Jan. 3, 1961 L. C. MATSCH ET AL 2,967,152

THERMAL INSULATION

Filed April 26, 1956

Fig. 1.

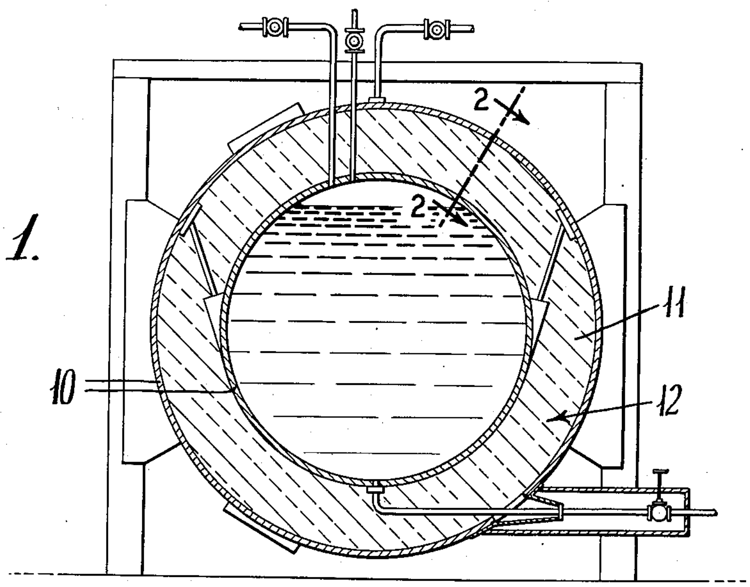
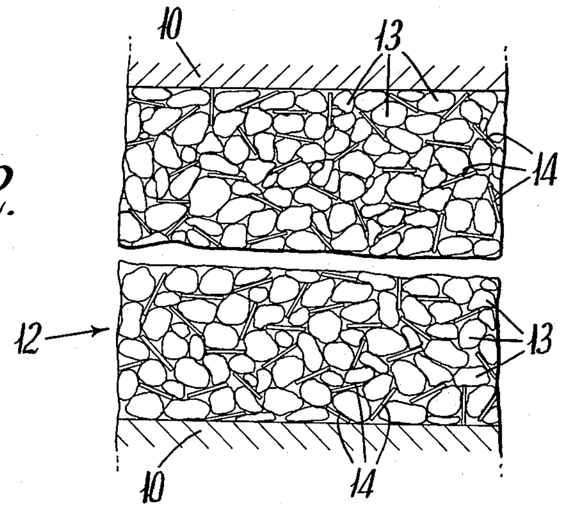


Fig. 2.



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THERMAL INSULATION

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This invention relates to an improved insulating material having a high resistance to all modes of heat transfer, and particularly concerns a low temperature insulating material for use in vacuum jackets of containers.

In the conservation and conveying of low-temperature commercial products, for example, perishable commodities which must be held at low temperatures for substantial periods of time, and of volatile materials such as liquefied gases having boiling points at atmospheric pressure below 233° K., for example, liquid oxygen or nitrogen, a major problem encountered is the control of heat leak to the material which, in the case of liquefied gases, results in loss due to evaporation. In the conventional double-walled liquid oxygen containers, the space between the walls is suitably insulated to limit this evaporation loss. Up to now, straight vacuum-polished metal or powder-in-vacuum insulation of the type disclosed in U.S. Patent No. 2,396,459, has been used to insulate the space between the walls. However, a general disadvantage of straight vacuum-polished metal insulation is the necessity of maintaining an extremely high vacuum. Powder-in-vacuum heat insulation is less sensitive to the presence of small traces of air in the insulation space, however, significant quantities of heat from the atmosphere are, nevertheless, transmitted from the external shell of the container to the inner vessel.

There is a great commercial need for efficient insulating materials capable of meeting more rigid and exacting requirements, and which will provide even lower thermal transmission than those afforded by either of the above described insulating systems. Provisions of such materials would permit study and development of important new and improved control techniques for many processes and products.

The present invention is based on the discovery of important behavior characteristics of finely divided insulating powders used as heat insulation. The geometry of the insulating material has the greatest effect on solid heat conduction, the rate of heat transfer by conduction varying directly with the cross sectional area and inversely with the length of the heat path. The contacts between powder particles are usually of relatively small cross sectional area. Consequently, in powders, the area available for conductive heat transfer is an infinitesimal fraction of the insulated area. It would seem, therefore, that by reducing the powder size, the resistance to the flow of heat by conduction and the permissible temperature gradient would be correspondingly increased. However, our investigations have shown that as the particle size is reduced, the faculty of the particles to reflect the radiant rays of heat undergoes changes. Powders with extremely small particle sizes are more transparent to infra-red radiation, and such radiant heat transparency increases as the ratio of the particle size to the wave length of radiation decreases. As a consequence, radiation can become the predominant mode of heat transmission through very fine powders even at low temperature.

In order to achieve acceptable combinations of the

various modes of heat transfer in an insulating material, means must be provided for reducing the infra-red radiation transparency effects accompanying small particle sizes without incurring an appreciable increase in heat transfer by solid conduction.

It is, therefore, an object of the present invention to provide in an insulation system, improved means for reducing the undesirable radiative effects in low conductive powders of relatively small particle sizes.

Another object of the present invention is to provide in a vacuum-solid insulation system, an improved and efficient insulating material having a relatively high resistance to the passage of heat by conduction and by radiation.

Still another object of the present invention is to provide in a vacuum-powder insulation system, additive material for minimizing the passage of heat by radiation without increasing the passage of heat by conduction to any significant degree.

Yet another object of the present invention is to provide a novel improvement in insulation material for use in an insulation system where radiation would otherwise be the predominant mode of heat transfer.

Other objects, features and advantages of the present invention will be apparent from the following detailed description.

In the drawings:

Fig. 1 is a view of a double-walled container for liquefied gas embodying the principles of the invention; and

Fig. 2 is a view of an enlarged section taken along line 2—2 in Fig. 1, showing the insulating material of the present invention.

According to the present invention, the undesirable radiative effects accompanying the use of a finely divided low heat conductive powder in a vacuum insulating space may be substantially reduced and minimized by incorporating therein a multiplicity of radiant heat barriers capable of interrupting the passage of infra-red radiation rays without significantly increasing the thermal conductivity across the insulating space. This may be accomplished by providing throughout the powder insulation a series of spaced, randomly dispersed radiation opaque or reflective bodies, which in combination with each other constitute a plurality of discontinous radiation barriers.

It is to be understood that the term "radiant heat barrier" as used herein is intended to apply to radiation opaque or radiant heat energy impervious materials or materials having lightly reflective surfaces, and capable of hindering, interrupting or stopping the penetration of infra-red heat rays through the insulation space either by radiant heat reflection, radiant heat absorption or both.

The term "vacuum" as used hereinafter is intended to apply to sub-atmospheric pressure conditions not substantially greater than 5000 microns of mercury, and preferably below 500 microns of mercury absolute.

In applying the principles of the invention to a conventional powder-vacuum insulation system, for example, a powder-vacuum type insulation system of the type disclosed in U.S. Patent No. 2,396,459, the combination of finely divided low conductive insulating powder with relatively small bodies of material having heat reflective or heat absorbing properties provides effective insurance against passage of heat leak.

A practical illustration of an apparatus embodying the invention shown in Fig. 1 may comprise a double-walled insulating vessel having spaced parallel walls **10** defining an evacuable insulating space **11** therebetween for the reception of a solid, powder-type insulation mixture **12** embodying the principles of the invention. The insulation mixture **12** may comprise a finely divided agglomerate of low heat conductive material **13** in which particles or bodies **14** of radiant heat barriers are intermingled.

The low heat conductive powder 13 used in the insulation of the invention should be a material which may be produced in fine particle sizes, or can be readily reduced to a fine powder. It should be strong and rigid enough to fill the insulation space, and not pack down excessively during normal service. Among the insulating powders which give excellent results are "finely divided silica" silicates such as perlite, alumina, magnesia and other similar metallic oxides, and carbon black, "finely divided silica" being preferred because of its low thermal conductivity, relative inexpensiveness, and general availability. The term "finely divided silica," as used herein, is intended to apply to naturally occurring silica as well as the various commercial preparations of silica, and is not intended to be limited to any specific form or preparation of silica.

The radiant heat barrier material 14 of the present invention may be either a metal, metal oxide, or a metal coated material such as copper coated mica flakes, or other radiation reflective material, or a radiation opaque material, or a suitable combination of reflective and other absorptive materials, which when mixed with the low conductive powder, i.e., finely divided silica, will provide a discontinuous series of multiple radiation barriers for decreasing and minimizing the passage of heat by radiation through the insulation space. The shape of the barrier particles should provide a large surface area per unit volume, thin flakes of relatively fine particle size being preferred. For example, the radiant heat barrier material may comprise aluminum or copper in powder or flake form, the latter being preferred.

In addition to the materials already specified as radiant heat barriers in the insulation mixture of the invention, other barriers such as copper paint pigments, aluminum paint pigments, magnesium oxide, zinc oxide, iron oxide, titanium dioxide, copper coated mica flakes, carbon black and graphite, either alone or in combination with each other, have been found to satisfactorily reduce the transmission of infra-red radiation, and to complement the desirably low conductivity characteristics of the powder insulation.

It should be understood that while the insulation mixture of the present invention comprises two or more component ingredients, it is entirely possible for the low heat conductive component and the radiation barrier component to have the same chemical composition, though widely varying physical properties. To illustrate, an insulating powder such as carbon black in extremely small ultimate particle sizes, i.e., below 0.1 micron, gives excellent low heat conductive results, but is deficient as a radiation barrier material. On the other hand, the same carbon black material in relatively larger particle sizes, i.e., above 10 microns, exhibits greatly improved radiation stopping characteristics, but has a high heat conductivity. We have found in general that the substantial elimination of heat flow by conduction through a single component insulation by reducing particle sizes may only be accomplished by sacrificing radiation opacity. We have been unable to find any single component insulation having uniform chemical and physical characteristics and possessing the combined properties of an extremely low heat conductivity and a high resistance to the transmission of radiant heat on the order of magnitude achieved by the insulation mixture of the invention.

In the preferred practice of the invention, the choice of particle size of the low heat conductive powder should be effective in reducing the heat leak by conduction below the values obtained with prior-known insulating powders. Particle sizes may vary up to about 1500 microns. Usually a maximum particle size of 420 microns is desirable for operation at low boiling liquefied gas temperatures, and for best operation particle sizes of 75 microns or smaller may be employed. The various particle sizes enumerated in this specification for the low heat conductive powder component refer to agglomerate particle sizes and not ultimate particle sizes, unless specifically identified as the latter.

Tests with insulation mixtures containing radiant heat impervious particles having maximum particle sizes of about 500 microns have produced very satisfactory results.

Radiant heat barrier material having a particle size below 250 microns have been tested with excellent results, while particle sizes less than 50 microns and flake thickness less than 0.5 micron are preferred.

It is an essential feature of this invention that the insulating powder 13 and the radiant heat barrier material 14 to be used in the powder-vacuum insulation system be thoroughly mixed prior to their introduction into the insulating space 11. Only in this fashion is it possible to maintain a random dispersion of radiant heat barrier material throughout the insulation powder, and realize maximum reduction in radiative heat transmission.

While we do not wish to be bound by any particular theory, we believe the reason for the far superior insulating results of the present invention resides primarily in the random physical dispersion of radiant heat resisting particles in the insulation mixture. This permits the use of high weight percentages of radiant heat barrier particles to bring about a marked reduction in radiative heat transmission with only a very slight increase in heat transfer by conduction.

The striking superiority of the insulation mixture of the present invention is believed to be partially attributed to the employment of small particle sizes of low heat conductive insulating powder 13 and radiation barrier flakes 14. This results in an insulation mixture in which the barrier flakes 14 are not in close surface contact with the insulating powder particles 13, but rather are in contact over a reduced surface area somewhat approaching point contact. The effect of this relationship between barrier flakes 14 and low conductive particles 13 is to prevent close contact between, and to separate insulating particles from each other, and to reduce the tendency for conductive heat to flow between particles by direct contact over a large contact area. This also restricts the passage of conductive heat flow across the insulation space to heat leak paths containing an indefinitely large number of exceedingly small contact areas, which offer considerable resistance to the flow of heat therethrough. As a consequence, heat entering the insulation space 11 may be further minimized by any combination of radiation reflection, radiation absorption by the radiant heat barrier flakes, the relatively high contact resistances between like and unlike particles, as well as the relatively low conductivity of the insulating powder.

Thus the mechanism of heat transfer which occurs in a typical combination of a particle of finely divided silica and a particle of aluminum flake might be as follows:

Heat will reach the particles by the modes of radiation and conduction. Of the radiant heat, part will be reflected, part will be absorbed by the aluminum flake, and the remainder will radiate through and around the particle of finely divided silica. The absorbed radiation will raise the temperature of the aluminum flake above the temperature of the adjoining finely divided silica particle. Through the mode of solid conduction, heat will pass from particle to particle and from flake to particle across the relatively small area of point contact. Thereafter such heat will travel by solid conduction across the low conductive particle of finely divided silica. By analogy it will be seen that an ordinary insulation layer having heat reflecting particles and an indefinitely large number of contact resistances between like and unlike particles is particularly efficient in preventing heat losses by radiation as well as by conduction.

Since the radiant heat barrier particles used in the insulation mixture of the invention have excellent heat conductive characteristics, it would seem that an increase in the barrier material contained in the insulation mixture would impair the conductive insulation efficiency. Contrary to this concept, we have found that substantial increases in the amount of barrier material continue to be beneficial to the overall insulating properties of the insulation mixture. In the present invention, increasing the amount of aluminum in a mixture of aluminum and silica particles reduces the radiative heat transfer, and only slightly increases the heat transfer by conduction. Optimum thermal resistance is obtained when the sum of these two modes of heat transfer is at a minimum.

A principal advantage residing in the use of the insulating mixture of the present invention is that it is possible to employ a decreased insulation thickness without sacrificing the benefits of small exchange of heat by radiation or conduction. The greater efficiency obtained from the use of a smaller insulation thickness arises from the multiple layers of reflective and absorptive particles available in the particle arrangement of the present invention. In this respect it is to be noted that the low value of heat transfer rate is only attained when the metal flakes are sufficiently separated by the particles of finely divided silica. If the metal flakes contact each other frequently enough, they will form a solid conductive path.

The thermal transmission from wall to wall of the container is herein stated in terms of "thermal conductivity" K and includes the total heat transfer in B.t.u. per hour, per square foot, per ° F. per foot.

To indicate still more fully the nature of the present invention, some of the test results of "thermal conductivity" obtained from insulation mixtures containing aluminum flake and finely divided silica are set forth in Table I. In these tests an insulation space of a double walled contained was maintained at an absolute air pressure of less than 0.1 micron of mercury (0.0001 mm. Hg) and one wall of the vessel maintained at a temperature of −183.2° C., while the remaining wall temperature was adjustably controlled at higher levels. The aluminum flake constituent of the insulation mixture employed in the tests was present in widely varying amounts ranging from about 1% to about 80% of the mixture, the percentage composition being on a weight basis, and based on a mixture of metal flake having particle sizes between 10 and 50 microns, and insulating powder particles with agglomerate sizes less than 75 microns.

However, it is to be understood that these tests are presented as illustrative only, and that they are not intended to limit the scope of the invention.

Table I

Material, by weight	Higher Temperature, ° C.	K×10³ B.t.u./Hr., Sq. Ft., ° F./Ft.
3% Aluminum+finely divided silica [1]	47.5	0.498
	27.5	0.445
	10.0	0.397
6% Aluminum+finely divided silica [1]	66.5	0.5155
	47.1	0.412
	24.3	0.3845
	0	0.314
10% Aluminum+finely divided silica [1]	40	0.2885
	30	0.2755
	20	0.258
	10	0.246
	0	0.232
28.6% Aluminum+finely divided silica [1]	40	0.211
	30	0.212
	20	0.187
	10	0.175
	0	0.172
40% Aluminum+finely divided silica [1]	40	0.167
	30	0.161
	20	0.162
	10	0.154
	0	0.145
50% Aluminum+finely divided silica [1]	50	0.207
	30	0.205
	20	0.203
70% Aluminum+finely divided silica [1]	35.0	0.497
	20.0	0.473
	−1.0	0.464

[1] Density of approximately 3 to 6 lbs./cu. ft.

As an alternative heat reflective material, copper flakes or copper powder may be mixed with finely divided silica. Table II below lists some of the results of insulation tests conducted under conditions similar to the previously described tests using insulation mixtures containing finely divided silica and copper flakes or powder.

Table II

Material, by weight	Higher Temperature, ° C.	K×10³ B.t.u./Hr., Sq. Ft., ° F./Ft.
5% Copper [1]+finely divided silica	42.5	0.622
	27.5	0.534
	20.0	0.490
45.5% Copper [1]+finely divided silica	44.6	0.240
	14.8	0.204
55.5% Copper [1]+finely divided silica	36.2	0.229
	13.5	0.192
62% Copper [1]+finely divided silica	40	0.311
	20	0.285
	0	0.255
75% Copper [1]+finely divided silica	39.7	0.434
	0.2	0.407

[1] Copper in partially oxidized state.

From the results shown in Tables I and II it will be seen that optimum reduction of heat transfer depends on the selection and proportion of finely divided materials used in the insulation mixture. The addition of small percentages of aluminum or copper flakes to the finely divided silica insulation substantially diminishes the thermal heat transfer properties of the mixture. Increasing the percentage of aluminum or copper admixture further reduces the radiative heat transfer and slightly increases the heat transfer by conduction. An inspection of Table I will indicate that an optimum mixture is a combination of 40% aluminum flake and 60% finely divided silica, the thermal conductivity being 0.163×10^{-3} B.t.u./hr., sq. ft., ° F./ft. Referring to Table II a minimum thermal conductivity occurs at 55.5% copper and 44.5% finely divided silica, which corresponds to a thermal conductivity of about 0.192×10^{-3} B.t.u./hr., sq. ft., ° F./ft. It has also been discovered that still lower thermal conductivity figures may be obtained by reducing the copper-oxide surface to copper.

As a feature of the present invention, improved thermal insulation over the results shown in Table I may be effected by employing barrier flakes having particle sizes less than 10 microns. The effect is to shift the optimum percentage composition of radiant heat barrier material to a numerically higher value, the magnitude of the shift corresponding to the degree of reduced particle size. For example, by using aluminum flakes sized between 5 and 10 microns, thermal conductivities as low as 0.0875×10^{-3} B.t.u./hr., sq. ft., ° F./ft. may be achieved with insulating mixtures containing 60% aluminum. The same holds true for the heat rate behavior of similarly sized copper flake-insulation mixtures, thermal conductivities as low as 0.105×10^{-3} B.t.u./hr., sq. ft., ° F./ft. having been obtained with mixtures containing 70% copper by weight.

Thus, depending on particle size, insulation mixtures containing high weight percentages of barrier material, such as aluminum or copper flakes, may be satisfactorily employed in the insulation mixture of the invention, even though the aluminum or copper flakes are themselves highly conductive. However, it is to be understood that the degree to which the particle sizes of the heat reflecting and absorbing aluminum bodies are to be reduced is largely controlled by the practical economics of the situation, particle sizes below 50 microns being preferred.

Table III below is representative of the unexpectedly superior results obtained from insulation mixtures of the present invention in comparison with the known insulation systems of the prior art.

Table III

Material	$K \times 10^3$ B.t.u./Hr., Sq. Ft., ° F./Ft.
Powder-in-vacuum insulation of the type disclosed in U.S. Patent No. 2,396,459, high vacuum-polished metal surface system	0.92
45.5% Cu (10 to 50 microns)+finely divided silica (less than 75 microns)	0.19
70% Cu (5 to 10 microns)+ finely divided silica (less than 75 microns)	0.105
40% Al (10 to 50 microns)+finely divided silica (less than 75 microns)	0.162
60% Al (5 to 10 microns)+finely divided silica (less than 75 microns)	0.0875

The unexpected results obtained from the practice of the present invention are very impressive. From the above Table III it will be seen that the passage of heat leak may be minimized by the insulation mixture of the present invention to as low as 0.0875×10^{-3} B.t.u./hr., sq. ft., ° F./ft., which is less than one-tenth the rate of heat transfer obtained by the most efficient insulating material in the prior art. Being in part a function of particle size, still further improvement in the reduction of heat leak may be effected by using even smaller flake sizes.

To further appreciate the advantages of the present invention, it should be noted that in U.S. Patent No. 2,396,459 it was pointed out that for containers up to two feet in diameter, vacuum-polished metal surfaces are more efficient and preferable to powder-vacuum insulation. For larger sizes, the powder-vacuum insulation is advantageous. As a result of the significantly low rate of heat transfer possessed by the insulation mixture of the present invention, insulation layers of extraordinarily reduced thicknesses may now be advantageously employed, thus reducing the overall dimensions of low temperature storage containers for the entire size range of containers, including those under two feet in diameter.

The possibilities in the resultant reduced insulation thickness with insulation mixtures of the present invention indicate the scope and importance of this product. For instance, if it is desired to insulate a 10 liter spherical container (diameter=10.5 inches), so that its holding time for liquid nitrogen is approximately four weeks (evaporation loss of 3.57% per day), it is to be expected that the necessary insulation thickness using the best known prior art insulating material will be several times the diameter, and many times the volume of the uninsulated container. Theoretical calculations show the required thickness of prior art vacuum-powder insulation having silica powder as the low heat conductive powder to be at least three feet. Expressing this figure in terms of volume, the resultant quantity of insulating material would be almost 500 times the volume of the uninsulated spherical container. In contrast, an insulation mixture containing 60% aluminum (5 to 10 micron flakes) and the remainder finely divided silica, permits the use of a singularly unusual insulating thickness of less than one-half inch.

The insulating product of the present invention is even more favorable in situations where longer holding periods may be desired. Thus, if the holding time for the spherical container is increased to 10 weeks, a thickness of 1.37 inches of the subject insulating mixture will meet this rigid specification. However, none of the prior art insulating materials possesses a sufficiently low heat rate to fulfill this function, no matter what thickness of insulating material is used. This is because the relatively larger external surface area for heat leak occasioned by an increase in insulation thickness completely counteracts whatever benefits may be derived from the lengthened heat flow path.

From the foregoing it will be seen that the thermal heat transfer rate of powder-vacuum insulating material may be materially decreased by uniformly incorporating

finely divided infra-red radiation impervious bodies in a finely divided low heat conductivity powder. The heat impervious bodies provide a series of heat reflective surfaces for minimizing the transmission of heat radiation through the insulation space. At the same time the small area contact between like and unlike particles provides maximum thermal resistance to the passage of heat by conduction. Increasing the proportion of radiation retarding bodies, substantially reduces the radiative heat transfer and slightly increases the heat transfer by conduction. Through the use of the subject highly efficient powder insulation mixture, the required thickness of insulation layer may be substantially reduced and the overall container dimensions minimized.

It will be understood that although the thermal insulation of the present invention has been described in connection with powder-in-vacuum insulating systems for the storage of liquefied gases, the insulation is also susceptible of use in the preservation of quick frozen biological specimens, living tissues and other perishable commodities, and may be applied as a thermal insulation at higher temperature levels, at which conditions the pressure in the insulation space will not be as critical or sensitive as at lower temperatures, without departing from the spirit and scope of the novel concepts of the present invention.

What is claimed is:

1. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided low heat conductive particles of agglomerate sizes less than about 420 microns being selected from the group consisting of silica, perlite, alumina, magnesia and carbon black; and finely divided radiant heat reflecting bodies of sizes less than about 500 microns and having metallic surfaces, such radiant heat reflecting bodies constituting between about 1% and 80% by weight of said insulating material.

2. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided low heat conductive particles of agglomerate sizes less than about 420 microns being selected from the group consisting of silica, perlite, alumina, magnesia and carbon black; and finely divided radiant heat reflecting bodies of sizes less than about 500 microns and constituting between about 1% and 80% by weight of said insulating material, said heat reflecting bodies consisting of at least one member selected from the group consisting of aluminum, copper, aluminum paint pigments, copper paint pigments and copper coated mica.

3. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided low heat conductive particles of less than about 420 microns agglomerate size being selected from the group consisting of silica, perlite, alumina, magnesia and carbon black; and finely divided radiant heat reflecting bodies of less than about 500 microns size, said radiant heat reflecting bodies consisting of aluminum flakes in an amount between about 1% and 80% by weight of said insulating material.

4. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided low heat conductive particles of less than about 420 microns agglomerate size being selected from the group consisting of silica, perlite, alumina, magnesia and carbon black; and finely divided radiant heat reflecting bodies of less than about 500 microns size, said radiant heat reflecting bodies consisting of copper flakes in an amount between about 1% and 80% by weight of said insulating material.

5. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided silica particles of less than about 75 microns agglomerate size; and finely divided radiant heat reflecting bodies of less than about 250

microns size and constituting between about 1% and 80% by weight of said insulating material being uniformly interspersed in said low conductive particles, said heat reflecting bodies consisting of at least one member selected from the group consisting of aluminum, copper, aluminum paint pigments, copper paint pigments and copper coated mica.

6. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided silica particles of less than 75 microns agglomerate size; and finely divided radiant heat reflecting aluminum flakes of less than about 50 microns size in an amount between about 1 and 80% by weight of said material.

7. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided silica particles of less than about 75 microns agglomerate size; and finely divided radiant heat reflecting copper flakes of less than about 50 microns size in an amount between about 1 and 80% by weight of said insulation material.

8. In combination with a vacuum insulating system, a mixture of finely divided low heat conductive particles so reduced in agglomerate size to less than about 420 microns as to substantially impede heat inleak by conduction and yield to the predominant passage therethrough of heat inleak by radiation, said low conductive particles being seelcted from the group consisting of silica, perlite, alumina, magnesia and carbon black; and finely divided radiant heat reflecting bodies of less than about 500 microns size and having metallic surfaces, such radiant heat reflecting bodies constituting between about 1% and 80% by weight of said mixture, whereby said system affords a high resistance to heat inleak by all modes of heat transfer.

9. In combination with a vacuum insulating system, a mixture of finely divided silica particles of less than about 75 microns agglomerate size; and finely divided aluminum flakes of less than about 50 microns size and having thicknesses of less than 0.5 micron, said aluminum flakes being present in an amount between about 1 and 80% by weight of said mixture.

10. In combination with a vacuum insulating system, a mixture of finely divided silica particles of less than about 75 microns agglomerate size; and finely divided copper flakes of less than about 50 microns size and having thicknesses of less than 0.5 microns, said copper flakes being present in an amount between about 1% and 80% by weight of said mixture.

11. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided low heat conductive particles of agglomerate sizes less than about 75 microns and ultimate particle sizes less than about 0.1 micron being selected from the group consisting of silica, perlite, alumina, magnesia and carbon black; and finely divided radiant heat reflecting metal flakes of sizes less than about 50 microns, such radiant heat reflecting flakes constituting between about 1% and 80% by weight of said insulating material.

12. An insulating material characterized by a low rate of heat transfer by conduction and radiation, consisting essentially of finely divided silica particles of less than about 75 microns agglomerate size and having a density of about 3 to 6 lbs. per cu. ft.; and finely divided radiant heat reflecting flakes of sizes less than about 50 microns and having metallic surfaces, such radiant heat reflecting flakes constituting between about 1% and 80% by weight of said insulating material.

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Disclaimer

2,967,152.—*Ladislas C. Matsch*, Kenmore, and *Arthur W. Francis*, Dobbs Ferry, N.Y. THERMAL INSULATION. Patent dated Jan 3, 1961. Disclaimer filed Aug. 30, 1963, by the assignee, *Union Carbide Corporation*.

Hereby enters this disclaimer to claims 1, 2, 3, 4 and 8 of said patent.

[*Official Gazette October 22, 1963.*]