Nov. 21, 1967 J. ROYET 3,354,021

THERMAL INSULATING DEVICES

Filed June 23, 1965

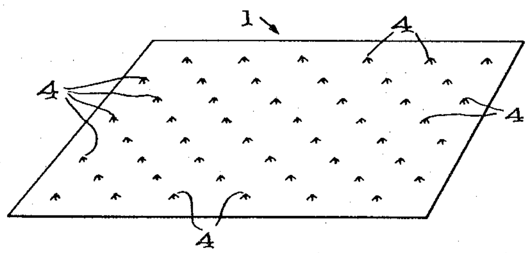


FIG. 1.

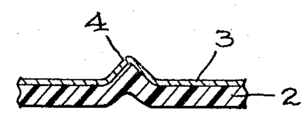


FIG. 2.

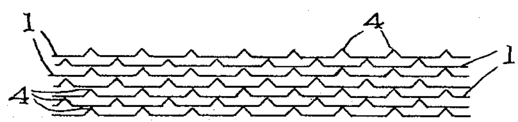


FIG. 3.

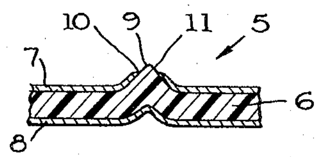
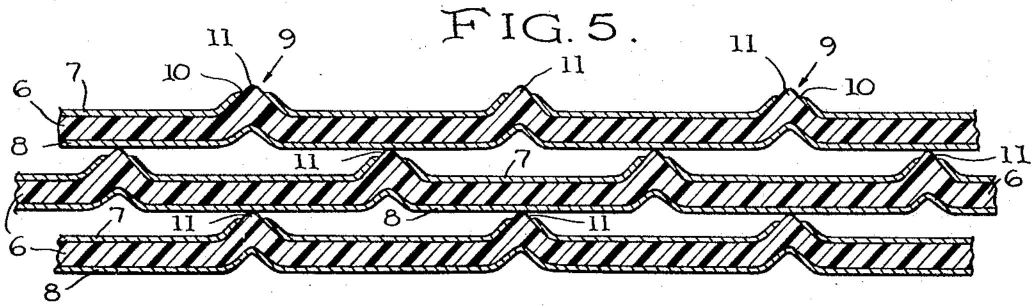


FIG. 4.

FIG. 5.



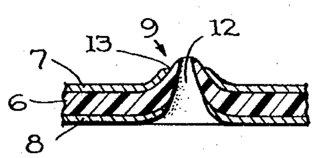


FIG. 6.

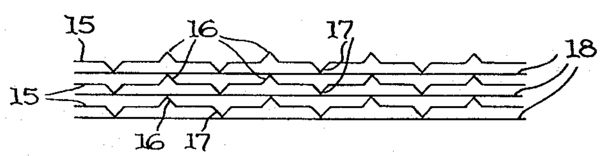


FIG. 7.

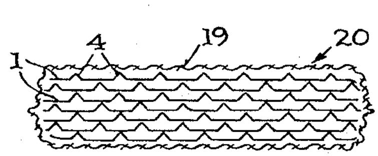


FIG. 8.

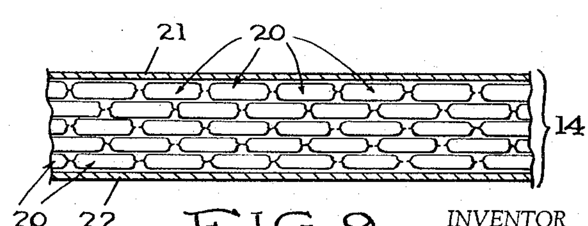


FIG. 9.

INVENTOR

JEAN ROYET

BY Edwin E. Greigg

ATTORNEY

United States Patent Office 3,354,021 Patented Nov. 21, 1967

1

3,354,021

THERMAL INSULATING DEVICES

Jean Royet, Saint-Maur, France, assignor to Compagnie Generale d'Electricite, Paris, France, a corporation of France

Filed June 23, 1965, Ser. No. 466,355
Claims priority, application France, Sept. 18, 1963, 947,900
9 Claims. (Cl. 161—111)

ABSTRACT OF THE DISCLOSURE

There is described an insulating assembly comprising a stack of metal coated plastic films each provided with protrusions in such a manner that the metal coating is ruptured and the plastic base protrudes therebeyond. Adjacent films are in contact through the plastic apical portions of each protrusion.

This application is a continuation-in-part of my copending application, Ser. No. 395,263, filed Sept. 9, 1964, now abandoned.

This invention relates to thermal insulating devices for use in cryogenics and is more particularly concerned with a multi-laminar insulator of novel structure resulting in a notable improvement of the insulating characteristics thereof.

With the rapidly expanding industrial use of very low temperature substances such as nitrogen, hydrogen or helium in the liquid state, the provision of an effective and economical thermal insulation on a mass production scale is constantly gaining in importance. The efficiency and over-all cost of superconductive apparatus or rocketry (two significant fields of application for cryogenics) depends in a significant degree on the quality of the thermal insulation that separates the inside of the liquid gas container from ambient temperature conditions.

So far, in cryogenics, the best insulating results have been obtained by stacks of metallic foils or very thin unilaterally metallized plastic films disposed in a high vacuum in the jacketed walls of the liquid gas container. The insulating films are preferably made of polyethylene terephthalate coated on one face with aluminum by means of vacuum deposition. In order to lessen the transversal thermal conductivity by contact between adjacent films of the insulating stack, it has been suggested by the prior art to crinkle the film prior to forming stacks therefrom. Adjacent crinkled films, when superimposed, are in irregular linear contact over their entire facing areas. The departure from a total area contact and the achievement of irregular linear contact by means of an initial crinkling step significantly reduced the thermal conductivity by contact across the insulating stack.

The disadvantage of the crinkling method lies in that the locations of contact between adjacent films are not minimized, but are only reduced in a haphazard manner without excluding the possibility of the presence of substantial areas in contact. A further drawback of the aforementioned structure is the possibility of the formation of random, hermetically insulated pockets which may retain trapped air particles after the wall jackets are subjected to vacuum. The presence of trapped air prevents obtaining a high quality vacuum essential for the best insulating results.

It has been further found that difficulties arise during the handling of unilaterally metallized plastic films due to the appearance of substantial electrostatic charges thereon. These electrostatic charges cause severe twisting of the films and attraction therebetween which clearly prevents an efficient assembling of the films into insulating

2

stacks. Also, the presence of electrostatic charges on the films after their assembly into stacks generates forces of attraction between the film elements thus increasing the contact areas causing the undesirable effect of increased contact conductivity across the insulating stack.

This invention obviates all of the above-enumerated disadvantages by means of improved structural features applied to very thin metallized plastic films.

Accordingly, the principal object of this invention is to provide a thermal insulating film element of improved structure to be assembled into a stack wherein adjacent superimposed films are in point contact with one another according to a predetermined definite pattern.

A further object of the invention is to provide a thermal insulating film element of improved structure to be assembled into a stack wherein the trapping of air particles between adjacent films of the stack is prevented.

Still another object of the invention is to provide a thermal insulating film element of improved structure to be assembled into a stack wherein the undesirable effects of static electricity are eliminated.

Other objects and advantages will become apparent from the ensuing specification taken in conjunction with the drawing wherein:

FIG. 1 is a slightly enlarged isometric view of a film element of the invention;

FIG. 2 is a greatly enlarged cross-section of a film element of one embodiment of the invention;

FIG. 3 is a schematic elevational view of several film elements of FIG. 2 in a stacked relation;

FIG. 4 is a greatly enlarged cross-section of a film element of another embodiment of the invention;

FIG. 5 is a sectional view of three film elements of FIG. 4 in a stacked relation;

FIG. 6 is a greatly enlarged cross-section of a film element of another embodiment;

FIG. 7 is a sectional schematic view of a modified assembly of the insulating film elements;

FIG. 8 is a sectional schematic view of an assembly unit of the insulating film elements;

FIG. 9 is a schematic sectional view on a reduced scale of a plurality of insluating assembly units disposed between the dual walls of a cryogenic container.

Referring now to FIGS. 1 and 2, there is shown an insulating film element generally indicated at 1. This element comprises a plactic base 2 made, for example, of polyethylene terephthalate and coated with a metallic layer 3, consisting, for example, of aluminum. The insulating film elment 1 is provided with a series of deformations each having a protrusion 4. These protrusions, which may be of any desired shape (such as pyramidal or conical), are made, for example, by passing the metallized film 2 through suitable roller dies (not shown). It becomes now apparent that by assembling a plurality of films into a stack, adjacent films will be exclusively in a point contact by the well-defined, patterned locations of the protrusions 4. The film elements 1 are shown in a stacked relation in the diagrammatic view of FIG. 3. The number of protrusions per square inch should be kept at a minimum in order to minimize thermal conductivity by contact, but, on the other hand, should be sufficiently large to prevent sagging and eventual contact of adjacent films between protrusions. To insure a uniform contact pressure and engagement between adjacent film elements, it is desirable to form the protrusions with substantially identical height dimensions and to space them substantially equidistantly over the film element.

Referring now to FIG. 4, there is shown an insulating film element generally indicated at 5. This element comprises a plastic base 6 made, for example, of polyethylene terephthalate and coated on both sides by a metallic layer, 7 and 8, consisting, for example, of aluminum. The use of bilaterally metallized plastic represents a marked improvement over the unilaterally metallized plastic film used heretofore inasmuch as the use of opposed metallic layers cancel out the undesired effects of electrostatic charges that unavoidably appear on the films during their manipulation.

Aluminum coated polyethylene terephthalate films, constituting the base material for practicing the present invention, are commercially available as stock material for capacitors.

Instead of polyethylene terephthalate the plastic base **6** of film element **5** may also be made of a polycarbonate, such as diphenol carbonate. Polycarbonates have two significant advantages over the polyethylene terephthalate in this environment: (1) polycarbonate sheets are more rigid; consequently the film elements used may be of reduced thickness and (2) the heat conductivity of polycarbonates is less than that of polyethylene polyterephthalate.

In order to avoid a metal-to-metal contact between bilaterally metallized film elements, which would disadvantageously increase the thermal conductivity between the film elements, care is taken that the areas of deformation take a particular configuration described hereinbelow with particular reference to FIG. 4 which is a greatly enlarged cross-sectional view of the film element **5** taken across one of the protrusions **9**. Here, it is to be observed that the film element **5** is deformed in such a manner that the upper metallic layer **3** is disrupted or pierced as shown at **10** and the upper portion **11** of the plastic film **6** protrudes therethrough. Thus, the highest portions of protrusions **9**, as viewed from the outer face of metallic layer **7**, will be the apical portions **11** of the plastic film **6**. Consequently, when film elements **5** are being superimposed to form insulating stacks, no metal-to-metal contact will take place between adjacent superimposed films. The film elements are shown in a stacked relation in FIG. 5 and from an observation thereof it is clear that each film element **5** is supported solely by the plastic apex portions **11** of protrusions **9** of the adjacent lower film elements **5**.

It has been found that for aluminum coated polyethylene terephthalate film of a thickness of 2–50 microns having a bilateral aluminum coating of 100–1000 Angstroms each, the number of protrusions, each having a base area of approximately 1 millimeter^2 and a height of somewhat less than 1 millimeter, is advantageously 20/cm.^{2}. It has been further found that diphenol polycarbonate films having a thickness in the order of 0.5 micron and provided with protrusions of pyramidal or conical configuration having dimensions in the order of 1/10 mm. may be successfully used for carrying out this invention.

In case film elements of more reduced thickness are used, the density of protrusions will have to be increased accordingly. It may be generally stated that there exists an inverse relationship between the density of the protrusions on one hand and the thickness of the film elements on the other hand.

Another embodiment of the invention is shown in FIG. 6. While the plastic film **6** is deformed without rupture in the precedingly-described embodiment of FIG. 4, it will be noted in FIG. 6 that there is shown here a film element wherein the lower metallic layer **8** and the plastic film **6** are ruptured to form a small aperture **12** extending through the entire deformation. It is to be noted that the torn upper portion **13** of the ruptured and thus apertured film **6**, as viewed from the surface of metal layer **7** is located higher than the highest edge portions of the dissupted upper metal layer **7**. Thus, again, metal-to-metal contact will be avoided when the film elements of the embodiment shown in FIG. 6 are superimposed to form an insulating stack.

It has been found that insulating stacks composed of apertured or ruptured film elements as described with reference to FIG. 6 also have distinct advantages over the prior known art inasmuch as they make it possible to obtain a better vacuum in the jacket **14** (FIG. 9) with the

same techniques of exhaustion. Apertures **12** prevent the formation of hermetically closed pockets between two adjacent film elements and thus no trapped air will remain within the stack to weaken the vacuum. It has also been found that the distinct advantages achieved by provision of minute apertures in the laminated stack thus effecting a better vacuum far exceeds any disadvantages attributable to the use of the perforations.

It will be understood that the particular protrusions described in connection with FIGS. 4 and 6 may be applied to a plastic base which is metallized on its top face only. It is apparent that if film elements of such a structure are arranged in a stacked relation, there will be an exclusively plastic-to-plastic contact therebetween which, from the point of view of heat insulation, is an improvement over a plastic-to-metal contact.

Measurements of heat conductivity taken of insulating stacks according to this invention showed remarkable improved results compared to the heat conductivity of the known crinkled insulator measured under identical conditions.

First, the lateral conductivity of insulating stacks was measured that consisted of 50–100 aluminized, poly-ethylene terephthalate films of a structure as shown in FIGS. 4 and 5, except that the films were only unilaterally aluminized at their top face. The thickness of the plastic film was 6 microns and the overall thickness of the stacks was 8–15 mm. The value of the vacuum was 10^{-5} mm. of mercury pressure, while the temperature conditions were 77° K. The lateral heat conductivity measured with industrial instruments was found to be 5.4×10^{-7} watt/cm.$^{-1/°}$ K. Next, under the same conditions stacks consisting of bilaterally aluminized film elements of the structure shown in FIGS. 4 and 5 were measured. The lateral heat conductivity now was found to be 2.4×10^{-7} watt/cm.$^{-1/°}$ K. The improvement in the heat insulating properties of bilaterally metallized stacks over unilaterally metallized stacks may be explained by the absence of electrostatic charges in the former. Such charges, present in unilaterally aluminized film elements, cause an attraction therebetween, thus increasing the heat conductivity.

The above noted results show that the heat insulating properties of insulating stacks consisting of film elements constructed in accordance with the invention are significantly improved over insulating stacks consisting of known unilaterally aluminized crinkled poly-ethylene terephthalate films of comparable dimensions. Under identical conditions the lateral conductivity of the latter was found to be 5.98×10^{-6} watt/cm.$^{-1/°}$ K.

The deformations in the film elements described hereinbefore and shown in FIGS. 1 through 6 are uniformly directed in that the protrusion resulting therefrom are all located on the one side of the film element. Referring now to FIG. 7 it is conceivable and within the scope of the invention to deform the film element in such a manner that its surface area is deformed on opposed sides. The deformations are preferably arranged on elements **15** in such a manner that adjacent protrusions on the same film element **15** are oppositely oriented. Thus, as seen in FIG. 7, adjacent protrusions **16** and **17** are on opposed faces of element **15**. When stacking such film elements it is preferred to alternate the same with non-deformed plastic films **18** which may be either metallized or non-metallized.

After preparing the film elements in accordance with the foregoing description, the same are cut to the desired size, assembled in stacks, and optionally enclosed in a fluid permeable envelope **19** (FIG. 8) made, for example, of cheese cloth to form a stack unit generally indicated at **20**. These units are then placed in jacket **14** formed by walls **21** and **22** of cryogenic container (not shown in its entirety). As a final step, the air is exhausted from the jacket by any means known to those skilled in the art.

It will be understood that if the accessability of the space to be insulated permits it, stack units, or a single stack of large area, may be used without first placing the assembled film in envelopes.

Although only four embodiments of the invention have been depicted and described, it will be apparent that these embodiments are illustrative in nature and that a number of modifications in the apparatus and variations in its end use may be effected without departing from the spirit or scope of the invention as defined in the appended claims.

That which is claimed is:

1. A film element to be assembled in plural superimposed layers into a thermal insulating stack comprising a plastic base having two faces, a metal coating on at least one face thereof, a series of individual protrusions in said element over at least one entire face thereof, each protrusion including a disrupted area of one of said metal coatings and an apical portion of said plastic face projecting beyond said disrupted area, said apical portions of said element constituting the sole, substantially point contact with an adjacent superimposed film element when assembled into a stack.

2. A film element as defined in claim **1**, wherein said protrusions are of substantially identical height dimensions and are spaced substantially equidistantly.

3. A film element according to claim **1**, wherein said protrusions are of a pyramidal shape.

4. A film element according to claim **1**, wherein said protrusions are of a conical shape.

5. A film element according to claim **1**, wherein said film element is punctured through at least some of said apical portions.

6. A film element as defined in claim **1**, wherein said plastic base is a polycarbonate.

7. A film element as defined is claim **6**, wherein said polycarbonate is diphenol carbonate.

8. A thermal insulating stack comprising two series of alternately superimposed films, each film of the first series having a plastic base, a metal coating on at least one face thereof, a plurality of individual protrusions in each of said films of said first series over both faces thereof, said protrusion being so arranged that adjacent ones in said films of the first series are located on opposite faces of the film, each said protrusion including a disrupted area of one of said metal coating and an apical portion of said plastic base projecting beyond said disrupted area, the films of said second series including a plastic base and having planar faces, said apical portions on said films of the first series constituting the sole, substantially point contact with the films of said second series.

9. A thermal insulating stack according to claim **8**, wherein films of said second series have a metal coating on at least one face thereof.

References Cited

UNITED STATES PATENTS

1,914,207	6/1933	Knight	161—137 XR
2,098,193	11/1937	Munters	161—137 XR
2,179,057	11/1939	Schuetz	161—130 XR
3,009,601	11/1961	Matsch	161—113 XR
3,152,033	10/1964	Black et al.	161—130 XR
3,190,412	6/1965	Rutter et al.	161—137 XR

MORRIS SUSSMAN, *Primary Examiner.*

ALEXANDER WYMAN, *Examiner.*

R. H. CRISS, *Assistant Examiner.*