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VACUUM PANEL INSULATION

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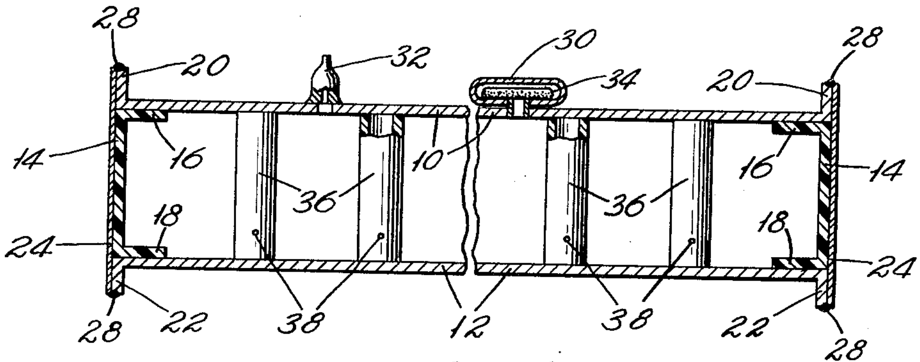

Fig. 1.

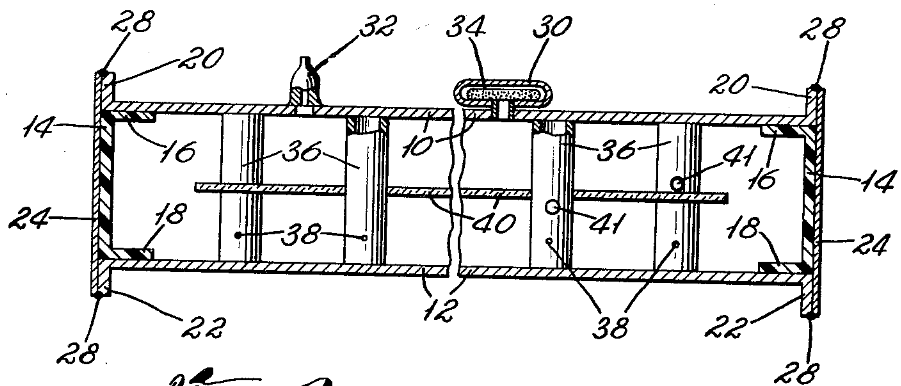

Fig. 2.

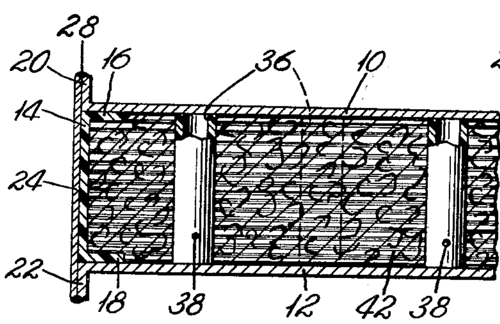

Fig. 3.

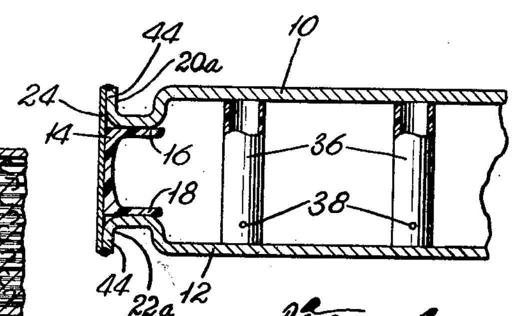

Fig. 4.

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VACUUM PANEL INSULATION
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This invention relates to improvements in vacuum panel insulations. The panel is characterized by an unusually low thermal conductivity and by substantially non-distortable panel walls. These features make the panel especially useful as wall, door or cover structures for refrigerators and freezers of either the home or commerical type, refrigerated panel trucks and cars, or in general in any chamber used in the freezing, refrigeration, storage or conveyance of perishable commodities as well as other low temperature products. However it is to be noted that the panel is also susceptible of use for high temperature service.

The panel of this invention will be described with particular reference to its use in home freezers and refrigerators but without limiting the invention thereto.

The construction of vacuum panels is complicated by the problem of supporting relatively flat surfaces under 15 p.s.i. atmospheric loading. It is readily calculable that the total atmospheric pressure loading on a relatively small panel, e.g. 24" x 24" is more than 8000 lbs. This load must be balanced without destroying the utility or appearance of the panel. The load cannot be balanced by edge supports alone for the side plates would be far too thick and heavy and edge supports would be too massive and heat conductive.

The vacuum panel constructions used heretofore have several shortcomings. For example, in insulating panels having a compressive type insulating material sealed within the panel, the insulating material is the principal means for withstanding atmospheric pressure and preventing distortion of the panel wall. Consequently, the amount of panel distortion is determined largely by the amount and the degree of precompression of the insulating material. The more compressed the insulation, the higher its thermal conductivity and the higher the heat inleak. On the other hand, a reduction in the amount or the degree of precompression of the insulating material causes distortion in the panel walls.

The well-known sensitivity of insulating materials to compression is due to the increased solid-to-solid contact between the particles or fibers forming the material. For example, diatomaceous earth in the high vacuum exhibits a thermal conductivity on the order of 0.5×10^{-3} B.t.u. per hr. per ft. per ° F. without compression. However, under a uniform compression of 15 p.s.i., its conductivity increases eightfold to approximately 4.0×10^{-3} B.t.u. per hr. per ft. per ° F. Therefore, the insulating filler for a vacuum panel should be protected from compression by internal supports or bracing structures which transmit the atmospheric pressure loading between the panel walls.

An internal bracing structure composed of a rigid material such as glass spheres offers a means of reducing thermal conductivity by virtue of the high thermal resistance at the glass-to-steel thermal contact point. However, the disadvantage of this type of construction is that the pressure loading is concentrated at the glass-to-steel contact points, which tends to deform the adjacent unsupported panel wall surfaces.

Moreover, it is not possible to approach an ideal point contact condition unless heavy thick steel panel walls are employed which are substantially non-deformable and will not be pierced or damaged by the supports. Also, from a practical standpoint, since it is only feasible to have a single layer of glass spheres between the panel walls, the spheres themselves provide spans of solid conductive heat paths of relatively low-resistance between such walls. In addition, spheres of reasonable size are necessarily too massive and too strong for the load they support.

Another possible means of balancing pressure forces independently of the insulation filler is by means of solid rods which span the insulation space between the walls. There are several factors, however, working against the efficient use of solid columns. One factor is that it is necessary to prevent buckling of the solid columns. This buckling tendency can be prevented by using large diameter columns, but this results in increased heat conduction through the columns. Heat conduction can be reduced by using fewer columns, but this will require thick panel walls in order to prevent deformation caused by increased spacing between the support columns. Another undesirable factor is that even if the buckling tendency is minimized, the relatively small cross-sectional area of the solid columns provides high localized stresses in the panel walls tending to create deformation.

It is, therefore, an important object of the present invention to provide an improved vacuum panel insulation provided with an internal bracing structure which will minimize distortion or collapse of relatively thin panel walls when vacuum is applied.

Another object of the present invention is to provide in a vacuum panel insulation an improved internal brace structure having a desirable combination of high structural strength and high resistance to conductive heat flow and providing uniform resistance to solid conduction heat flow between the walls of the panel.

Another object of the invention is to provide an internal bracing structure for a vacuum panel insulation adapted to minimize the occurrence of panel distortion and having a uniformly high conductive heat resistance across the vacuum panel space.

Another object of the invention is to provide a novel method of assembling a vacuum panel insulation comprising positioning a plurality of wall panel supports of low heat conductive material of minimum cross sectional area, yet capable of distributing support for the wall panels over a substantially larger area than spherical panel supports, in approximately uniformly spaced relation and arranged transversely of the panel walls, sealing the edges of said panel and evacuating the panel.

Another object of the present invention is to provide a novel method of positioning the bracing structure of a vacuum panel wherein prior to placing the panel walls in closure position the bracing structure is supportably located by means of an isotherm sheet spaced between said panel walls.

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

In the drawing:

FIG. 1 is a view of a cross section of a vacuum panel embodying the principles of the invention;

FIG. 2 is a view similar to FIG. 1 but showing a modification thereof;

FIG. 3 is a similar view of a portion of another modification of the vacuum panel shown in FIG. 1; and

FIG. 4 is a view similar to FIG. 1, but showing another modification thereof.

The interior construction of a thermal insulating panel wall is illustrated in FIG. 1 for a freezer compartment comprising the usual spaced apart outer and inner panel walls or plates 10 and 12, respectively, preferably made of sheet metal and rectangularly formed, although other suitable shapes and materials can be employed.

The space between the edges of the panel walls is joined by a low conductive structure which supports the edges under atmospheric pressure loading and also seals the edge of the vacuum space tightly. This structure comprises a non-metallic compression member of relatively heavy cross section which supports the panel edges, and a metallic member of very small cross section which seals the panel edges. As shown in FIG. 1, the non-metallic compression member may comprise a generally U-shaped plastic supporting channel having a web **14** and terminal legs **16, 18** adapted to supportingly engage the inside surfaces of the panel walls **10** and **12**, respectively. Cleat strips (not shown) may be positioned against the ends of legs **16, 18**, and secured to walls **10** and **12** as by welding in order to hold the channel firmly in alignment with the panel edges.

Provision is made for a narrow out-turned border or flange **20, 22**, integral with each edge of the panel plate **10, 12**, which together with web **14** forms a flat coplanar supporting surface for receiving thereon a thin-gage elongated metal sealing sheet or strip **24**, such as stainless steel, having a thickness of up to about .005″ and preferably less than .002″. The flanges **20, 22** provide an extension of the panel edge against which the metal sealing strip **24** is firmly clamped and welded along its longitudinal edges **28**, top and bottom, as disclosed in copending application to C. M. Heath and A. F. Axelson, Serial No. 783,820, filed December 30, 1958, now Patent No. 2,975,266. Since the surfaces of flanges **20, 22** are disposed in coplanar relation, the thin sealing strip **24** may be run continuously around the panel edge, and the strip does not require forming or overlapping at the corners of the panel which would wrinkle and distort its welding edge.

A modification of the clamping flanges is shown in FIG. 4 wherein the outermost edges of clamping flanges **20*a*** and **22*a*** are approximately flush with panel walls **10, 12**. This arrangement is advantageous when a flush panel is desired. A plastic member (not shown) may be provided, if so desired, to protectingly cover the strip **24**.

Evacuation of the panel insulating space is accomplished by a vacuum pumping system (not shown) which is connected to a tube **32** in panel wall **10**. To produce a suitably low vacuum, a sealed glass vial **34** containing a gettering material such as powdered activated barium can be provided in a getter chamber **30** in communication with the insulation space. The getter material can be conveniently exposed and placed in active contact with the residual gases in the insulation space by deforming the getter chamber **30**, thereby breaking the vial **34**.

According to the present invention, there is provided an improved vacuum panel comprising an internal bracing structure which does not depend on thermal point contact resistance between the bracing structure and the panel walls, and yet possesses a high resistance to conductive heat flow and substantially minimizes the occurrence of panel distortion. This is accomplished by means of columnar stays comprising preferably as illustrated, a plurality of hollow thin-walled cylinders, tubes or columns **36** having flat ends and arranged in substantially uniform spacing with one another and disposed transversely of the panel walls **10, 12** with the flat ends in contact with said panel walls. In order to facilitate evacuation of the hollow tubes, each tube includes a small opening **38** which places the inside of the tube in communication with the panel insulation space.

The tubes **36** can be of a non-metallic, low conductive, relatively non-gas-evolving material having good compressive strength characteristics, a suitable material being glass or quartz. Preferably, the tube material should be a glass filled plastic laminate, e.g., a glass-reinforced phenolic resin such as glass fabric reinforced melamine formaldehyde resin. For high temperature use above about 300° F. the tube material can be a ceramic material.

The dimensions of each of the tubes **36** are self-limiting. It should be thin enough to restrict the path of heat flow, and at the same time be thick enough to provide a sufficient support area at the cylinder face. It should be sufficiently long to provide a suitable temperature gradient. Yet it should have a suitable length to diameter ratio in order to avoid buckling. It should have a sufficiently large diameter so as to provide a broad panel wall support but also not so great as to provide a heat leak path of excessive cross sectional area. The walls of the column supports should be straight and aligned perpendicularly to the panel plates in order that the buckling tendency is minimized, thus permitting the use of a column having a minimum cross sectional area to transmit maximum loads. With consideration for these factors, the outside tube diameter can vary between about ¼″ and ½″ and preferably should be approximately ⅜″. A preferred tube thickness is approximately ¹⁄₁₆″, although thinner or thicker tube walls may be used if so desired. The spacing between tube centers can range between 1½″ and 4″, a desirable spacing being 2″ to 3″. Depending upon the number of tubes, the tube dimensions, and the tube spacing, the distance between panel plates can be as low as ¾″, using face plates as thin as ¹⁄₁₆″. It should be understood that other suitable forms of bracing elements may be used in the practice of the invention, for example hollow rectangular or elliptical tubular stays.

An important advantage of the multi-cylindrical bracing structure of the present invention is that the flat cylinder support faces aid in distributing the panel loading and substantially reduce the high concentration panel loading conditions which are so prevalent in bracing structures having point contact supports. In addition, the uniformly cross sectioned cylindrical stays produce a more desirable and efficient temperature gradient across the panel walls than solid spherical supports, despite the fact that the flat face of a cylinder does not possess the desirable high thermal point contact resistance of a sphere. An obvious advantage of the invention is that the deformation of the panel plates attributable to point contact support is avoided and consequently a small panel thickness can be used.

Vacuum panel insulation tests conducted with ⅜″ glass spheres and ⅜″ diameter glass reinforced plastic columns of ¹⁄₁₆″ wall thickness both positioned on 4″ centers resulted in thermal conductivities of 16.8×10^{-3} and 0.605×10^{-3} B.t.u. per hr. per ° F. per ft. respectively. In addition, the plastic columns provided a smooth flat panel whereas the spheres produced noticeable and objectionable dimpling of the surfaces.

In the modification illustrated in FIG. 2, there is shown a novel means for positioning the columnar stays **36** comprising one or more thin plates **40**, preferably of low thermal conductivity material, such as glass fiberboard disposed between and approximately parallel to the face plates **10, 12**. These internal plates **40** are suitably apertured to receive therethrough the columnar stays **36** and serve to stiffen the stays and reduce their buckling tendency. In addition, these plates can lie against the edge material **14** and similarly support the edge material when a vacuum is applied. Since the plates **40** lie in isothermal planes throughout the major portion of the panel, they have practically no effect upon the heat flow across the vacuum panel. In assembling the vacuum insulating panel suitable pins **41** extending from the cylindrical stays **36** may be provided to supportably hold the plates **40** in place. The pins **41** can be appropriately disposed on opposite sides of the plate **40**, as for example in the alternate arrangement shown in FIG. 2.

In the modification shown in FIG. 3 a light weight insulating material **42**, such as a composite laminar insulation or a powder insulation disclosed in the copending application, Serial No. 597,947 of L. C. Matsch filed July 16, 1956 or Matsch et al., Serial No. 580,897 filed April 26, 1956, respectively, is used as the filler material surrounding the stays to further improve the efficiency of the vacuum panel. In the case of the composite insulation, suitable holes may be provided in the material to accept stays 36 and thus avoid compressing the insulation between the ends of the stays and the panel walls. A reasonably close fit between the stays and the holes may eliminate the need for plates 40 to position the stays. However, plates 40 may still be required to stiffen the stays against buckling. If desired, the space inside the stays 36 may be filled with a low conductive fibrous or particulate material to reduce gaseous conduction through such space.

The structural advantages and the excellent leak tightness of the panel-type insulation of this invention were demonstrated by construction of a model cold box. The box comprised an outside open-top cube 10″ on each dimension, and an inside open-top cube having each of its walls spaced 1″ away from the parallel wall of the outside cube. Five tubular plastic supports ⅜″ diameter with $\frac{1}{16}$″ wall thickness were located on approximately 3″ centers between the parallel walls of each side. The supports were held in position by isothermal sheets located approximately midway between the warm and cold walls substantially as shown in FIG. 2. A plastic channel 14 was also installed substantially as shown in the modification of FIG. 4 with its web spanning the insulation space between the top edges of the inner and outer cubes to support such edges against the force of atmospheric pressure. The inner and outer marginal edges 44 at the top of the double-walled cube were flanged inwardly and outwardly respectively to provide flat co-planar surfaces framing the insulation space. In order to seal the insulation space an enclosing sheet of stainless steel foil (24) .002″ thick was arc welded to the edges 44.

The insulation space was evacuated to an absolute pressure below 10 microns mercury and the evacuation connection was sealed off. A glass vial having sealed within it approximately 1 gram of a preactivated barium getter was then crushed within a sealed extension of the insulation space. Very low absolute pressure could be maintained without noticeable increase in absolute pressure. In addition, there was no noticeable deformation or sagging of the sides of the box between the columnar supports. That an extremely tight insulation space is obtainable with this construction is attested to by the fact that approximately one year after the insulation space was evacuated, measurements showed a vacuum equal to or better than that originally imposed.

The vacuum panel construction of this invention affords improved means for building a domestic type refrigerator or freezer having an overall thermal conductivity of 4×10^{-3} B.t.u./hr.-° F.-ft. or lower. In contrast, the presently used insulations for such appliances have conductivities on the order of 20×10^{-3} B.t.u./hr.-° F.-ft. Advantage may be taken of this improvement by reducing the thickness of the insulation and thereby utilizing more efficiently the space occupied by the appliance. With 4 inches of conventional fibrous non-vacuum type insulation, the volume of the insulation is usually more than half the total space occupied by the appliance. The same insulating effect can be obtained with only 0.8 inch thick vacuum panel insulation of this invention thereby reducing the volume of the insulation by about 80%.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the invention.

What is claimed is:

1. In a heat insulated vacuum panel having spaced parallel panel walls, an improved panel edge sealing construction comprising a non-metallic low conductive compression member supporting the ends of said spaced parallel panels, a flat coplanar supporting surface formed by the edges of said spaced parallel panel walls and said non-metallic low conductive compression member for receiving thereon a metallic member which is gas tightly secured to said edges so as to form a leak-proof construction.

2. In a heat insulated vacuum panel having spaced parallel panel walls an improved panel edge construction which comprises a flange at the edge of each of said spaced parallel panels, a non-metallic, low conductive compression member supporting the ends of said spaced parallel panels, a flat coplanar supporting surface formed by said flanges and said non-metallic low-conductive compression member for receiving thereon a metallic member which is gas tightly secured to each of said flanges so as to form a leak-proof construction.

3. In a heat insulated vacuum panel having spaced parallel panel walls an improved panel edge construction which comprises a flange at the edge of each of said spaced parallel panels, a plastic, U-shaped supporting channel having a web and terminal legs and supporting the ends of said spaced parallel panels, a flat coplanar supporting surface formed by said flanges and said web of said plastic U-shaped supporting channel for receiving thereon a metallic member which is secured to each of said flanges thereby forming a tightly sealed panel edge construction.

4. A heat insulating vacuum panel comprising, in combination, spaced parallel panel walls; an improved panel edge construction including a non-metallic low conductive compression member supporting the ends of said spaced parallel panels, a flat coplanar supporting surface formed by the edges of said spaced parallel panel walls and said non-metallic low conductive compression member for receiving thereon a metallic member which is gas tightly secured to said edges and defining with said parallel panel walls an evacuable insulating space; and a plurality of thin-walled, hollow, cylinders of high strength and low heat conductivity and having an outside diameter of between about ¼ inch to ½ inch and being disposed perpendicularly to said panel walls and traversing said insulating space in approximately uniform spacing to each other, the spacing between cylinder centers being about 1½ inches and 4 inches, each of said cylinders having a flat annular end surface supporting said panel walls along small areas but minimizing sagging of the unsupported areas of said panel walls.

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