Jan. 25, 1966 H. N. K. PATON 3,231,312

FLUIDIZING MAT FOR CONTAINERS

Filed April 5, 1962 4 Sheets-Sheet 1

Fig. 1.

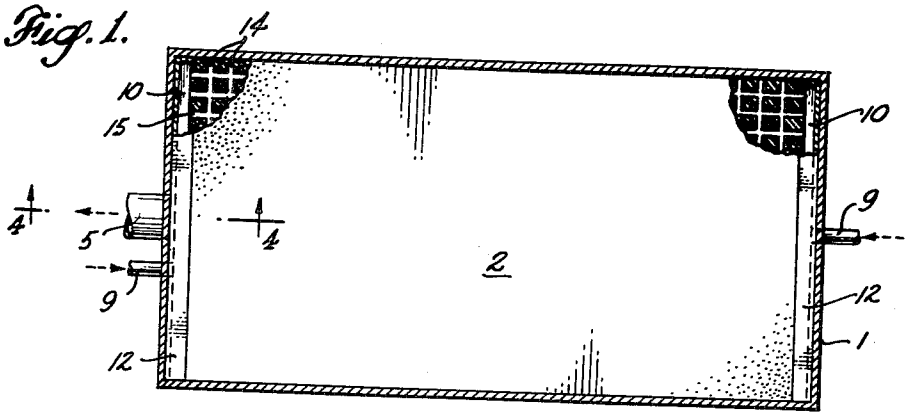


Fig. 2.

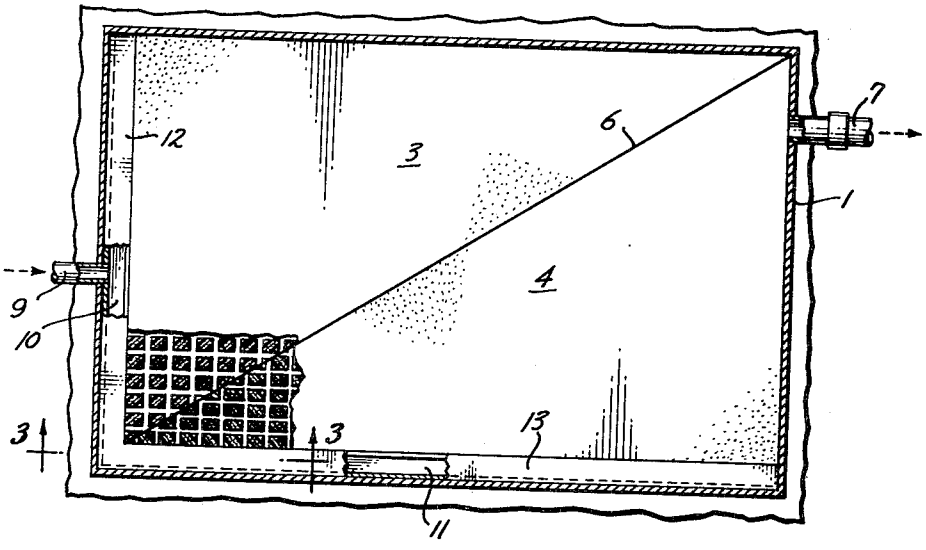


Fig. 3.

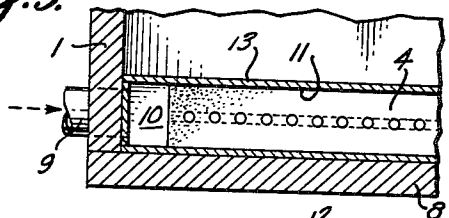


Fig. 4.

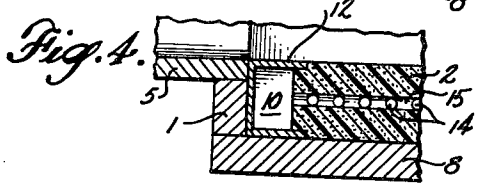
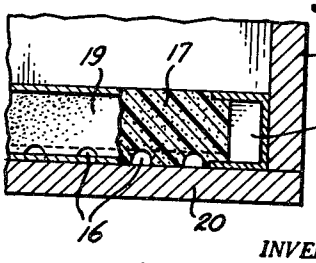


Fig. 5.



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Fig. 6.

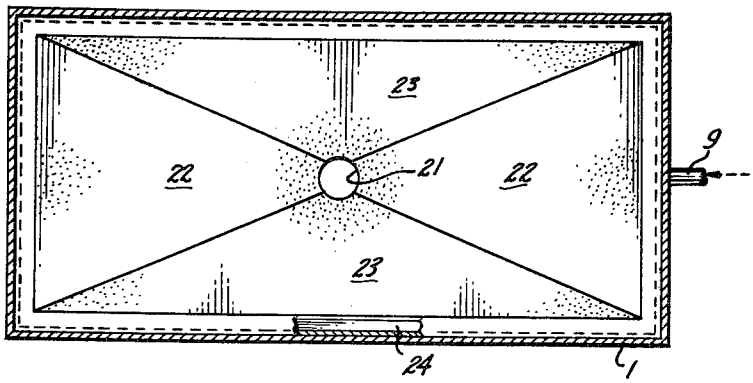


Fig. 7.

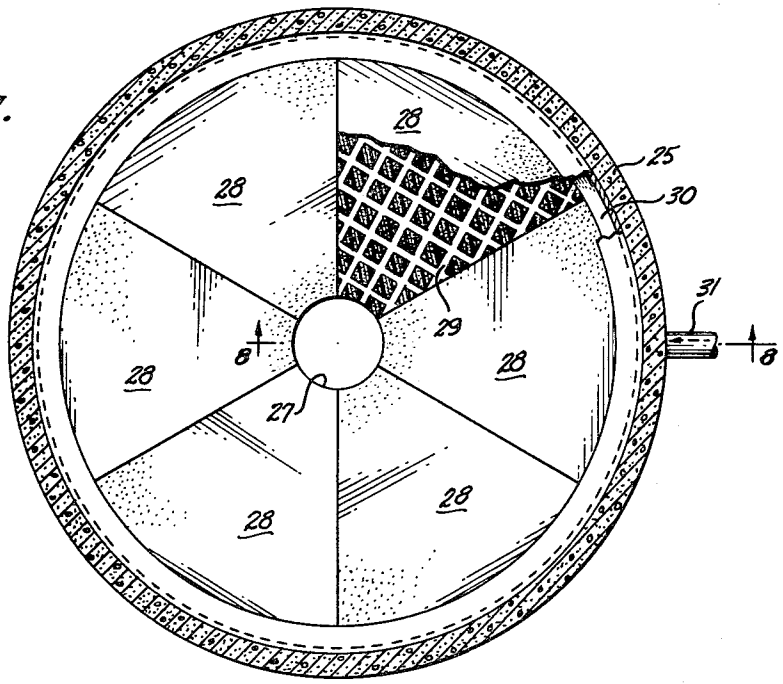
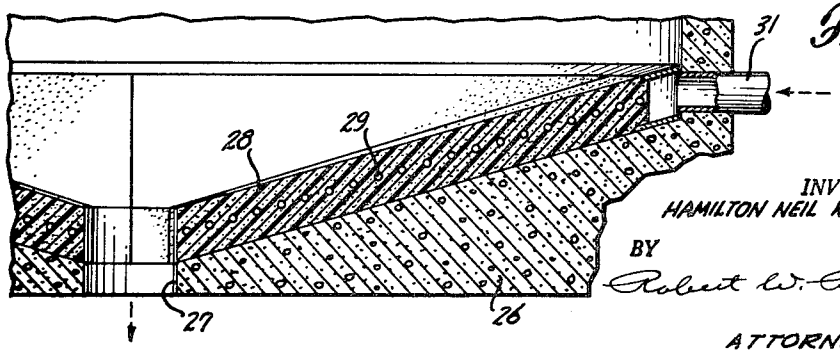


Fig. 8.



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Fig. 12.

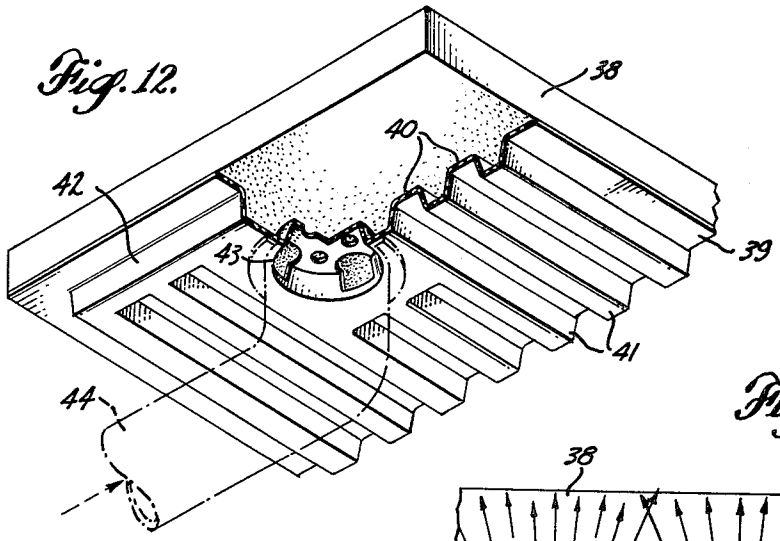
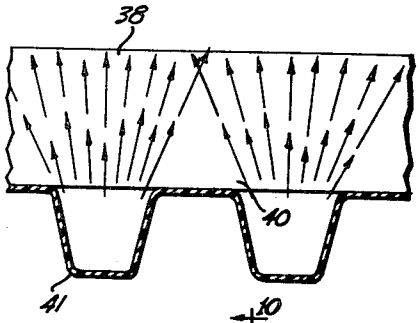


Fig. 13.



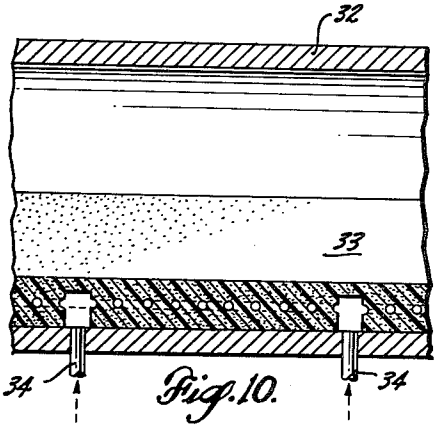
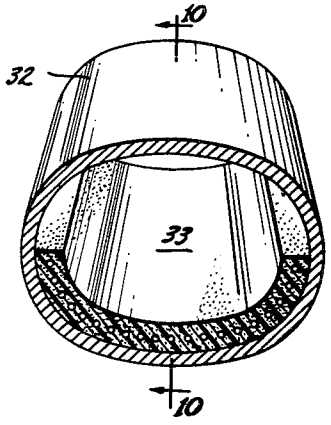


Fig. 10.

Fig. 9.



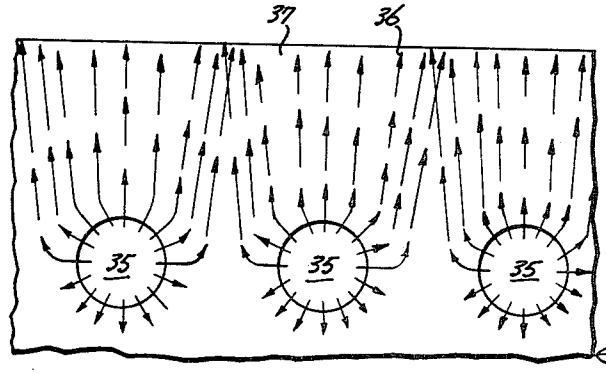


Fig. 11.

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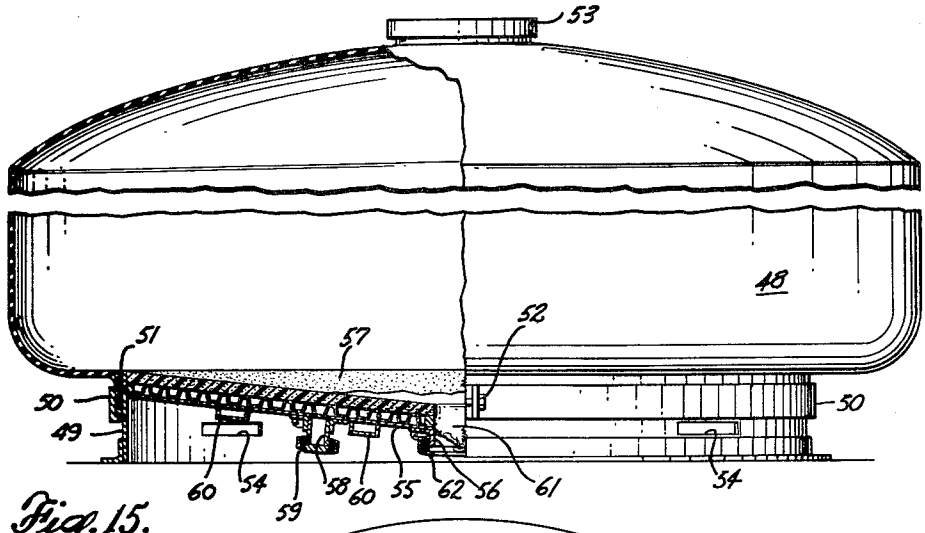


Fig. 15.

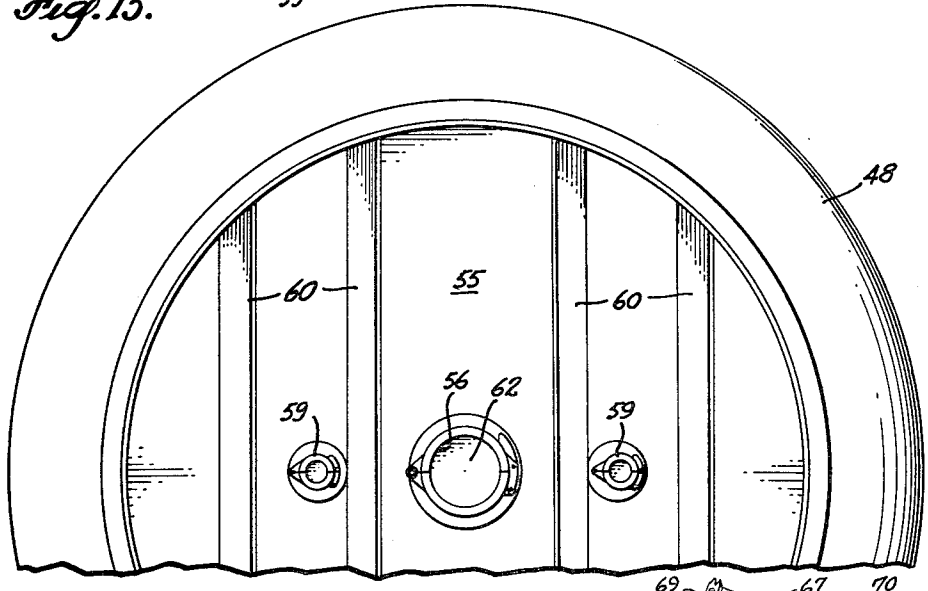


Fig. 16.

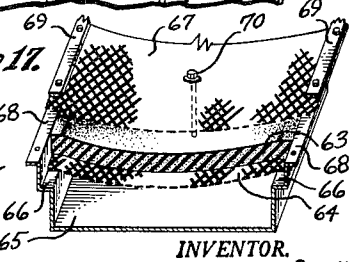


Fig. 17.

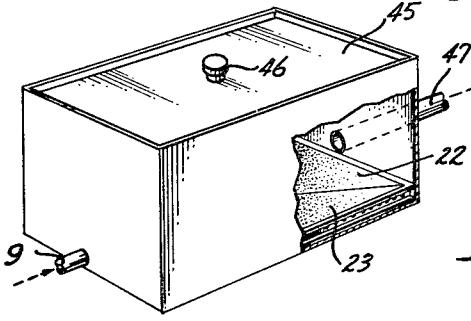


Fig. 14.

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United States Patent Office 3,231,312 Patented Jan. 25, 1966

3,231,312

FLUIDIZING MAT FOR CONTAINERS

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Filed Apr. 5, 1962, Ser. No. 185,482
10 Claims. (Cl. 302—29)

The fluidizing mat of this invention is utilized as a floor element for a container in which granular material of either fine or coarse character is stored or transported. The purpose of such a mat is to aerate dynamically the granular material at and near the bottom of the mass in the container to facilitate discharge of such material through a discharge opening in the lower portion of the container. This application is a continuation-in-part of my abandoned patent application Serial No. 827,582 filed July 16, 1959 which was a continuation-in-part of my earlier abandoned patent application Serial No. 704,164, filed December 20, 1957 for Fluidizer Mats and Unloading Methods.

Examples of fine granular material for which such invention is useful are flour, powdered sugar and cement, examples of coarser granular material for which the invention can be used are granulated sugar and cracked wheat, and an example of a still coarser material for which such invention can be used is whole wheat.

The theory of dynamically aerating granular material for fluidizing it to flow through ports from containers or along conduits is not new, but the equipment used for this purpose heretofore has had various disadvantages. The principal devices used for this purpose have included a porous layer overlying a plenum chamber. Such overlying layer has, for example, been heavy cloth of close weave such as canvas stretched taut over the chamber or a hard material such as porous stone or cement. In either case, it was necessary for the material to be strong enough to bridge across the plenum chamber and support the load of material above it. Because of the load bearing limitations of such material, the width of the plenum chamber and, consequently, of the conduit or other container in which the aerating equipment was located, was limited. Also, the quantity of material which could be carried in such a chamber without damage to it was limited by the load bearing capacity of the porous material. It was, therefore, impractical to use aerating equipment of this type as the floor of a large bin.

Porous stone or concrete slabs used to cover plenum chambers for fluidizing granular material above them have had the disadvantage of being heavy, requiring complex and expensive supporting structures to support such equipment. Moreover, such slabs, while hard, were also brittle and subject to failure by cracking, particularly if subjected to a sharp impact or concentrated bearing conditions caused by warpage of the supporting structure. Moreover, such material was likely to chip and the chips would adulterate the granular material supported by it, which would be undesirable, if such material were a food product such as flour, sugar or wheat. Expansion and contraction of such material caused by temperature changes present a difficult problem of sealing joints between adjacent sections of such material.

A body of felted unspun fibers of wood, glass, mineral wool or asbestos has been proposed, but it is difficult to provide such a layer with uniform permeability.

The fluidizing mat of the present invention has decided advantages over equipment of the types previously used as described above. An installation according to the present invention can be used either as the permanent floor of a container such as a bin or conduit, or can be

provided in sections of any size to be interconnected and assembled at will in the bottom of a container. Moreover, such a fluidizing mat can be used in connection with a container having rigid walls, or a container of collapsible type having limp membrane walls.

The material of which the fluidizing mat is made is light, flexible and resiliently compressible and, therefore, has the advantage that it cannot be broken by impact or warpage of its support, or being supported on an uneven surface.

An object in utilizing such resiliently compressible material of sponge-like character is to enable the porosity of the material surface to be regulated automatically both by the inherent sealing tendency of the ruptured cell walls and by the amount of load imposed on the mat by the material in the container, thus effecting an automatic air valving action.

An advantage of the particular resiliently compressible material used is that it can be easily repaired if it is ruptured simply by cutting out the defective portion of the mat, replacing it with a replacement portion and bonding such replacement portion to the remainder of the mat.

In proportioning the resiliently compressible material of the mat and the air supply duct work for it, it is an object to correlate these features so as to obtain an emanation of air distributed uniformly over the mat when the load of the material in the container is exerting uniformly distributed pressure on the mat, while the emanation of the air from different portions of the mat varies if the load of material on it is not uniform, and such variation in air flow is substantially inversely proportional to the pressure exerted by the material on the mat. Such distribution of air emanation from the mat is attained while at the same time providing adequate support for the resiliently compressible material of the mat.

A specific object is to provide an effective combination of a fluidizing mat and a collapsible container wall forming a bag which may be collapsed into a small bundle for storage purposes.

Alternatively, it is an object to provide fluidizing mat units of various sizes and shapes which can be readily assembled and connected for cooperation as a temporary floor in containers of various types.

These advantages and objects can be obtained by utilizing a fluidizing mat made of sponge material having fine pores which is resiliently compressible. Preferably, such material is of synthetic character so that it can be manufactured under controlled conditions to particular desired specifications. One satisfactory material for this purpose has beeen found to be polyurethane foam, and another satisfactory material is produced by bonding together small rubber particles. Air is supplied to such resiliently compressible or spongy foam material through supporting structure underlying it which may provide an air distribution duct work. The ducts of such duct work are located sufficiently close together to afford substantially uniform air distribution through the interconnected pores of the foam or bonded particle mass for emanation from the upper surface of the mat material in a substantially uniform pattern while being located far enough apart so that the flexible material will have adequate ability to bridge across the ducts without excessive deformation under load.

FIGURE 1 is a plan of a fluidizing mat in the bottom of a container formed as a single unit with parts broken away, and FIGURE 2 is a plan of a generally similar structure but showing the mat formed in two complemental sections also with parts broken away. FIGURE 3 is a detail section taken on line 3—3 of FIGURE 2. FIGURE 4 is a detail section on line 4—4 of FIGURE 1.

FIGURE 5 is a detail section through a portion of a fluidizing mat generally similar to FIGURE 3 but showing an alternative type of construction.

FIGURE 6 is a plan of a modified type of fluidizing mat section arrangement in the bottom of a container having a central discharge opening, parts being broken away.

FIGURE 7 is a plan of a sectional fluidizing mat in the bottom of a container of circular cross section, such as a silo, with parts broken away, and FIGURE 8 is an enlarged cross section through such mat and the floor supporting it taken on line **8—8** of FIGURE 7.

FIGURE 9 is a top perspective of a conduit having a fluidizing mat installed in it, the near end of the conduit being broken away to reveal its interior. FIGURE 10 is a vertical section through the conduit of FIGURE 9 taken on line **10—10**.

FIGURE 11 is a diagrammatic vertical section through a fluidizing mat illustrating the theory of air permeation through the mat and emanation from the mat surface.

FIGURE 12 is a bottom perspective of a modified type of fluidizing mat structure with parts broken away. FIGURE 13 is a fragmentary detail vertical section through a portion of the fluidizing mat unit shown in FIGURE 12.

FIGURE 14 is a top perspective on a reduced scale of a collapsible type of container having a fluidizing mat unit floor.

FIGURE 15 is a side elevation with parts broken away of another form of collapsible container having a fluidizing mat floor and a central discharge opening. FIGURE 16 is a bottom plan view of this container with parts broken away.

FIGURE 17 is a top perspective of a fragment of aeration surface of a different type of construction.

In order to illustrate effectively the construction of the fluidizing mat, it will be understood that in the drawings it is shown much thicker and with air supply ducts much closer together than would actually be the case in relation to the size of the container in which the mat would normally be installed. In FIGURES 1 and 2 the container is shown in the form of a bin having rigid walls **1**. The fluidizing mat constituting the floor of the container in FIGURE 1 is formed as a single unit **2** extending over substantially the entire floor area of the container, while in the structure of FIGURE 2 the mat is composed of complemental fluidizing mat sections **3** and **4**. Such sections are of triangular shape having abutting hypotenuse portions. In FIGURE 1 the single mat element, if desired, may be supported to slope somewhat in the direction indicated by the arrow toward the discharge duct **5**, while in FIGURE 2 the sections **3** and **4** may be coplanar or may slope oppositely toward their abutting hypotenuse portions and the hypotenuse line **6**, itself, may be sloped somewhat toward the opening into the outlet conduit **7** adjacent to one corner of the container. In each instance, the outlet conduit will open into the interior of the container immediately above the fluidizing mat.

Also, in each of the instances shown in FIGURES 1 and 2, the fluidizing mat element or elements are supported by the container bottom **8** as shown in FIGURES 3 and 4, and these units can be formed as an integral and permanent part of the container structure or can be simply fitted in the lower portion of the container so that they can be lifted and removed from the container at will. The construction of the fluidizing mat unit itself and the duct work by which air is supplied to the mat is shown in the sectional views of FIGURES 3 and 4, and in the portions of FIGURES 1 and 2 which are broken away. Air is supplied to the mat of FIGURE 1 by air supply pipes **9** communicating respectively with channels **10** extending along opposite ends of the mat. In the installation of FIGURE 2, air is supplied through the pipe **9** to a channel **10** along the end of the mat section **3** and this channel also supplies air to the channel **11** extending along the longer side of the mat section **4**.

The nature of the fluidizing mat is a very important aspect of the invention. The fluidizing mat is made principally of resiliently compressible sponge material, preferably of synthetic character. A suitable material has been found to be polyurethane foam, which is an elastomeric material, specific examples of which are polyester foam and polyether foam. Another suitable material is composed of bonded rubber particles. These materials have fine pores which are interconnected to enable air to ooze through the material under a low pressure head. Such sponge material not only is readily compressible but also is highly resilient so that it will return to or substantially to its initial condition after it has been relieved of a load which has compressed it. Also the walls of its air cells are ruptured so the material is porous but the cell walls are resilient so that they close when not subjected to air pressure, thus deterring penetration of fine material, such as the flour or other powdered material being fluidized, into the mat cells to clog the cell passages through them. While compressed, however, the surface pores will largely be pressed closed to increase the resistance to flow of air through such compressed portion of the material and thus produce an automatic valving effect. The degree of restriction of the pores will depend on the load on the mat material.

Because the mat material is resiliently compressible, it cannot be fractured by impact nor can it be cracked or broken by being bent or twisted, as it would be when subjected to an uneven load or when subjected to a load while being supported on an uneven surface. In fact, such material will yield sufficiently to conform to an uneven supporting surface so as to be substantially uniformly supported by it. Nevertheless, a pad of such material of fair thickness, such as about an inch thick, will bridge across ducts from one-half to three-quarters of an inch in width and be sustained in substantially coplanar relationship even under a very substantial uniformly distributed load. Another desirable characteristic of the spongy mat material is that it is odorless and inert and, since it is not brittle, fragments cannot break from it which would adulterate a food product.

A satisfactory specification for resiliently yieldable mat material which is satisfactory for a fluidizing mat of the present invention is that such material have:

(1) Substantially uniform permeability throughout the entire mat from 10 to 40, which numerical value is the quantity of air in cubic feet per minute which will emanate from each square foot of mat area if the pressure of the air supplied to the foam mat one inch from its surface is 10 inches of water, which is approximately ⅓ of a pound, or more.

(2) No surface pore greater than $\frac{1}{16}$ of an inch in diameter and 90% of the pores not over $\frac{1}{32}$ of an inch in diameter, although the diameter of some of the pores in the interior of the mat might be as much as ⅛ of an inch in diameter. Some of the pores could be as small as $\frac{1}{100}$ of an inch in diameter.

(3) Resiliency such that the thickness would return substantially to its original thickness after the load had been relieved for a short time.

(4) Compression resistance such that a uniformly distributed load of 3.5 pounds per square inch sustained for a period of 30 days would not produce a compression under load exceeding 25% of the thickness of the porous material.

(5) The ability to return almost immediately to a thickness within 10% of its original thickness after a deformation of 25% for 30 days.

(6) Have no odor and be completely nontoxic within 10 days after its manufacture.

(7) A weight not exceeding 10 pounds per cubic foot.

Mat material having the foregoing characteristics can be manufactured initially as porous mat material, or it

can be formed by bonding together rubber particles. To manufacture such mat material from rubber particles scrap rubber of medium hardness is ground to form particles. Such rubber may have a hardness of 60 to 70 durometer, such as used automobile tire stock. Such scrap rubber should be ground so that virtually all of the resulting rubber particles will pass through a 20 mesh screen, but half of the particles will not pass through a 35 mesh screen and the other half of the particles will pass through a 35 mesh screen but will not pass through a 40 mesh screen.

Such ground rubber particles can then be bonded together to form a mat. While such a bond can be effected in different ways a suitable binder is composed of neoprene in toluene as a vehicle in the proportion of 15% of the binder by weight being neoprene. The binder and ground rubber particles can be mixed together in the ratio of one part of binder to four parts of rubber particles by volume. The binder can be sprayed onto the mass of rubber particles as they are tumbled and mixed to obtain substantially a homogeneous distribution of the binder through the rubber particles.

The mixture of binders and rubber particles can be placed in a mold having a smooth surface, which mold surface can be covered by parting film such as polyester resin film to which the cured mat would not adhere. The binder can then be cured by heating the mass to a temperature of 250 degrees Fahrenheit to 300 degrees Fahrenheit and maintaining such temperature for approximately an hour while the mixture mass is subjected to pressure of approximately one pound per square inch. Pressure of this order would compress a depth of rubber and binder mixture approximately one and one-half inches deep without pressure to a thickness of approximately one inch.

Instead of using neoprene in a toluene vehicle as the binder other types of binders could be used. Urethane adhesive, for example, which would set at room temperature could be used. Also, instead of using rubber particles of natural latex or even of neoprene, or butyl rubber uniformly throughout the mat it may be desirable to make at least the upper surface of the mat which is exposed to the material to be aerated of a substance which has greater abrasion resistance qualities, such as urethane, or which can withstand high temperatures, such as silicone rubber. The upper surface of the mat is subjected to considerable abrasive action by flow of the material being aerated over such surface and by brushing the upper surface of the mat for cleaning it. Consequently, the principal thickness of the mat could be made of a layer of rubber material containing natural latex, neoprene or butyl, or some combination of these mixed with the binder, and a thinner surface layer of urethane particles mixed with a binder could be placed over the principal layer and the entire composite mat bonded together under a slight amount of pressure, as discussed above, with or without the application of heat as might be required to cure the binder.

From such resiliently compressible, porous material the fluidizing mat elements shown in FIGURES 1 to 4 are made and duct work is incorporated in such mat elements for distributing air under small pressure to local areas of the mat. In the mat structures shown in FIGURES 1 and 2 similar arrangements of duct work are provided. The channel passages **10** and **11** may be formed by metal marginal members **12** and **13**, respectively, received in the lower portion of the container and having edge portions of the mat sections received between the upper and lower flanges of the channel member. In the mat structures of FIGURES 1 to 4, inclusive, the duct work for supplying air to local portions of the mat structure is shown formed as rows of parallel bores located between the surfaces of the mat with such rows arranged so that the bores intersect substantially perpendicularly. Thus, in FIGURE 1 the bores **14** extending transversely of the mat in parallel arrangement are disposed coplanar with the row of bores **15** extending lengthwise of the mat in parallel arrangement.

In the portions of FIGURE 1 broken away, the intersecting pattern of the bores **14** and **15** is shown by which air is conveyed from the header ducts **10** at each end of the mat to various locations within the body of the mat. In this instance, the entire thickness of the mat body is made of the same resiliently compressible sponge material and the plane of the duct work is parallel to the principal faces of the mat element. Preferably, also, the distance between the plane of the duct work and the upper surface of the mat is approximately one inch. Air will ooze from the duct work upward in flared paths so that the air will emanate substantially uniformly over the entire surface of the mat. Air is prohibited from being emitted downward from the mat because the lower surface of the mat lies contiguously on the bottom **8** of the container.

It will be understood that the ducts in the duct work **14** and **15** should be sufficiently close together so that the air moving upward from the ducts in flared patterns will move so that such patterns approximately meet at the upper surface of the pad. Such flow patterns might overlap slightly without any appreciably detrimental effects resulting. Such ducts should be sufficiently narrow so that the resiliently compressible material of the mat will not be deformed down into such ducts to close them by the maximum uniformly distributed weight on the mat which can be expected from loading the container. There is less danger of thus collapsing the air supply network if the ducts are located a reasonable distance, such as one inch, from the upper surface of the mat since, ordinarily, the surface portions of the mat are compressed by the load of the material in the container more than underlying portions of the mat. On the contrary, if the air supply duct work is placed too far below the upper surface of the mat, there would tend to be too much overlap of the flaring permeation patterns of air flow through the mat as they approach the surface of the mat unless the ducts were located farther apart. Such increase in spacing might be sufficient to reduce the quantity of air discharged from the upper surface of the mat desired for a given pressure of air supplied by the air supply pipes **9**.

While the air supply network ducts **14** and **15** are shown in FIGURES 3 and 4 as being located approximately midway between the upper and lower surfaces of the mat, the various design factors mentioned above can be altered to obtain the desired air flow and automatic valving. Assuming that the load initially is uniformly distributed throughout the container, the load ordinarily will compress the fluidizing pad sufficiently to prevent virtually all emanation of air from the mat because of the constriction of the mat pores adjacent to the mat surface. Assuming that it is desired to unload the container, the outlet duct **5** will be unplugged and some of the granular material adjacent to this outlet will flow out because of the effect of gravity on it. Such initial flow will relieve the pressure on the mat sufficiently to allow air to escape into the material around the outlet, thus fluidizing it to expedite its flow.

Discharge of material from the container above and immediately adjacent to the discharge conduit will create a pocket extending downward in tapered fashion from the upper surface of the material in the container. Below this pocket, therefore, the load on the fluidizing mat will be relieved, the compression of such mat will be reduced and, consequently, because of the resiliency of the mat, the pores will be expanded so that some air will emanate from that portion of the mat immediately below the pocket. The granular material directly above this portion af the mat will thereby be dynamically aerated and fluidized to expedite the flow of material through the outlet **5**. As more material is thus discharged, the size

of the pocket will increase and the load of the material on that portion of the fluidizing mat adjacent to the discharge duct will be reduced further so that the pores in this portion of the mat will be expanded and both the area of the mat from which air emanates and the amount of air emitted will increase to aerate and fluidize the granular material to a greater extent. This effect progresses steadily away from the outlet as the discharge of granular material through it proceeds until air is being emitted from the entire surface of the fluidizing mat to assist the flow of granular material to and through the outlet.

The phenomenon of progressive increase in emanation of air from the mat away from the outlet **5** occurs, as has been described, because of a progressive reduction in the load of material on the mat and not because of any lack of uniformity in the supply or air to local portions of the mat through the ducts **14** and **15**. In fact, it is preferred that the air be supplied through these ducts at approximately uniform pressure to every location of the mat. Where the mat is rather long, therefore, air under pressure is supplied to both ends through the air supply ducts **9** shown in FIGURE 1. The arrangement of FIGURE 2 enables approximately equal air pressure in the ducts of the two sections **3** and **4** although air is supplied by only one connection **9** because of the interconnection of the two air supply header passages **10** and **11**. It will be evident that additional air supply connections can be provided, if that should be necessary, and, of course, the amount of air discharged from the mat can be adjusted by regulating the pressure of the air supplied by the conduits **9**. All of the ducts **14** and **15** communicating with the header ducts preferably are of approximately the same size and of approximately constant cross sectional area throughout their lengths.

In formation of the mat units, the duct work passages **14** and **15** can be formed by making the mat in two halves, each having a surface formed as a gridwork of crossed grooves. The grooved surfaces of the mat components can then be placed in face-to-face engagement and bonded together. Alternatively, the units can be manufactured with only one set of ducts **14** or **15**, which ducts would be slightly larger than would be required for a grid type of duct work. Another arrangement utilizes only one section of mat in which grooves have been formed in one surface. Such a construction is shown in FIGURE 5 in which parallel grooves **16** are provided in the bottom surface of the mat **17**. These grooves are formed as a grid but, again, could include one set only of parallel grooves. In the form shown, one set of grooves is supplied with air by the header **18** and the other set is supplied from the header **19**. Air is prevented from escaping from the grooves **16** other than through the sponge material of the mat by the contiguous engagement of the lower surface of the mat with the solid imperforate floor **20**.

In FIGURE 6 a somewhat different type of fluidizing mat is installed in the bottom of the container formed by the walls **1**. In this instance, instead of the discharge outlet being through one wall just above the fluidizing mat, outlet for the contents of the container is provided through the central opening **21** in the bottom of the bin. The floor is then arranged in sections, all sloping toward this central outlet. Consequently, each of the end sections **22** and the side sections **23** are of substantially triangular shape having apexes located at the discharge opening. Adjacent edges of adjacent sections meet substantially along a diagonal of the rectangular container. The fluidizing mat for each of these sections is, however, flat but conforms in plan to the shape of the corresponding floor section.

Fluidizing air again is supplied to the container through a pipe **9** which communicates with a header passage or channel **24** extending around the entire periphery of the container. Since such header is of reasonably large cross section and, therefore, affords little impediment to the flow of air, it is not necessary to provide more than one air supply pipe, although additional pipes may be connected to the channel header at other locations, if desired. Each of the fluidizing mat sections **22** and **23** is of a construction like that shown in FIGURES 3 and 4 or in FIGURE 5, being formed of readily compressible, resilient, porous material to which air is supplied by suitable duct work which may be either of the type shown in FIGURES 3 and 4 or of the type shown in FIGURE 5. In this case, during a discharging operation, flow of granular material through the outlet **21** will form a cavity at the center of the container which will expand progressively in all directions transversely of the tank as the discharging operation continues. Correspondingly, fluidizing air will be emitted from the portions of the fluidizing mat units **22** and **23** adjacent to the aperture **21** first and then the air emission area will be expanded progressively away from the aperture **21** as the load of the granular material in the container on it is reduced. As in the fluidizing mats described in connection with FIGURES 1 to 4, inclusive, the fluidizing mat sections **22** and **23** may be installed permanently in the bottom of the container or may be separable and removable.

FIGURES 7 and 8 show a container of circular cross section, such as a silo, of permanent construction. The circular wall **25** and floor **26** are shown as being made of concrete. Such floor is formed in six sections of sector shape which are inclined downwardly from the container wall **25** toward the central discharge outlet **27** in the middle of the floor. Fluidizing mat sections **28** of sector shape corresponding to the shape of the floor sectors are placed over such floor sectors, respectively, as shown in FIGURE 8. Again, the adjacent edges of adjacent mat sections abut and such mat sections can be installed permanently or may be removable. The construction of each mat section is similar to that described above, as shown in FIGURES 1 to 5, inclusive, and includes a network of air distribution ducts **29** arranged parallel to the upper surface of each mat section. Air is supplied to this duct work from an annular header conduit **30** extending around the container, which is in turn supplied with air under small pressure from the air supply pipe **31**. The fluidizing action of the granular material in this container is accomplished by the mat sections **28** in a manner similar to that described in connection with FIGURE 6.

Another adaptation of the fluidizing mat of the present invention is for conduits, an example of which is shown in FIGURES 9 and 10. If the conduit were of rectangular cross section, a flat fluidizing mat of the type described above in various installations could be used, but the conduit **32** shown in these figures is of circular cross section. The fluidizing mat can simply be laid on the bottom of such a pipe largely irrespective of the sharpness of its contour and, because of the material of which it is made, the mat will be sufficiently limp to bend in conformity with the curvature of the pipe. Such a mat should be of a width sufficient to extend a substantial distance upward along the sides of the pipe, the mat **33** in FIGURES 10 and 11 being shown as extending substantially half way up the sides of the pipe to its horizontal diametral plane. The mat units can be of any desired length and pipes **34** can be provided at desirable intervals along the length of the pipe to supply air under a small pressure to the mat. The air distribution duct work for the mat can be similar to that described above for container bottom fluidizing mats.

In all of these installations described, it has been found that a fluidizing mat of resiliently compressible, porous material having fine pores will enable a uniformly distributed emission of air to emanate from the surface of the mat when air under low pressure is supplied to it. The pores of the material are interconnected and, presumably, are dilated to some extent by the air oozing through

them. Whether or not this is actually the case, the surface of the mat has in it pores sufficiently small so that when even a small amount of fine granular material, such as powdered sugar, cement or flour, is lying on the mat, such material will not penetrate into the mat any appreciable distance. Consequently, the mat will not be adulterated even by very fine granular or comminuted material and can be cleaned readily. Substantial pressure exerted on the surface of the mat by a considerable depth of granular material will compress the mat material sufficiently to constrict the pores to a greater or lesser extent near the surface of the mat so as to reduce the emanation of air from it and if sufficient pressure is exerted by the granular material, the pores at and adjacent to the surface of the mat will actually be closed.

It has been found that a substantially uniform emanation of air from such a fluidizing mat can be obtained by supplying air through duct work a substantial distance below the surface of the mat as described, in which duct work the ducts are spaced apart a considerable distance. It is therefore evident that the air supplied by the duct work oozes upward through the mat in a flaring flow pattern and a pattern probably followed substantially by the air flow is shown diagrammatically on an enlarged scale in FIGURE 11. The arrows from each duct **35** extending upward to the surface **36** of the mat **37** flare sufficiently so that the adjacent air flow patterns substantially meet adjacent to the surface of the mat. Such patterns can overlap slighly as shown but, in any event, should not be spaced apart sufficiently to leave an unaerated pile or line of granular material on the upper surface of the mat.

In order to obtain such a composite air flow pattern, it will be evident that the ducts **35** must be sufficiently far below the surface of the mat for a given duct spacing to enable the flaring paths of the air flow to merge adjacent to the upper surface of the mat. It has been found that this effect can be obtained if the air distribution ducts are located below the surface of the mat a distance at least substantially equal to the spacing between the air ducts. Thus, for example, such ducts can be located approximately one inch below the surface of the mat and spaced apart a distance three-quarters of an inch to one inch. Moreover, it is desirable for the air distribution ducts to be sufficiently narrow with relation to their distance below the surface of the mat so that a substantial load on the mat will tend to compress it approximately uniformly rather than forming depressions above the air distribution ducts. The width of the ducts should, therefore, not appreciably exceed their distance below the surface of the mat and preferably the duct width is somewhat less than such distance. Thus the supporting structure will engage the mat at locations spaced three-quarters of an inch to one inch apart. This structure can therefore support the one inch thick pad against being depressed excessively downward into the ducts. Obviously, at the edge of any mat unit the ends of the air distribution ducts should be closed unless they communicate with ducts in an adjoining fluidizing mat section.

Whether the air discharged by the distribution ducts moves through precisely the flaring path indicated by the arrows in FIGURE 11 is not known, but it has been observed that the width of the mat surface over which the air emanates extends to a width beyond the side of each duct at least approximately one-half of the depth of such duct below the surface of the mat. The porous character of the resiliently compressible mat material not only effects such lateral distribution of the air from the air supply ducts at the surface of the mat, but such spongy material provides an effective thermal insulation element for the bottom of the container. Consequently, even in cold weather, when the granular material within the container is warm, no moisture condensation occurs on the surface of the mat. Therefore, there is no possibility of such condensate moistening a granular material, such as flour, to form a paste which would produce a coating on the surface of the mat.

In FIGURES 12 and 13, a somewhat modified type of fluidizing mat is shown. In this instance, the resiliently compressible, porous material is in the form of a pad **38** of uniform thickness, such thickness preferably being approximately one inch. This pad is mounted on a base **39** made, preferably, of stiff plastic material, although it could be of sheet metal. This base is corrugated to form alternate pad-engaging supporting strips **40** and intermediate air supply ducts **41**. In this structure, such air supply ducts extend in only one direction instead of forming a grid type of duct work. Air can be supplied to such ducts **41** by a header **42** communicating with corresponding ends of the ducts **41**, which header in turn is supplied with air from a fitting **43** to which an air supply pipe **44** may be connected.

A fluidizing mat unit of this type can be made without any special molding procedure since the pad **38** is simply of uniform thickness rectangular shape. The base **39** can be molded or postformed from suitable stiff plastic material to the desired shape and then bonded to the pad **38** by a suitable adhesive, such as epoxy resin. The resulting unit is very light for its area, is very durable and not brittle, and can be made in a variety of convenient sizes for use as removable fluidizing mat sections which can be interconnected readily or can be installed permanently in the bottom of a container. FIGURE 13 shows diagrammatically a probable pattern of air flow from the ducts **41** upward through the mat. In any event, the effect of substantially uniformly distributed air emanation from the mat occurs. The general action of such mat will be similar to that discussed in connection with FIGURE 11 and the other types of mat structure described above.

FIGURE 14 illustrates a container in the form of a collapsible bag **45** having an inlet **46** in its top. The bottom of this bag is shown as having in it four fluidizing mat sections of generally triangular shape **22** and **23** of the type shown in FIGURE 6. As described in connection with that figure, such mat sections may slope to a central outlet or such mat sections can be disposed in coplanar relationship and a discharge outlet **47** can be provided in an end wall of the bag near its bottom. Alternatively, the bottom of this bag **45** can be provided with any one of the fluidizing mat units described above. Air is directed into the fluidizing mat through the inlet pipe **9** which extends through the end wall of the bag opposite that to which the outlet duct **47** is connected.

Because of the resiliently compressible and flexible character of the porous material of which the fluidizing mat is made, such mat and the bag **45** may be collapsed and folded up for storage purposes if the header or headers supplying air to the fluidizing mat are of foldable material, such as rubber, or are arranged so that such headers do not afford any appreciable impediment to the folding or rolling operation in collapsing the bag. A bag of this nature is well adapted for installation in transport vehicles, such as a truck or railroad car, having walls against which the walls of the collapsible bag can bear in order to keep the bag walls from bulging outwardly too far under pressure of granular material supplied to the bag through the inlet opening **46**. When the granular material has been discharged from the collapsible bag by use of the fluidizing mat at the destination, the bag can be collapsed and rolled or folded up, removed from the truck or railroad car, and returned in such collapsed condition to the shipper for reuse.

In some instances, it may be preferable to provide collapsible containers which are not dependent upon engagement with encompassing walls for support. Such a container, as shown in FIGURES 15 and 16, can be constructed of circular cross section and generally cylindrical shape so that the entire wall tends to be placed under approximately uniform tension around the periph-

ery of the container by the weight of granular material within it. This container includes the wall **48** of impervious, strong, flexible material, such as elastomer-coated fabric or fabric-reinforced elastomer material. A suitable construction, for example, is a nylon or Dacron fabric coated with neoprene, vinyl or other inert, impervious elastomer material. Alternatively, the flexible wall could be made of molded neoprene or vinyl material reinforced with strands of nylon or Dacron. A stiff ring **49**, preferably of metal, extends over most of the area of the container bottom and includes a clamp ring **50** encircling a downwardly extending neck **51** of the container, which can be contracted by a bolt **52** at each side of the clamp ring to contract such ring for clamping the container neck **51** tightly to the ring **49**. The ring **49** can be located over a discharge opening in the floor of a truck, a trailer or a railroad car within which the collapsible container is located. The upper end of the container has attached to it a ring **53** encircling a filling port which, normally, will be closed by a suitable cover. Such collapsible containers can be of large capacity, such as sufficient to hold 5 tons of flour, and, consequently, are rather bulky to handle. A convenient procedure for installing such a container in a vehicle is to inflate it by a connection to the filling port **53** of a hose supplying air under pressure to the interior of the container. Such pressure will distend the walls of the container until the top of the container adjacent the filler opening can be secured to the roof of the vehicle to hold the container expanded.

The base ring **49** may have in it apertures **54** spaced apart horizontally a distance corresponding to the spacing of the prongs of a fork-lift truck so that the entire container can be readily lifted into or removed from a vehicle. The ring **49** is held rigidly against collapsing by securing within it the metal disk **55** which, preferably, is of slightly conical shape with its central portion depressed. In such central portion of the disk is formed the discharge opening **56** through which granular material may flow from the container. A fluidizing floor mat element, preferably of the type shown in FIGURES 12 and **13**, is supported on the disk **55**. Instead of such disk being exactly conical, it can be made of planar sectors of the type illustrated in FIGURES 7 and 8. Thus, the fluidizing mat structure **57** can either be constructed as a single unit or it can be made in sector sections, each of planar shape corresponding to the shape of the sheet metal disk **55**.

The fluidizing mat structure will include an upper resiliently compressible, porous pad and a stiff, corrugated base portion providing air distribution ducts for the sponge pad. Such corrugation channels may be of arcuate shape concentric with ring **49**, as indicated in FIGURE 15, or may extend radially. Depending upon the configuration of such base duct work, one or more pipe nipples **58** are provided for connection with a source of air under pressure and these are in communication with headers which supply air to the duct work of the corrugated structure. When not connected to a source of air under pressure, the air supply nipples **58** are closed by caps **59**. The entire bottom structure of the container can be strengthened and stiffened adequately to support the load of granular material in the container by structural channel beams **60** extending chordwise beneath the disk **55** as shown in FIGURE 16. Because of the flexible and resilient character of the fluidizing mat, however, such mat cannot be injured by any working or warping of the bottom disk **55** caused by twisting or bending of the vehicle frame.

To enable the discharge of granular material from the container through opening **56** to be controlled easily, it is preferred to secure in the outlet opening a fabric sleeve **61** of a length to extend outward a considerable distance beyond the lower edge of the outlet opening. Such lower end of the sleeve can be rolled up and confined above the closure cap **62** for the discharge opening when the container is empty or is filled with material before it is ready to be discharged.

In FIGURE 17 an alternative type of fluidizing floor construction is shown which can be used in any of the various types of receptacles or containers described above. In this instance the porous fluidizing mat **63** is supported by a perforate sheet **64** which can be made of flattened expanded metal having diamond shaped openings as shown, or the openings in the sheet could be circular or of other shape. If the mat **63** is approximately one inch thick the openings in the sheet **64** should be distributed uniformly over it and should be approximately one-half the area of the sheet so that the mat will be supported properly while at the same time the air supply openings will be located sufficiently close together so that the air passing upward through the mat will emanate from virtually its entire surface area. Because of the upward pressure of the air on the bottom of the mat it is preferred that the perforate sheet **64** be bonded to the bottom of the mat.

The sheet **64** has sufficient strength to support the mat **63** in a position bridging across an air supply chamber formed by the pan **65**, which can be of rectangular shape as shown, or can be circular. Such pan is shown as having ledges **66** on which the opposite edges of the mat supporting sheet **64** rest and such sheet edges may be bonded or otherwise secured to such ledges. Such sheet is shown as being somewhat concave in the form of a catenary curve so that the weight of the material carried by the pad **63** will produce tension forces in the sheet **64**.

If the pressure of air in the air supply chamber **65** is not very great the structure described may itself be sufficient. It may, however, be desirable to confine the upper surface of the mat by a perforate sheet **67** which has as large an open area as possible, so that its structure will interfere as little as possible with the aeration of the material supported by the mat. This upper sheet **67** can be secured to flanges **68** on opposite sides of the air supply chamber pan **65** by clamping such sheet edges down with bars **69** which may be bolted to the flanges **68**. In addition, one or more bolts **70** can connect the sheet **67** and pan **65**. Conveniently, such bolts can be in the form of studs having their lower ends welded to the pan so that such studs project upward through the sheet **64**, mat **63** and sheet **67**, and their upper ends can be threaded to receive a nut **70**.

In FIGURE 17 the perforate sheets **64** and **67** are shown as being connected separately to the air supply chamber pan **65**, but if desired the edges of both of these sheets can extend beyond the mat **63** and be brought together in face-to-face engagement so that the margins of both sheets are secured to the opposite edges of the air supply chamber pan, respectively. Such sheets when thus connected may more effectively share the load imposed on them by the granular material supported by the mat.

In discharging granular material from any of the enclosures shown and described above the container can be air tight, except for the porous mat and the discharge opening. In order to fluidize the granular material it is necessary for the pressure of the air in the air supply chamber to be greater than the air pressure in the container on the opposite side of the mat. The pressure to which the air in the container will build up depends on the resistance to flow of material through the discharge opening. A delivery hose or conduit, such as **47** shown in FIGURE 14, may be connected to the discharge opening from the container and such conduit may be of considerable length which would produce substantial resistance to movement of the fluidized granular material through it. In such cases it would be necessary for the air pressure within the container to be a substantial value, such as up to 100 pounds per square inch, in order to deliver the granular material in sufficient volume through a comparatively small discharge conduit. In order to force

air through the mat to fluidize the material in the container it would be necessary for the air pressure in the air supply chamber at the lower side of the mat to be somewhat greater than the pressure of the air in the container above the mat.

In the foregoing description reference has been made to supplying air under pressure to fluidize the granular material, but it may be desirable in some instances such as where the granular material is flour, to supply to the interior of the container through the mat or in some instances directly to the container an inert gas, such as nitrogen. Such gas could remain in the container under pressure during a storage or transportation period prior to discharge of the granular material from the container for the purpose of deterring deterioration of the flour by pests.

I claim as my invention:

1. A fluidizing unit for containers to hold granular material, comprising a thick bottom mat of resiliently compressible polyurethane foam material extending continuously between its opposite edges and having intercommunicating pores, means disposed a substantial distance beneath the upper surface of said mat communicating with such pores to supply gas escaping upward through such pores for emanation of the gas from substantially the entire area of the upper surface of the mat, and supporting means supporting said mat at distributed, closely spaced locations between its opposite edges, said mat material being resiliently compressible against said supporting means by load on its upper surface and expandable as the load decreases.

2. A fluidizing unit for containers to hold granular material, comprising a thick bottom mat of resiliently compressible polyurethane foam material extending continuously between its opposite edges and having ruptured cell wall pores, means disposed a substantial distance beneath the upper surface of said mat communicating with such pores to supply gas escaping upward through such pores for emanation of the gas from substantially the entire area of the upper surface of the mat, and supporting means supporting said mat at distributed, closely spaced locations between its opposite edges, said mat material being resiliently compressible against said supporting means to a thickness less than half its unloaded thickness by load on its upper surface and expandable as the load decreases.

3. A fluidizing unit for containers to hold granular material, comprising a thick bottom mat of resiliently compressible porous material extending continuously between its opposite edges and having intercommunicating pores, corrugated sheet supporting means having a plurality of elements supportingly engaging the lower surface of said mat, the spacing between adjacent ones of said elements being approximately equal to the thickness of said mat, and said elements defining therebetween a plurality of spaced channels located below the upper surface of said mat a distance at least substantially as great as the width of one of said supporting means elements and communicating with such pores, and means for directing gas under pressure into said channels to pass upward through the pores of said mat for emanation of the gas from substantially the entire upper surface of the mat.

4. A collapsible container to hold granular material, comprising a substantially cylindrical wall of limp material, a circular bottom joined to said wall and having an outlet therein, a thick bottom mat of resiliently compressible elastomeric foam material having intercommunicating pores and disposed within said container, and means disposed a substantial distance beneath the upper surface of said mat communicating with such pores to supply gas passing upward through such pores of the mat for emanation of the gas from substantially the entire upper surface of said mat to fluidize the granular material in the container for flow to the outlet.

5. A fluidizing unit for containers to hold granular material, comprising a corrugated sheet material supporting member having a plurality of supporting elements spaced apart, a mat of resiliently compressible porous material having a thickness several times the thickness of said sheet material supporting member overlying, engaging and supported by said spaced elements of said supporting member, and means for supplying gas under pressure to the spaces between said supporting elements to pass through such spaces upward through the pores of said mat for emanation from the upper surface of said mat.

6. The fluidizing unit defined in claim **5**, in which the supporting member is of corrugated plastic defining ridges constituting the mat-engaging and supporting elements and troughs therebetween.

7. The fluidizing unit defined in claim **5**, in which the supporting member is of corrugated plastic defining flat ridges constituting the mat-engaging and supporting elements and troughs therebetween, each of said troughs being of a width substantially equal to the width of a ridge.

8. In combination, a collapsible container to hold granular material having a substantially cylindrical wall of limp material, a circular bottom joined to said wall and having an outlet therein, a thick bottom mat of resiliently compressible elastomeric foam material extending continuously between its opposite edges and having intercommunicating pores, supporting means supporting said thick bottom mat in said circular bottom having a plurality of elements supportingly engaging the lower surface of said mat, the thickness of said mat being greater than the width of each of said elements, and means for directing gas under pressure between said elements to pass upward through the pores of said mat for emanation of the gas from substantially the entire upper surface of the mat.

9. A fluidizing unit for containers to hold granular material, comprising a thick bottom mat of resiliently compressible elastomeric foam material extending continuously between its opposite edges and having intercommunicating pores, means disposed a substantial distance beneath the upper surface of said mat communicating with such pores to supply gas escaping upward through such pores for emanation of the gas from substantially the entire area of the upper surface of the mat, and supporting means supporting said mat at distributed, closely spaced locations between its opposite edges, said mat material being resiliently compressible against said supporting means by load on its upper surface and expandable as the load decreases.

10. The fluidizing unit for containers defined in claim **9**, in which the supporting means includes a sheet material-supporting member having a plurality of supporting elements spaced apart which cooperatively define an upwardly concave surface.

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