United States Patent [19]

McGrew

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[45] Aug. 28, 1973

[54] **CELLULAR INSULATION FOR USE WITH LOW TEMPERATURE LIQUIDS**

[75] Inventor: **Jay L. McGrew**, Littleton, Colo.

[73] Assignee: **Martin Marietta Corporation**, New York, N.Y.

[22] Filed: **Oct. 16, 1970**

[21] Appl. No.: **81,400**

[52] **U.S. Cl.** .... **161/68**, 161/113, 161/127, 220/9 LG, 220/10, 220/15

[51] **Int. Cl.** **B32b 3/02**, B32b 3/12, B65d 25/18

[58] **Field of Search** .... 161/68–69, 109, 112, 113, 161/127; 220/10, 15, 9 LG

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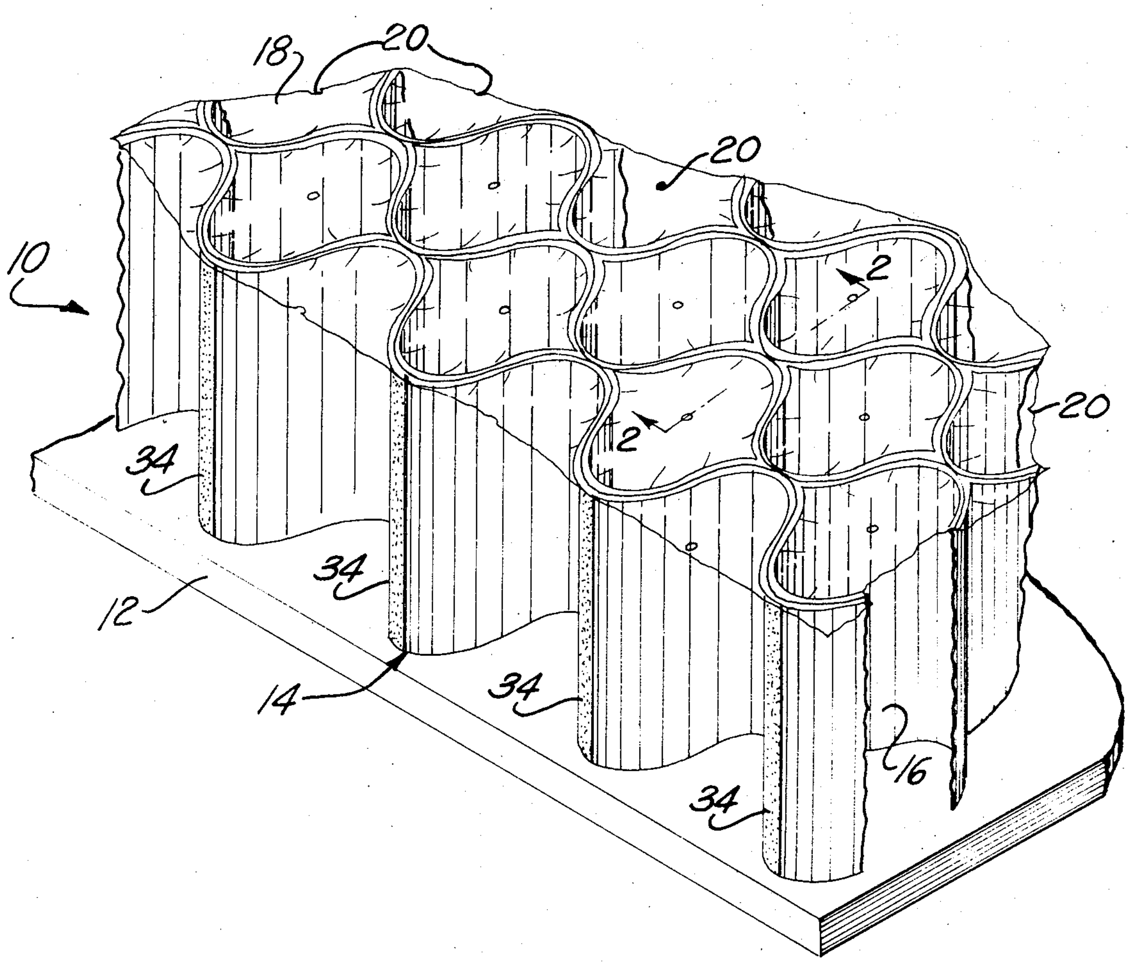
Primary Examiner—Philip Dier
Attorney—Phillip L. DeArment and Gay Chin

[57] **ABSTRACT**

Capillary insulation for low temperature liquids in which a cellular structure defines a plurality of discrete cells enclosed by a capillary cover with capillary openings communicating with each cell. The cell walls and the cover are designed to minimize the effects of strains imposed thereon by providing an excess of material both in the walls and the cover thereby permitting them to deflect without adversely affecting operation of the insulation. The cell walls are formed in an S-shaped configuration and the cover is dimpled to provide the desired excess material. The capillary openings are reinforced by a toroidal rib extending around each opening.

7 Claims, 5 Drawing Figures



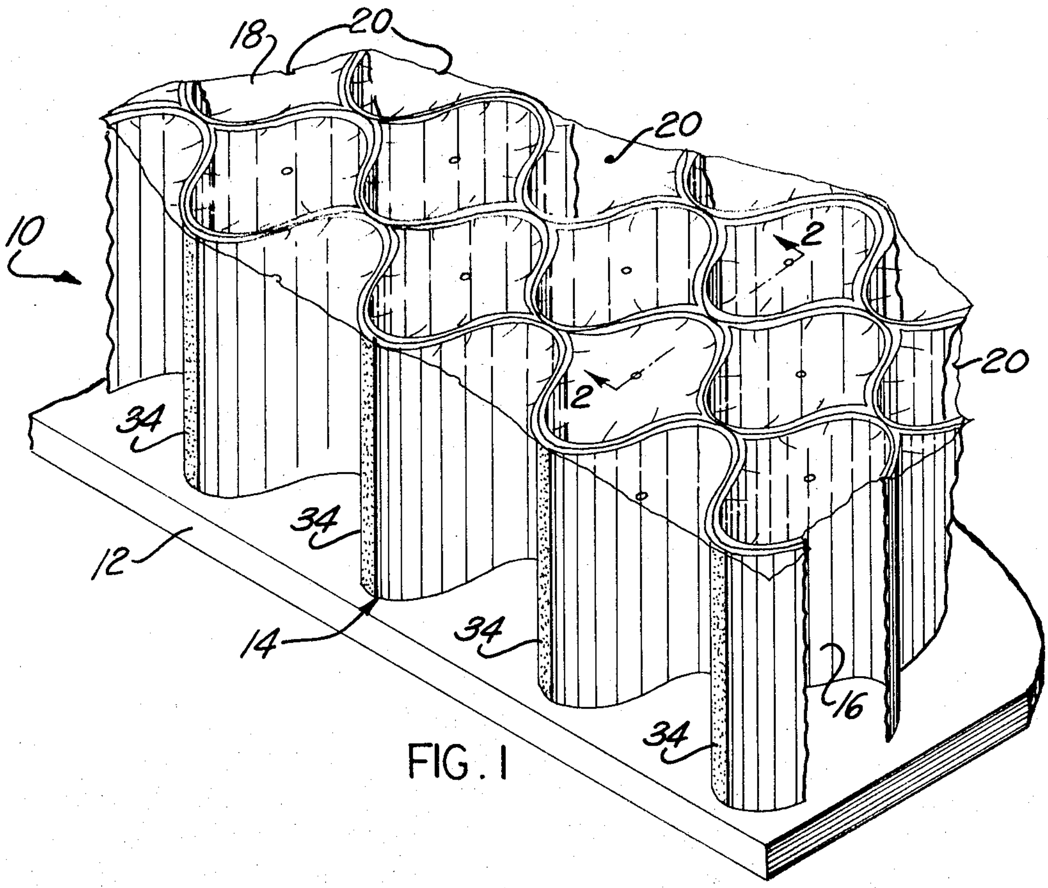


FIG. 1

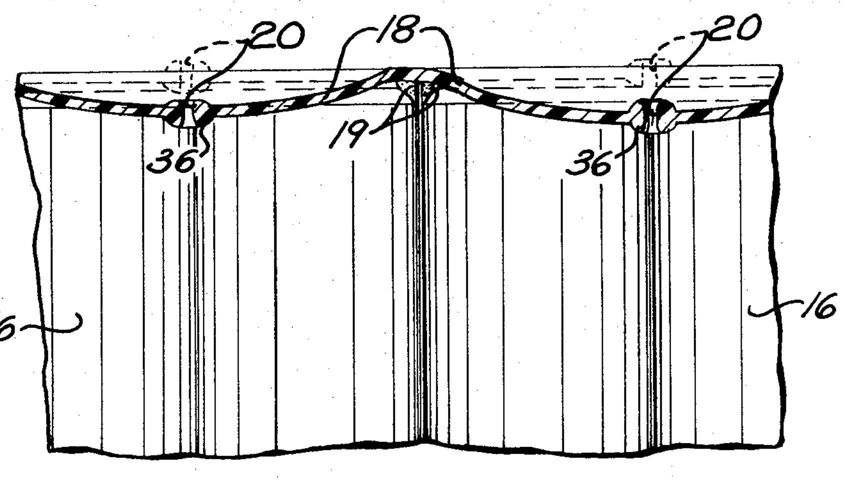


FIG. 2

INVENTOR
JAY L. McGREW

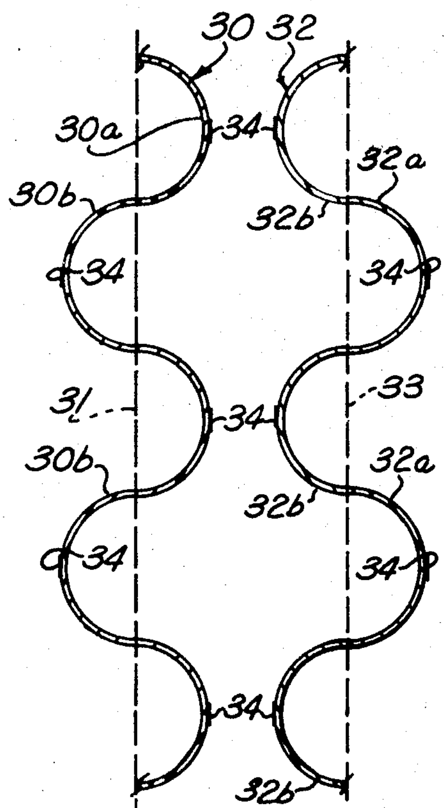


FIG. 3

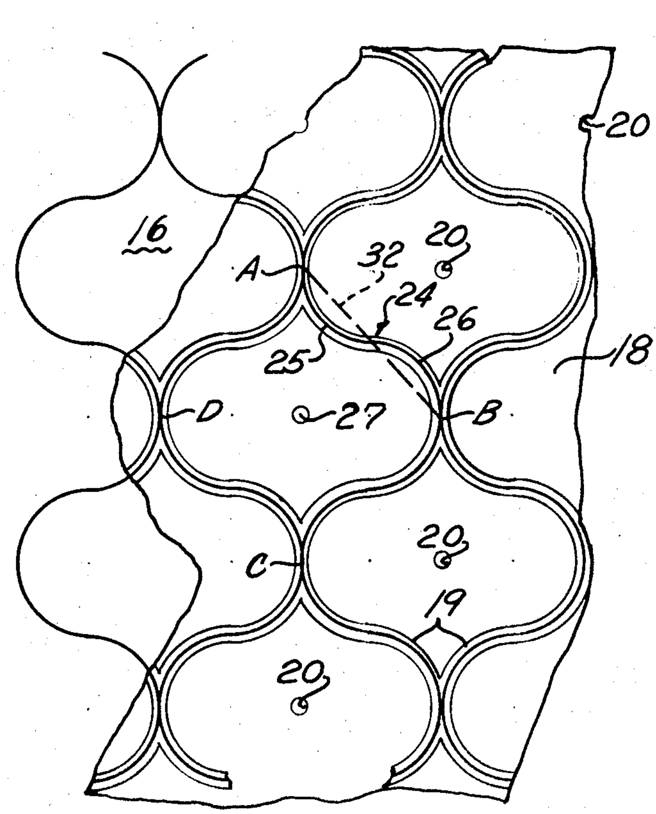


FIG. 4

INVENTOR
JAY L. McGREW

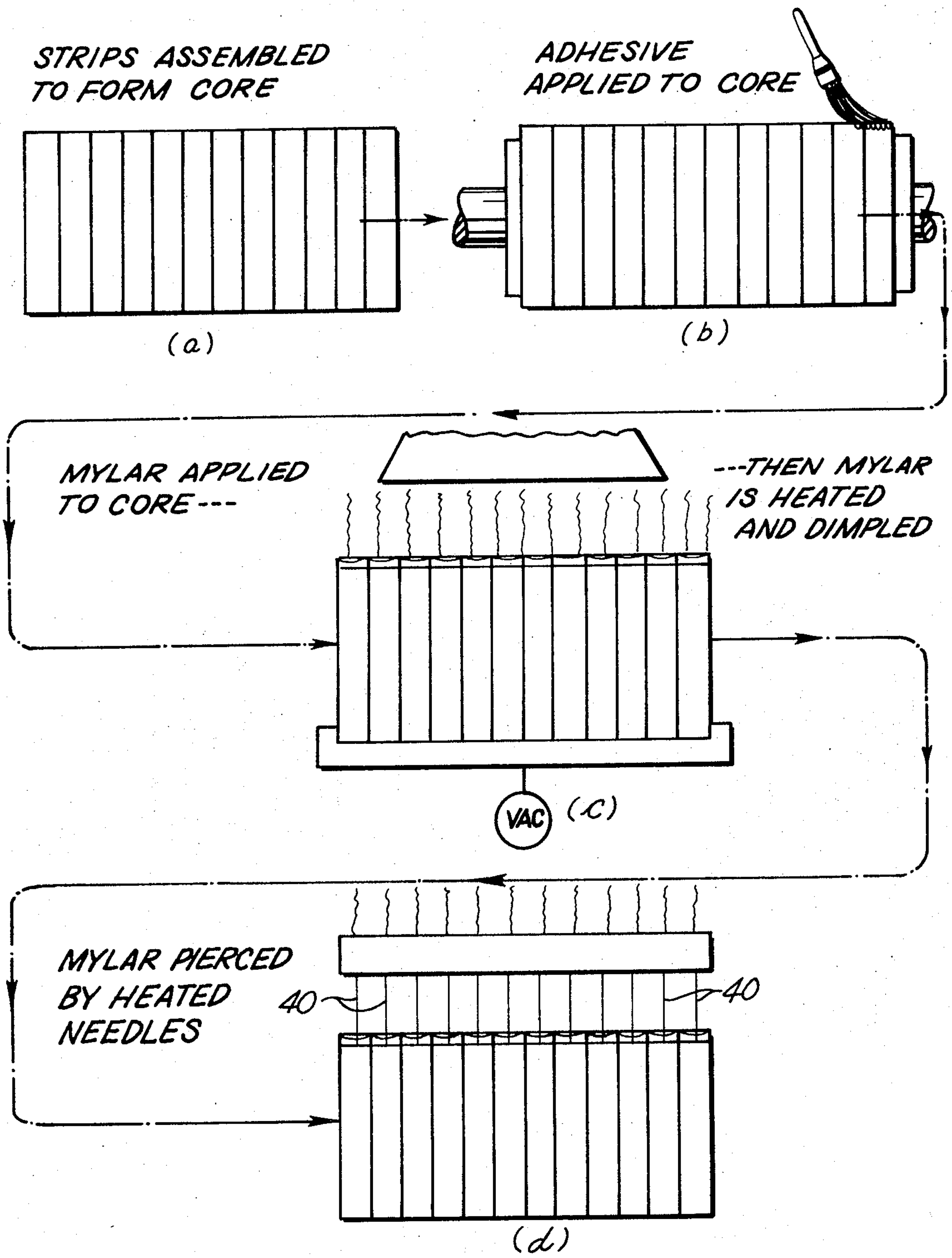


FIG. 5

INVENTOR
JAY L. McGREW

CELLULAR INSULATION FOR USE WITH LOW TEMPERATURE LIQUIDS

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.D. 2457).

This invention relates to insulating structures and, more particularly, to an improved insulation for use with low temperature liquids.

The handling and storing of low temperature liquids such as liquid nitrogen, liquid hydrogen and liquid oxygen have presented substantial problems. One particularly trouble-some problem relates to the need for a suitable insulation which is relatively inexpensive but which is effective over long periods of time.

There is disclosed in copending application Ser. No. 44,678, filed June 9, 1970 now U.S. Pat. No. 3,675,809, and assigned to the assignee of this invention, a new concept in insulation for handling and storing low temperature liquids and which appears to be practical and effective solution to the insulation problem and a substantial improvement over prior insulation techniques. As disclosed in that application, the insulation comprises a cellular structure which provides a plurality of discrete cells in which a gas column is established between the container wall and the body of liquid. A capillary cover substantially closes the liquid side of each cell with the cover having at least one capillary opening per cell. The capillary openings are so designed that a stable capillary gas-liquid interface or membrane is formed at the capillary opening. These gas columns and their associated stable gas-liquid interfaces insulate the liquid from the container walls and, in addition, support the liquid in the container thereby permitting fabrication of the cellular structure from materials which have low strength and weight as well as low thermal conductivity. For example, as disclosed in that application, the cellular structure may be fabricated from various materials.

The low structural requirements of the cellular structure results in a construction in which the cellular material actually contacts but a very small area of the surface of the container while the gas columns contained within the cellular structure cover a far larger area of the container wall. Thus, the thermal conductivity of the insulation approaches that of gas in the cells. Moreover, the small amount of cellular material required to form the cellular structure reduces both the thermal conduction through the material and the liquid boil-off required to cool the insulation to the operating temperature.

While the loads imposed on the cellular structure are relatively small due to the support provided by the gas columns, nonetheless it is subjected to some loading. These loads arise primarily because of the large temperature difference or thermal gradient which exists across the insulation and also from mechanical loading, particularly when the container or tank is being filled.

Such loading can have an effect on the operation of the insulation. For example, the size of the capillary openings in the capillary cover is important in establishing and maintaining the desired gas-liquid interface. Loads imposed on the capillary cover, which is very thin and flexible, could cause enlargement or even tearing of the opening, in which event the liquid-gas interface would be adversely effected. Another example is

where the capillary cover or the wall for one of the cells is subjected to some strain causing it to deflect or bend. Absent some provision to accommodate such deflection, it will be transmitted to the next adjacent cell and so on across the entire cellular structure. Moreover, the deflection will tend to be magnified and multiplied as it passes from cell to cell so that a relatively large total deflection may be experienced by the insulation structure which in many instances will cause physical damage to the structure.

Accordingly, it is desirable to construct the capillary insulation in such a manner that the effect of undesirable stresses or loads, even through relatively small, on the cellular material are minimized, and it is the principal object of this invention to provide a capillary insulation of the type described in which the effects of mechanical and thermal stresses on the insulation are minimized.

More specifically, and in accordance with the principles of this invention, there is provided a capillary insulation comprising a cellular structure which provides a plurality of contiguous discrete cells with a capillary cover closing one side of the cells and capillary openings in the cover communicating with each cell. The cellular structure is so formed that the cell walls have an excess of material between points of interconnection. In the preferred embodiment, this excess material is characterized by cell walls which are S-shaped in cross-sectional configuration. This is achieved by forming the cells from a plurality of strips of material each of which is in the form of a sine wave with adjacent strips being staggered and connected at spaced points therealong. The resultant cells have cell walls of the aforementioned S-shaped configuration which permit the individual cell walls to expand and contract relative to the other cells and prevents stress accumulation in the panels.

The principles of the invention further contemplate minimizing stress buildup in the capillary cover by providing excess cover material for each of the cells. The excess cover material may be provided in the form of dimples of folds in the capillary cover. In this way, the capillary cover over each cell may deflect as required to accommodate such stresses and strains as are imposed on the individual cells without affecting the adjacent cells.

The principles of the invention further contemplate minimizing the effects of strains imposed on the capillary cover by forming each of the capillary openings with a reinforcing rib or torous which extends around the periphery of each opening. This toroidal reinforcement minimizes any tendency of the capillary cover to tear at the capillary opening and insures that stresses imposed on the capillary cover will not enlarge the dimension of the opening.

Other aspects and features of the invention will be apparent to those having ordinary skill in the art to which the subject matter pertains from the following description which, together with the attached drawings, discloses a preferred form of the invention.

Referring now to the drawings wherein like reference numerals indicate like parts in the various views:

FIG. 1 is a perspective view of a portion of the capillary insulation constructed in accordance with the principles of this invention;

FIG. 2 is a sectional view along line 2—2 of FIG. 1;

FIG. 3 is a plan view schematically illustrating the strips from which the cellular material is constructed;

FIG. 4 is a top plan view of the assembled capillary insulation with a portion of the capillary cover removed to expose the cellular construction; and

FIG. 5 is a schematic illustration of the method by which the capillary insulation of FIG. 1 may be produced.

Referring now more in detail to the drawings wherein the showings are for the purposes of illustrating a preferred embodiment of the invention only, there is illustrated in FIG. 1 a capillary insulation assembly indicated generally by the reference numeral **10.** The capillary insulation is secured to and carried by a support wall **12** which may be the wall of a tank or any other surface which it is desired to insulate from a low temperature boiling point liquid.

The insulation assembly **10** comprises a cellular structure **14** which includes a plurality of discrete cells **16** and a closure means in the form of a capillary cover **18** extending across the cells and secured by suitable means such as an adhesive **19** to the cellular structure **14.** A suitable filling, not shown, such as rock wool or polystyrene chips, may be provided in the cells to reduce radiation and convection currents. Capillary openings, holes or pores **20** are formed in the cover **18** with each opening being associated with one of the cells **16.**

The cellular structure **14** may be fabricated of any lightweight material which is compatible with the liquid being insulated and which has a low thermal conductivity. For example, plastic impregnated Kraft paper may be used. Both materials are relatively flexible in all directions transverse to the plane of the paper. The capillary cover **18** may be made from a suitable plastic film such as one-mil Mylar film.

As disclosed in detail in the aforementioned copending application, the capillary insulation contemplates the formation of a plurality of discrete gas columns within the cells **16** with the gas columns extending between the surface of the wall **12** and the liquid. The size of the openings **20** are such that a stable capillary interface or membrane is formed at the interface of the gas columns and the liquid, with the membrane preventing liquid from penetrating the gas column so that the gas columns function as insulators. In addition, the gas columns provide support for the liquid so that the relatively weak cover **18** need not support the liquid. A detailed description of the operation and structural details of the capillary insulation, including the size of the openings **20,** is contained in the aforementioned application and the subject matter thereof is incorporated herein by reference.

In accordance with the present invention, the cellular material **14** is constructed such that an excess of wall material is available to permit expansion and contraction of individual cells independently of adjacent cells. This is accomplished in the preferred embodiment by forming each quarter or 90° segment of the cell wall in generally S-shaped configuration. As shown in FIG. **4,** each cell is defined by four quarter segments of the cell wall. These quarter segments extend respectively between points A,B; B,C; A,D; and D,C. It will be noted that the cross-sectional configuration of each of the four quarter segments of the cell wall, extending between any two of the points A, B, C and D, is generally S-shaped in configuration. For example, the quarter segment of the cell wall extending between points A and B and designated **24,** includes a first arcuate portion **25** which bows inward of the cell and a second arcuate portion **26** which bows outward of the cell. Each point along each of the portions **25,26** has a radius as measured from the longitudinal axis **27** of the cell which differs from the radius of the next adjacent point in that portion of the wall. The distance between the two points A,B along the dotted straight line **32** is substantially less than the distance between the same two points as measured along the curving surface of that segment **24** of the cell wall. Accordingly, it should be apparent that more material is provided in the segment **24** due to the curved configuration thereof than if the segment **24** was straight. The excess material thus provided constitutes means which permits the wall **24** to deflect transverse to the axis of the cell without altering the distance between points A and B.

The advantage provided by the excess material can be best appreciated by considering what occurs when a low boiling point liquid is poured into a tank having the insulation of the present invention therein. When the insulation is installed within a tank and the low boiling point liquid is poured into the tank or container and contacts the insulation, the temperature of the insulation, particularly that portion thereof which engages or contacts the liquid, immediately decreases. As a result, the material of which the cellular structure is made tends to contract. Due to the excess material provided in the cell walls, resulting from the S-shaped configuration of a quarter segment of the cell wall, the contraction does not put any undesirable stress or strain on the material, notwithstanding the fact that the entire bottom edge of each cell is fixedly attached to the container wall; rather, the quarter segment tends to straighten out from the full-line position shown in FIG. **4** toward a position represented by the dotted line **32** shown in FIG. **4.** There is a minimum tendency for the material upon contraction to pull points A and B, for example, together which would result in a large total deflection of the insulation structure due to the fact that this would be magnified from cell to cell.

A cellular structure having S-shaped walls may be fabricated in various ways but in the preferred form is achieved by fabricating the structure from a plurality of individual strips or ribbons of material which are then assembled in the configuration shown in FIG. **4.** For example, referring to FIG. **3,** two strips or ribbons **30,32** as they are shaped in the assembled structure are illustrated. Each of the strips is in the general form of a sine wave defined by loops **30*a*, 30*b*** and **32*a*, 32*b*** extending in opposite directions on either side of the neutral axes **31,33** of the strips. The strips are assembled by offsetting one strip from the other in the manner shown in FIG. **2** so that every loop **30*a*** of one strip extending in one direction engages every loop **32*b*** of the other strip extending in the opposite direction. Adhesive means **34** may be used to securely fasten the two abutting loops together. However, it should be noted that the area over which the adhesive **34** is applied is relatively small so that the cell walls immediately adjacent the adhesive remain free to deflect.

While cell walls having a sinusoidal configuration have been illustrated, it will be appreciated that other non-planar geometrical configurations may be used as well, and it is not the specific configuration but rather the provision of an excess of cell wall material between the points where the strips are connected which is important to this invention.

In addition to providing excess cell wall material to accommodate stresses imposed on the cellular structure, similar provision is also made for relieving the stresses imposed on the capillary cover **18.** To this end, an excess of cover material is provided for each of the cell **16.** As shown in FIG. **2,** the capillary cover **18** is illustrated as being non-planar, having a concave or dish-shaped configuration over each of the cells **16** so that the distance across the cell as measured along the surface of the cover **18** is greater than the corresponding width of the cell. This excess of material permits the capillary cover for each cell to deflect between the positions shown in solid lines and the position shown in dotted lines in FIG. **2.** This enables the capillary cover to accommodate strains imposed on each individual cell without transmitting these strains or stresses to adjacent cells.

When the liquid having a low boiling point is poured into the container and contacts the cover **18,** the cover, as discussed above in connection with the material of the cell walls, also tends to contract due to the temperature change therein. The cover **18** is made of polyethylene terethphalate film marketed under the trademark Mylar. This contraction results in the Mylar cover deflecting from its full-line position, shown in FIG. **2,** to the dotted position shown in FIG. **2.** Due to the fact that the cover deflects in this manner, which is possible because of the excess material provided therein, a minimum of stress is imposed in the cover due to the temperature change therein.

In addition to minimizing the effects of stresses imposed on the capillary cover, there is an additional important benefit achieved by this construction. In particular, the dimpled cover construction insures that the size of the capillary opening **20** remains substantially constant even when the capillary cover is subjected to stresses and strains resulting from contact with the liquid. This benefit is best understood by considering the capillary cover as being stretched taut across each cell **16.** Under those conditions, any temperature change in the cover **18** results in stresses therein and, which may alter the size of the opening **20.** Since the dimensions of the capillary openings **20** are of critical importance to the maintenance of the proper capillary interface between the liquid and gas, any change in the size of the opening will have an adverse effect on that interface. However, by providing the dimpled or concave construction of the capillary cover, sufficient excess cover material is provided to permit deflection of the cover without causing undue stretching of the cover.

Additional provision is made to preclude any enlargement of the capillary openings **20** due to stresses imposed on the capillary cover **18.** This additional provision is illustrated in FIG. **2** and comprises reinforcement means **36** which extend around each of the openings **20.** As shown, this reinforcement means comprises a thickened section of the cover which, in cross section, is in the form of a torous. The toroidal reinforcement **36** thus provides additional strength at the capillary openings so that any tendency of the openings to enlarge or tear when the cover is under stress is effectively resisted.

Referring now to FIG. **5** there is schematically illustrated one method by which the described insulation may be produced. Thus, a plurality of strips of the type shown in FIG. **3** are assembled. If desired, the strips may be previously corrugated to the desired configuration and adhesive applied to the points **34** where the adjacent strips are to be interconnected. The strips are then moved together and the adhesive allowed to harden to form the basic cellular structure. Thereafter, as shown at step (b), adhesive is applied to the upper edges of the joined strips. A film is then layed over the cellular structure and in engagement with the applied adhesive. After the film is attached, pressure differential is established across the film as shown at step (c). While the pressure differential is applied, heat is also applied to the cover. As shown, the pressure differential is in the form of a vacuum, and the combination of heat and vacuum dimples the cover over each cell by stretching the film beyond its elastic limit and pulling the film a small distance down into the cell. The vacuum is applied after the adhesive has set up and secured the cover to the cellular structure so that the stretching of the film occurs only in each individual cell. Thereafter, the dimpled cellular structure is moved to step (d) where a plurality of heated needles **40** pierce the holes **20** in the dimpled capillary cover. These needles melt the film in the area immediately adjacent to the pierced hole causing the plastic material to flow away from the hole and form the desired toroidal configuration shown in FIG. **2.** The needles are then withdrawn and the completed insulation is ready for use.

It will be apparent from the foregoing that the described insulation is well suited to achieving the objectives set forth. Thus, the cellular structure is designed to accommodate thermal strains resulting from temperature changes therein. Similarly, the capillary cover is designed to minimize development of stresses. Still further, the critical sized capillary openings are designed to maintain the desired opening dimension even when the cover is subjected to stresses. Each of these features is accomplished in an insulation assembly which can be fabricated from relatively inexpensive materials and by relatively simple manufacturing techniques.

For ease of description, the principles of the invention have been set forth in connection with a single preferred embodiment. However, it is not intended that the illustrated embodiment or the terminology employed in describing it is to be limiting since variations of these may be made without departing from the spirit of the invention. Rather, it is desired to be restricted only by the scope of the appended claims.

Thus having described the invention, what is claimed is:

1. An assembly for retarding heat transfer between a surface and a liquid, said assembly comprising:

a cellular structure adapted to be associated with the surface to be insulated and including at least one cell for containing insulating gas,

means for providing a stabilized capillary gas-liquid interface closing the end of said cell, and

said means comprising a cover having an opening therein for providing said stabilized gas-liquid interface,

said cover comprising an excess of material in the portion thereof extending across said cell whereby said cover may deflect relative to said cellular structure due to temperature change experienced by said cover, said portion of said cover being curved into said cell that the distance between the walls of the cell at the closed end thereof is less than the dimension of the cover extending therebetween.

2. The insulation assembly of claim **1** wherein said cellular structure defines a plurality of cells,

said cover comprising a flexible cover sheet extending across each of said cells, said cover having a plurality of openings therein, each opening communicating with one cell and providing a stable capillary gas-liquid interface therein, and

each portion of said cover extending across each of said cells being curved into its respective cell.

3. Insulation for retarding heat transfer from a surface to a liquid comprising,

first means providing a plurality of discrete cells each having a longitudinal axis and adapted to contain insulating gas,

means for providing a stabilized capillary gas-liquid interface closing the ends of the cells, and extending transversely to the longitudinal axes of said cells,

said plurality of discrete cells being defined by a cellular structure constructed of a plurality of ribbons which are interconnected at spaced locations,

said ribbons comprising cell walls defining each cell and having portions thereof common to the adjacent cell, and

the portions of said ribbons extending between said points of interconnecting being nonplanar in configuration to enable movement thereof to occur transverse to the longitudinal axis of the cell in response to temperature changes encountered thereby.

4. The assembly of claim **3** wherein said non-planar portions of said cell wall are generally S-shaped in cross-sectional configuration.

5. Insulation for reducing heat transfer from a surface to a liquid comprising,

first means adapted to be connected with the surface and providing at least one cell adapted to contain insulating gas,

means for providing a stabilized capillary gas-liquid interface closing the end of said cell,

said means closing the end of said cell comprising a cover sheet having an opening therein communicating with the interior of said cells for providing said stable gas-liquid interface, and

reinforcement means extending around said opening in said cover sheet.

6. The insulation of claim **5** wherein said cover sheet comprises a thin flexible cover sheet extending across said cell and said reinforcement means comprises a generally toroidal rib extending around said opening.

7. The insulation of claim **5** wherein said first means comprises a cellular structure defining a plurality of open cells and said cover sheet extends across each of said cells,

said cover sheet having openings communicating with the interior of each cell,

said reinforcement means comprising a generally toroidal rib extending around each of said openings, said toroidal rib being a thickened section of said cover sheet.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,755,056 Dated August 28, 1973

Inventor(s) Jay L. McGrew

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 7, line 30, change "interconnecting" to --interconnection--.

Signed and sealed this 20th day of November 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents