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SUSPENSION SYSTEM FOR CONTAINER FOR STORING LIQUEFIED GAS

Filed Oct. 30, 1956

2 Sheets-Sheet 1

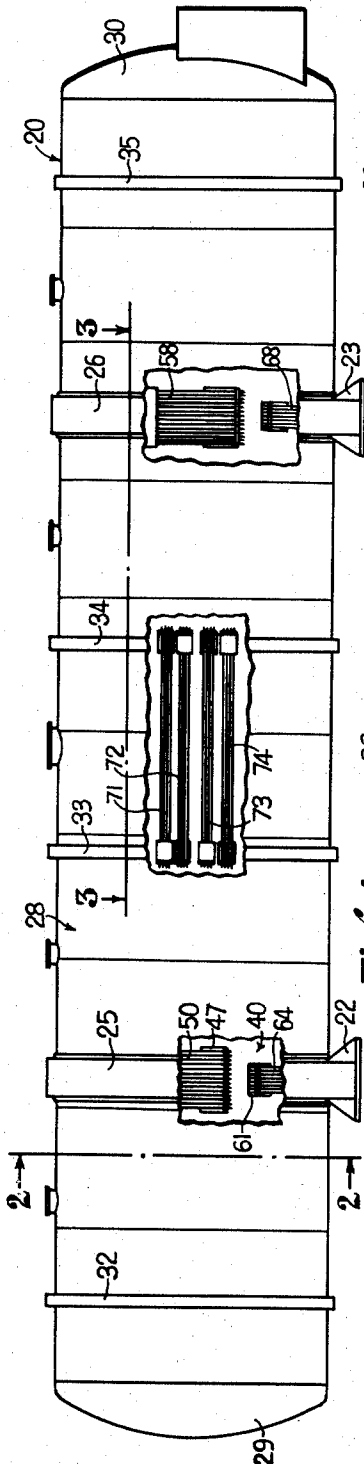


Fig. 1

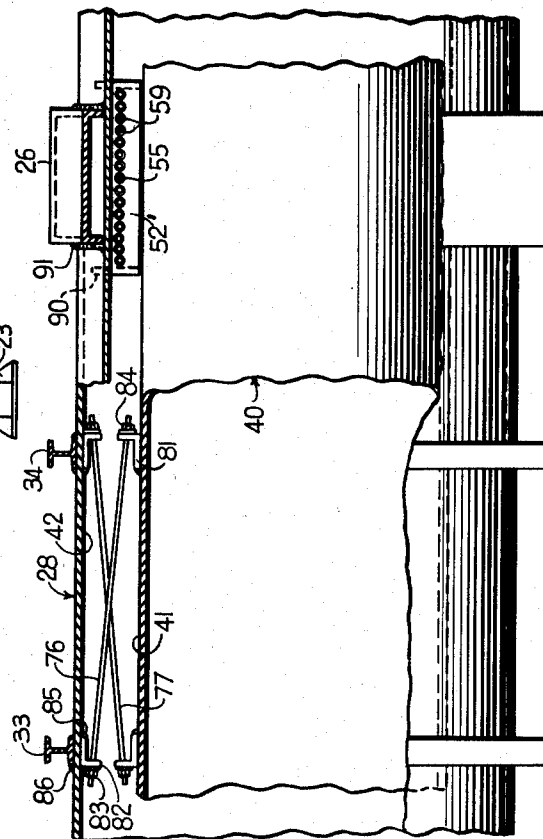


Fig. 3

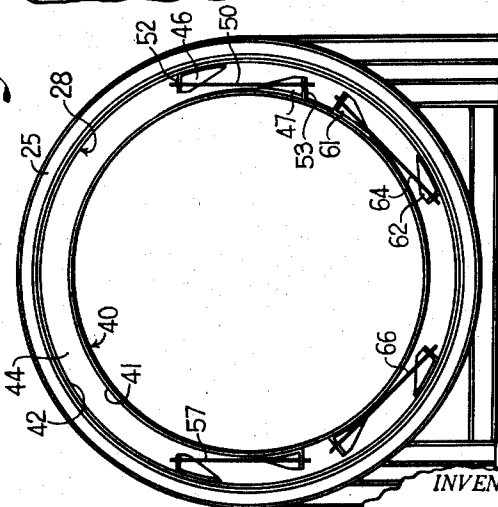


Fig. 2

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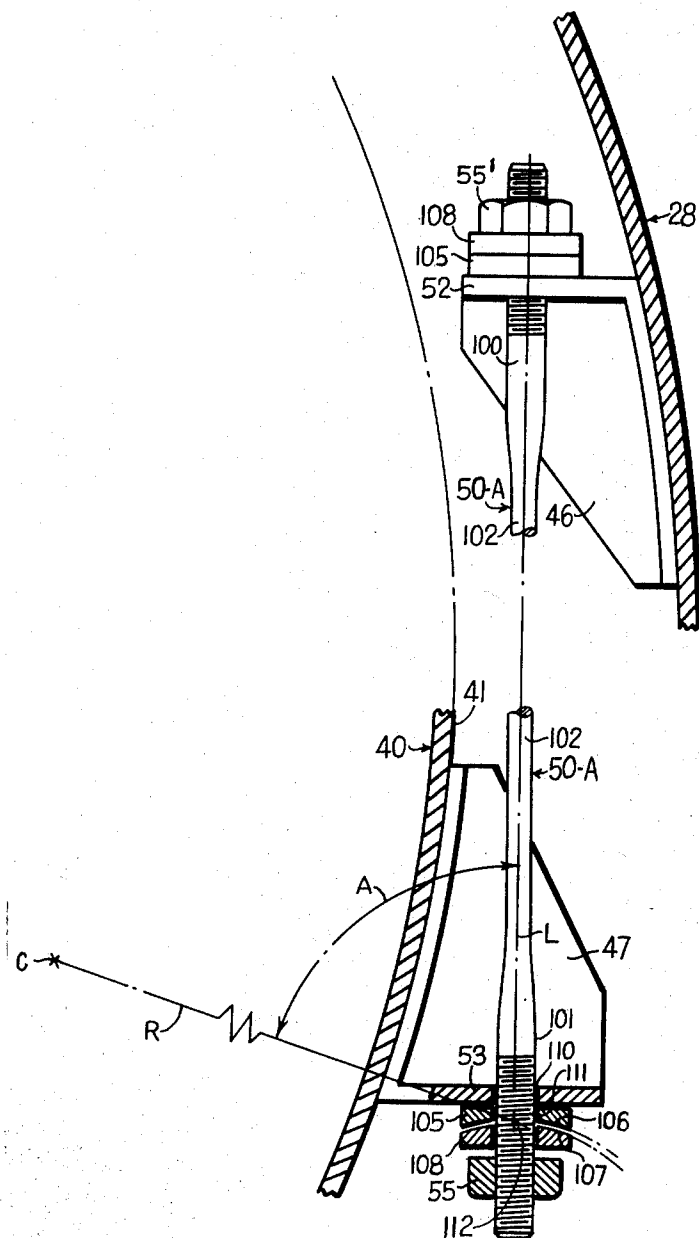


Fig. 4

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SUSPENSION SYSTEM FOR CONTAINER FOR STORING LIQUEFIED GAS

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7 Claims. (Cl. 220—15)

This invention relates to apparatus for storing liquefied gases having boiling point temperatures materially below 273° Kelvin.

This is a continuation-in-part of my co-pending application Serial Number 530,323, filed August 24, 1955, now abandoned.

In storing liquefied gases at low temperatures, insulated storage vessels are utilized, which vessels include a container for the liquid being stored surrounded by an air-tight jacket spaced from the outer wall of the container. The air is exhausted from the space, and suitable insulating material may be placed therein, to form an insulating means which surrounds the container and shields same from heat leakage from the environment.

It is desirable to surround the container, as completely as possible, with insulating means, but since the container must be structurally supported within the jacket, the structural members required, which are connected between the container and the jacket form metallic heat leak paths along which a certain amount of heat is continuously being transferred to the container, and hence to the cold liquefied gas being stored therein.

The present invention provides a storage vessel having a novel suspension system for mounting the above described container in spaced relationship within its jacket in a strong, rigid and highly efficient manner. According to the present teachings, the container shell is supported by a relatively large number of small rods, having relatively small cross-sectional areas as compared to their lengths, which rods are fabricated from a suitable material that possesses high tensile and impact strength, at low temperatures, and a low thermal conductivity. The rods are mechanically subjected to a pre-loaded force which provides the advantage of nullifying the thermal stresses imposed by the large temperature variations to which the structure must be subjected; further, through such pre-loading, a rigidity is realized which can only be obtained otherwise, by heavy heat-conducting structure. As an example, this novel construction provides an extremely light weight suspension structure even when designed to withstand a force of 3 G in a vertical downward direction, under full load, which permits a relatively light weight storage vessel to meet earthquake conditions.

When the suspension system of the present invention is utilized in a storage vessel construction, heat flow from the environment to the jacketed container is confined to long heat leak paths through small rods which reduce the suspension members to a plurality of small ineffective heat conductors and make possible an extremely high efficiency for a storage vessel from which loss of liquid as boil-off, due to heat leak through the suspension system and piping, can be reduced to only .007 of one percent of the full liquid capacity, per twenty-four hour day.

It is therefore an object of the present invention to provide a storage vessel of the type described which minimizes heat leak from the environment to the liquid being stored.

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It is another object of the present invention to provide a storage vessel of the type described which eliminates potential leakage of the vacuum insulating space.

It is another object of the present invention to provide a storage vessel of the type described provided with novel suspension means, for the container within the jacket, which suspension means compensates for thermal stresses imposed on the structural members by the large range of temperatures to which the vessel must be subjected.

It is another object of the present invention to provide a storage vessel of the type described provided with novel base means including reinforcing structure, for the outer jacket of the vessel, adapted to receive the loads imposed by an entirely internal suspension system for supporting the container within the jacket.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred form of embodiment of the invention is clearly shown.

In the drawing:

Figure 1 is a partially broken side elevational view of a liquefied gas storage vessel constructed according to the present invention;

Figure 2 is an end view, partially in section, of the storage vessel of Figure 1, with the section being taken along the line 2—2 of Figure 1;

Figure 3 is a partial top sectional view of the storage vessel of Figure 1, with the section being taken along the line 3—3 of Figure 1; and

Figure 4 is an enlarged view, partially in section, of a portion of the storage vessel of the preceding figures and showing a typical support member incorporated in the construction thereof.

Referring to the drawing, a storage vessel constructed according to the present invention is indicated generally at 20. The vessel includes base means 22 and 23 which are connected to and support a pair of annular reinforcing members 25 and 26. The reinforcing members 25 and 26 encircle a horizontally disposed cylindrical outer jacket, or outer shell, 28 with such reinforcing members being in contact with and welded to the outer surface of jacket 28. The first and second major reinforcing bands 25 and 26 embrace the jacket at zones between its midsection and the ends of the storage container 40. Jacket 28 further includes opposite end walls 29 and 30, and, in addition to the reinforcing members 25 and 26 which are supported directly by the base means, a plurality of additional reinforcing members 32, 33, 34, and 35 are welded to the outer surface of jacket 28 at longitudinally spaced intervals. The minor reinforcing bands 33 and 34 embrace the jacket 28 at zones intermediate between its midsection and the major reinforcing bands.

A cylindrical container, or inner shell, 40 is provided to directly contain the liquid being stored, and the outer surface 41 of horizontally disposed inner storage container 40 is spaced from the inner surface 42 of the jacket 28 to provide an intermediate insulating space 44. Suitable pumping means, not illustrated, is utilized to exhaust the air from insulating space 44, and suitable insulating material, such as finely divided particles of silica, is contained in the space 44 for increasing its insulating efficiency.

As seen in the figures, a plurality of supporting means are provided for mounting container 40 in spaced relationship with jacket 28. As seen in Figure 2, the vertical positioning of supporting means comprises an upper bracket 46 secured to the inner surface 42 of jacket 28, and a lower bracket 47 secured to the outer surface of container 40. A first plurality of vertically disposed members or tension rods 50 are connected between

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brackets 46 and 47 with the end of members 50 being extended through flanges 52 and 53 of brackets 46 and 47, respectively. The ends of rods 50 are secured to the flanges by suitable adjustable connecting means; for example, individually adjustable fastening means can be provided for the ends of each member 50 by nuts similar to nuts 55, best seen in Figure 3. The plurality of vertically disposed members 50, together with the other groups of rod members indicated as third, second, and fourth pluralities at 57, 58, and 59, are subjected to tension by the weight and vertically downwardly directed inertia forces imposed by the container and the stored liquid carried therein. All of these rods are alongside the container and extend transversely of the direction of its axis. Pluralities 50 and 58 are located on one side of the storage container and pluralities 57 and 59 are located on the opposite side of the storage container.

Referring again to Figure 2, a second pair of brackets 61 and 62 are provided, with the two brackets being secured to the outer surface of the container 40 and the inner surface of the jacket 28, respectively. A first plurality of diagonally disposed members 64, included in lateral positioning means, are connected between brackets 61 and 62 in a manner identical to that previously described in connection with the plurality of members 50.

It will be noted that brackets 61 and 62 are horizontally spaced one from the other, and members 64 are diagonally disposed so that laterally directed inertia forces, which tend to move container 40 to the right as viewed in Figure 2, are resisted by diagonally disposed members 64 which members are subjected to tension thereby.

In a corresponding manner, the lateral positioning means includes a third plurality of diagonally disposed members 66, which resist the effect of laterally directed inertia forces in the opposite direction, and, two additional groups of diagonally disposed members are provided at the other end of the vessel, at the reinforcing member 26, with one of such other two pluralities being shown at 68 in the drawing. This group 68 is referred to in the claims as the second plurality of members in the lateral positioning means.

As seen in Figure 2 rods 50 and 64 are arranged in a particular geometry whereby the preloaded tension forces on rods 50 and 64 are decreased upon thermal contraction of container means 40. Such thermal contraction will of course be considerable where container 40 is large, and the thermally imposed stresses on rods 50 and 64 can be extremely high so as to readily cause failure of preloaded rods of the type employed unless the novel geometry of the present suspension system is followed. Specifically, with the geometry of Figure 2 rods 50 or 64 will be caused to shorten, and the preloaded stress imposed thereon will decrease when the fastening means 47 or 61 is moved radially inwardly upon thermal contraction of container 40 when such container is cooled. This is true because the projection of the longitudinal axis of a rod 50 or 64, on a plane normal to the wall surfaces 41 and 42 at the end connection of such rod, forms an acute angle with a radial line in said plane which line passes through the center of the container 40 and said end connection. Such angular configuration serves to define the present novel suspension geometry which provides a decrease in the preloaded force in rod 50 or 64 upon thermally imposed contraction of container 40 when such container is being cooled.

Referring again to Figure 1, four groups of horizontally extending members are mounted as axial positioning means between the reinforcing members 33 and 34, with such groups being indicated generally at 71, 72, 73, and 74. Four identical groups of members are provided at the other side of the vessel, with two of such groups being illustrated generally at 76 and 77. Elements 71-74 form the first plurality of criss-cross arranged tension rods of the axial positioning means. Similar ele-

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ments 76-77, etc. form the second plurality. The members of upper group 76 are connected between a bracket 82 welded to the inner surface 42 of the jacket 28, and a bracket 81 welded to the outer surface 41 of the container 40. Threaded elements such as 83 and 84 provide means for applying a pre-loaded force to each of the members 76 and adjustably securing them to the jacket and storage container.

It will be noted that bracket 82 is welded to the inner surface 42, as indicated at 85, and the outer reinforcing member 33 is welded to the outer surface of the jacket 28 as seen in 86. With this arrangement, longitudinal tension loads imposed on member 76, due to a longitudinal inertia forces applied to container 40 will be transmitted directly to bracket 82, through jacket 28 to reinforcing member 33.

Members 77, lying directly below the group of members 76, extend transversely to group 76 and are mounted in a manner identical thereto. With this arrangement, the group of members 77 will resist inertia loads in the other longitudinal direction and transmit the forces to the other reinforcing member 34.

Referring to Figures 1 and 2 it will be noted that the members 76 and 77, which resist longitudinal and lateral inertia forces, are located at the central portion of the relatively long container means 40. Specifically, the opposite connections 81 and 82 of rods 76 are located on opposite sides of a vertical plane through the longitudinal center of container 40. Similarly, the connections for rod 77 are located on opposite sides of said central plane. Hence when container 40 is subjected to thermally imposed contraction the rods 76 and 77 are subjected to only a relatively small portion of the total longitudinal contraction of container 40 i.e. the contraction of the longitudinal extending portion of the container wall lying between fastening means 81 and 82. This arrangement is particularly important where the liquefied gas container is of considerable length. It will be readily understood that with a relatively long container, such as Figure 1 depicts, if the longitudinally stressed members 76 and 77 were attached to the container at the end portions thereof, instead of to the central portion illustrated, then such members would be subjected to a much greater portion of the total longitudinal contraction of the container 40 and hence the thermally imposed stresses applied to members 76 and 77 would be very greatly increased. Moreover, since members 76 and 77 are subjected to preloaded tension prior to cooling, the thermally imposed stresses on such members are negative and merely act to decrease the magnitude of the preloaded tension force. By considering Figure 3 it will be realized that when the portion of container 40 lying between fastening means 81 and 82 contracts longitudinally, the tendency will be to shorten preloaded rods 76 and 77 whereby the tensile force in such rods can never be augmented by thermally imposed contraction of container 40.

With continued reference to Figure 3, the bracket 52' is welded to the inner surface of jacket 28 at 90, and the annular reinforcing member 26 is welded to the outer surface of jacket 28 at 91. With this arrangement, vertical loads and inertia forces, applied to the vertical members by container 40, are transmitted through shell 28 to reinforcing member 26 and thence to base means 23.

As seen in Figure 2, the members 50 extend from the outer surface of container 40 in a direction opposed to the direction of extension of the diagonally disposed members 64. Since these members extend from the same surface in opposed directions, a preloaded tensile force applied to members 50 will be opposed by a corresponding tensile force applied to members 64. Hence it is seen that by means of the adjustable connecting means, provided by the nuts 55 at the mounting brackets for the ends of the members, pre-loaded forces can be applied to the members, which preloaded forces are in addition to the normal static and inertia forces applied thereto.

In a similar manner the diagonal members 64 are pre-

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loaded against the opposite group of diagonal members 66 provided at the opposite side of the vessel. In addition, the longitudinal members 76 and the longitudinal members 77 are extended in opposite directions from the same surface and can therefore be preloaded against each other.

Reference is next made to Figure 4 which illustrates a novel support member 50-A which includes upper end portion 100, lower end portion 101, and an intermediate portion 102, the cross-sectional area of intermediate portion 102 being reduced relative to the cross-sectional areas of end portions 100 and 101.

Such reduction of cross-sectional area of intermediate portion 102 is effected by cold working member 50-A in a suitable manner such as by cold rolling or cold drawing the member. Such cold working of member 50-A serves to increase the ultimate strength of the member for any given cross-sectional area. Hence the total weight of members 50-A is reduced and the area of the heat leak path provided by each member is materially reduced as compared to a member which has not been cold worked to effect the above described reduction in cross-sectional area.

A plurality of the members 50-A are connected between brackets 46 and 47 in the manner illustrated in Figures 1, 2, and 3 with such plurality of members being subjected to preloaded tension and in coextensive arrangement to provide combined resistance to a common load.

It will be understood that the other members 57, 64, 66, 71, 72, 73, and 74 can all or in part be provided with a portion of reduced cross-sectional area formed by cold working of the member and mounted at their ends in the specific manner next to be described.

Reference is again made to Figure 4 which illustrates a novel end connection illustrated in connection with one of the members 50-A. Such end connection is formed by an inner washer 105 provided with spherical surface 106 engaged by a confronting spherical surface 107 on an outer washer 108. As previously described in connection with members 50, a nut 55' is utilized on each threaded end of members 50-A to provide means for mounting said members to brackets 46 and 47 and to provide means for applying preloaded tension to said members.

With reference to Figure 4 it will be noted that clearances are provided as illustrated at 110 between member 50-A and flanges 52 and 53 and also at 111 between member 50-A and the wall of the holes through inner washers 105. This arrangement permits sliding movement at the confronting surfaces 106 and 107, of washers 105 and 108 when nuts 55 are being tightened or when the configuration of the system is in any way changed under variations in imposed loading. Hence the longitudinal axis L of member 50-A will at all times be aligned between end connections and members 50-A will at no time be subjected to bending stresses.

With further reference to Figure 4 it will be noted that the longitudinal axis L of member 50-A, forms an acute angle A with a line R in said plane passing through said fastening location 112 and the center C of the container. Such acute angular configuration between axis L and radial line R provides a suspension configuration wherein thermally imposed contraction of container 40 upon cooling, and the resulting inward movement of wall 41, relative to the outer shell 28 tend to foreshorten members 50-A and reduce the previously mentioned thermal stresses imposed on such members. Accordingly the preloading tensile forces on members 50-A will never be augmented by thermally imposed stresses caused by contraction of container 40 upon cooling. Hence the resulting combined stresses imposed on members 50-A will always be positive and hence always maintain members 50-A in tension under static and normal dynamic loadings. It will be understood, of course, that under

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high dynamic loadings the stresses in certain members may decrease to zero.

It will be understood that the foregoing description of members 50-A, shown in detail in Figure 4, also applies to members 64 and 66, and members 71, 72, 73 and 74.

While the forms of embodiments of the present invention as herein disclosed constitute preferred forms, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow:

I claim:

1. An apparatus for storing a volatile liquid having a boiling point temperature materially below 273° K. comprising

a horizontally disposed cylindrical outer insulating jacket,

a horizontally disposed cylindrical inner storage container,

the jacket and storage container defining an intermediate insulating space,

first and second major reinforcing bands embracing said jacket at zones between its midsection and the ends of said container;

first and second minor reinforcing bands embracing said jacket at zones intermediate between its midsection and the major reinforcing bands;

and a suspension system positioned within said insulation space and located radially outwardly of said container for supporting said container within said jacket, said system comprising axial positioning means, vertical positioning means and lateral positioning means;

the axial positioning means comprising first and second pluralities of criss-cross arranged tension rods extending generally axially but diagonally of said container, one plurality of said rods being disposed on each side of said container,

and means for adjustably securing the ends of said rods to said jacket and container at points aligned with said minor reinforcing bands;

the vertical positioning means comprising first, second, third and fourth pluralities of vertical tension rods extending transversely of said container, two of said pluralities being located on each side of said container, one at each end,

and means for adjustably securing the upper ends of said vertical tension rods to the jacket and their lower ends to the container at points aligned with said major reinforcing bands;

and the lateral positioning means comprising first, second, third and fourth pluralities of diagonal tension rods extending transversely of said container and in non-overlapping relation to the vertical rods, two of said pluralities being located on each side of the container, one at each end,

and means for adjustably securing the upper ends of said diagonal tension rods to the container and their lower ends to the jacket at points aligned with said major reinforcing bands.

2. Apparatus in accordance with claim 1 in which the ends of the tension rods are secured to swivel-bearing brackets.

3. An apparatus for storing a volatile liquid having a boiling point temperature materially below 273° K. comprising

a horizontally disposed cylindrical outer insulating jacket,

a horizontally disposed cylindrical inner storage container,

the jacket and storage container defining an intermediate insulating space,

and a suspension system positioned within said insulation space and located radially outwardly of said container for supporting said container within said jacket, said system comprising axial positioning means, vertical positioning means and lateral positioning means;

the axial positioning means comprising first and second pluralities of criss-cross arranged tension rods extending

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generally axially of said container, one plurality of said rods being disposed on each side of said container,
and means for adjustably securing the ends of said rods to said jacket and container;

the vertical positioning means comprising first, second, third and fourth pluralities of vertical tension rods extending transversely of said container, two of said pluralities being located on each side of said container, one at each end,

and means for adjustably securing the upper ends of said vertical tension rods to the jacket and their lower ends to the container;

and the lateral positioning means comprising first, second, third and fourth pluralities of diagonal tension rods extending transversely of said container and in non-overlapping relation to the vertical rods, two of said pluralities being located on each side of the container, one at each end,

and means for adjustably securing the upper ends of said diagonal tension rods to the container and their lower ends to the jacket.

4. Apparatus in accordance with claim 3 in which the ends of the tension rods are secured to swivel-bearing brackets.

5. Apparatus in accordance with claim 3 in which the tension rods are formed with reduced cross sections intermediate the ends.

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6. Apparatus in accordance with claim 3 in which the tension rods are threaded at each end to be secured between the jacket and container.

7. Apparatus in accordance with claim 3 in which one end of at least one of the tension rods is secured to a swivel bearing bracket comprising a bracket member having an opening through which said end freely projects, a pair of washer members formed with complementary curved surfaces and carried by said end of said rod, and a lock nut threaded onto said end.

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