically nil. Substances that can be ground

extremely fine, and which are not combustible, may also be used. As examples of such substances may be mentioned kaolin, gypsum, zinc white and platinum black. Most colouring matters are suitable. Certain colours soluble in acetone, may with advantage be used in cellulose acetate foils. An admixture of absorbent substances developing fire-extinguishing vapour is also conceivable. Heat absorbent materials, which are colourless in themselves and transparent, may also be used, by means of which insulating boards according to the present invention, which are completely transparent to light, may be produced.

From the cellulose ester mass intermingled with heat absorbing substances in the form of very fine particles there are produced in accordance with the present invention, foils which are considerably thinner than foils of the basic mass alone of a thickness sufficient to ensure complete impermeability to heat radiation. Of these foils with which fine heat absorbing non-metallic particles had been admixed, a multi-layer insulation in the form of a board is built up. The heat absorbing substance is intermingled with the foil substance in such a proportion that in spite of its reduced thickness the foil becomes completely impermeable to heat radiation.

Over foils made of cellulose esters alone with the same impermeability to heat radiation, the foils of this invention offer the great advantages resulting from the fact that they are considerably thinner.

It is furthermore, a decided advantage that according to this invention the use of metal powder in cellulosic foils is avoided; instead thereof substances may be used which are cheaper and less inflammable and in addition thereto are preferable from the point of view of manufacture. When metal powder is admixed with the foil material, it is of no importance that the powder be very fine. Contrariwise, the substance to be intermingled, in accordance with the invention, with the foil substance should be in a very fine divided form. In this way, the foil material is extremely homogeneous and its tenacity is scarcely affected through the particles intermingled therewith. Moreover, the proportion of material which is to be admixed with the basic mass of the foils, in order to obtain the desired increase of the heat absorption power, is small. According to the invention substances of colloidal particle size may be used with advantage.

In known insulations of cellulose esters with aluminium powder admixed therewith the average distance between the foils in insulating boards built up of corrugated foils has, in general, been kept between 5–7 mm. In foils according to the present invention it has proved suitable, from a technical-economical point of view, to use average distances of 2.5–6 mm. The distance may be larger but for good insulation boards it should not exceed 10 mm. On the other hand, it is quite useless to make the distance less than 2.5 mm. because the quantity of material as well as the direct conduction through the foil material increases with the number of foils on a certain board thickness. For economical reasons and with regard to the direct conduction of heat the thickness of the foils should be as small as possible but it has proved that for practical reasons the foils should not be thinner than 0.01 mm. A suitable foil thickness for manufacturing insulation boards composed of several corrugated foils is about 0.04 mm. Said foils are

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sufficiently elastic and solid to enable the manufacture of light and durable insulation boards. Such foils weigh about 50 g./m.^{2} and ready insulation boards of such foils with an average distance between the foils of for example 6 mm. have a volume weight of about 12 to 14 kg./m.^{3} The price of the foils is practically directly proportional to the thickness, from which it is clear that insulation boards manufactured of thicker foils become considerably more expensive and at the same time heavier. The weight of the boards is of great importance, particularly when using insulating material on board boats, in railway carriages, motor-cars, aeroplanes, and so on. In those cases in which particularly light boards are desired and the solidity is of less importance it might be desirable to use foils of a thickness down to 0.01 mm.

The quantity of heat absorbing substance intermingled with the foil mass will depend upon the permeability, the covering property, the specific gravity and so on of the substance in question. In relation to the quantity of the total foil mass the quantity of the heat absorbing substance should not be less than 2 per cent by weight and, in general, need not amount to more than 20 per cent by weight. An insulation board made of cellulose acetate foils with a thickness of about 0.04 mm. without intermingled particles according to the invention and with an average foil distance of about 6 mm. has an insulation efficiency corresponding to the heat conduction coefficient λ=0.055 kg. cal./m.^{2}/m./° C. (the corresponding American measure is about λ=0.44 B. t. u./ft.^{2}/in./° F./hr.). The inventor's tests have shown, that if a suitable quantity of graphite powder is mixed into the basic mass of the foils and exactly equally made insulating boards are used built from equally thick foils, with the same average distance between the foils, one obtains an improvement of the insulating effect and the same board, however with the graphite powder intermingled therewith, has now a heat conduction coefficient λ=0.040 kg. cal./m.^{2}/m./° C. (American measure λ=0.32 B. t. u./ft.^{2}/in./° F./hr.).

In the boards of the cited example the intermingled graphite quantity amounted to 13 g. finely comminuted graphite per 100 g. dry cellulose acetate. In addition to the cellulose acetate, the foils contained about 20 g. softening means—as examples of such means may be mentioned tricresyl phosphate and triphenyl phosphate—and thus the percentage of graphite powder in the foils amounts to about 13 per cent by weight. As the weight of the foils is about 50 g./m.^{2} it is, thus, clear that a content of 6.5 g. graphite per m.^{2} foils of the above mentioned thickness was sufficient to obtain the observed improvement of the insulating effect. The measurements made have shown that clear cellulose acetate foils with the above mentioned thickness of 0.04 mm. let through about 8 per cent of the dark heat radiation at normal temperatures. The admixture of 6.5 g. graphite per m.^{2} foils caused the permeability to heat rays to be reduced to about 1 per cent, and through said admixture there is thus obtained an improvement of the insulating effect of boards composed in the above mentioned way which amounts to no less than about 25 per cent. Of course, it is possible to completely prevent all penetration of dark heat rays in thin foils through intermingling therewith larger quantities of graphite than in the above mentioned example, but the result is practically satisfactory if the penetration can be reduced to 1 per cent or there-

below. The proportion of graphite can be made larger or smaller than in the above mentioned example according to the thickness of the foils. In very thin foils of about 0.01 to 0.02 mm. the proportion of graphite should preferably amount to about 25 per cent, while in foil thickness of about 0.07 to 0.1 mm. a proportion of 5 to 10 per cent of graphite is sufficient. The used filling material should be extraordinarily finely comminuted not only, in order to obtain a complete covering effect but also for making possible the production of such foils for instance in casting machines.

Preferably the substance to be admixed with the basic mass should be in an extremely fine divided form, for example finely ground in a ball mill while being stirred in a suitable softening agent, for instance, tricresyl phosphate.

In literature many solid admixing materials are known for increasing the incombustibility of cellulose acetate. Certain such materials are very suitable for the purpose of this invention.

Salts in a finely divided form may also be contained in the basic mass in order to increase the heat absorption and at the same time reduce the combustibility. Such salts are, for instance boric acid, sodium biborate, ammonium sulphate, antimony salts, calcium sulphate, cerium oxalate, aluminium fluoride, aluminium phosphate, calcium tartrate, magnesium tartrate and magnesium nitrate.

Substances of a high absorbing power, which are soluble in acetone or other solvents for the cellulose esters in question, are particularly suitable admixing materials.

Having now described my invention, what I claim as new and desire to secure by Letters Patent is:

1. Heat insulation comprising a plurality of sheets of insulating material arranged to provide air spaces therebetween, said sheets comprising as a base material a cellulose ester in the form of foil having a thickness not exceeding approximately 0.1 mm., said foil including a non-metallic substantially non-reflecting heat absorbing agent in finely divided particle form in an amount not exceeding by weight approximately 25% of the weight of the foil.

2. Heat insulation comprising a plurality of sheets of insulating material arranged to provide air spaces therebetween, said sheets comprising as a base material a cellulose ester in the form of foil having a thickness not exceeding approximately 0.1 mm. and including graphite in finely divided particle form in an amount not exceeding by weight approximately 25% of the weight of the foil.

3. Heat insulation comprising a plurality of sheets of insulating material arranged to provide air spaces therebetween, said sheets comprising as a base material a cellulose acetate in the form of foil having a thickness of approximately 0.04 mm. and including graphite in finely divided particle form in an amount not exceeding by weight approximately 25% of the weight of the foil.

4. A heat insulating board consisting of a plurality of superposed corrugated sheets of insulating material arranged to provide air spaces therebetween, the height of said corrugations providing an average distance between adjacent sheets of approximately 6 mm., said sheets comprising as a base material cellulose acetate in the form of foil having a thickness of approximately 0.04 mm. and including graphite in finely divided particle

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form in an amount not exceeding approximately 25% by weight of the weight of the foil.

5. Heat insulation comprising a plurality of sheets of insulating material arranged to provide air spaces therebetween, said sheets comprising as a base material cellulose acetate in the form of foil having a thickness of approximately 0.04 mm. and including graphite in finely divided particle form in the amount of approximately 13% by weight of the weight of the foil.

6. An insulating board comprising a plurality

of corrugated sheets superposed directly one upon another and with the corrugations of adjacent sheets extending in different directions, the height of said corrugations providing an average distance between adjacent sheets of approximately 6 mm., said sheets each comprising as a base material cellulose acetate having a thickness of approximately 0.04 mm. and including graphite in finely divided particle form in an amount by weight of approximately 13% of the weight of the sheet.

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