

[54] **PNEUMATICALLY OPERATED LIFT DEVICE**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 183,554, Sept. 24, 1971, abandoned.

[52] U.S. Cl. **254/93 HP**

[51] Int. Cl. **B66f 3/24**

[58] Field of Search **254/93 R, 93 HP**

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[57] **ABSTRACT**

A lifting device comprising an upper platform to support a load; a lower base platform and an inflatable envelope interposed between the two platforms for inflation to lift the load, the envelope being of a configuration to stabilize the upper platform. The envelope may be of generally toroidal configuration to form a central compartment which may or may not be pressurized to cooperate in the support of the upper platform. In some practices of the invention, the upper platform is flexible to conform to loads that have non-planar bottom surfaces. In such practices of the invention, the central compartment may be vented to the atmosphere to favor central downward bowing of the flexible platform for a greater area of pressure contact with a downwardly bulging load.

28 Claims, 13 Drawing Figures

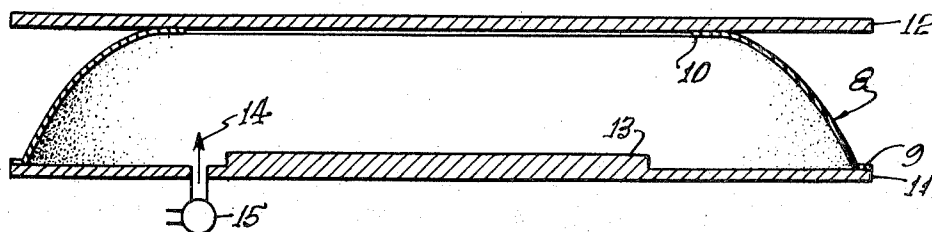


FIG. 1.

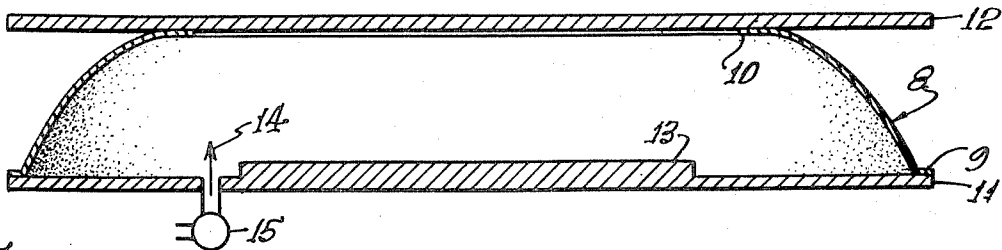


FIG. 2.

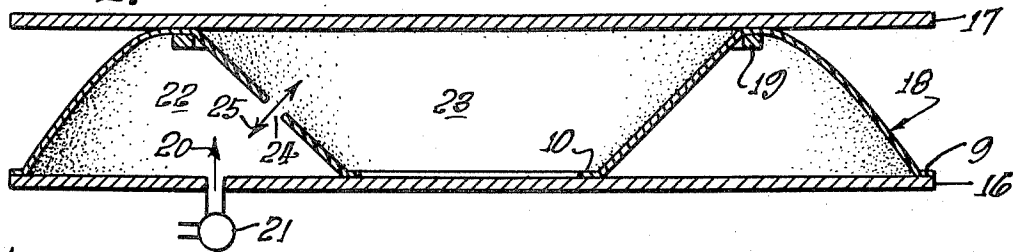


FIG. 3.

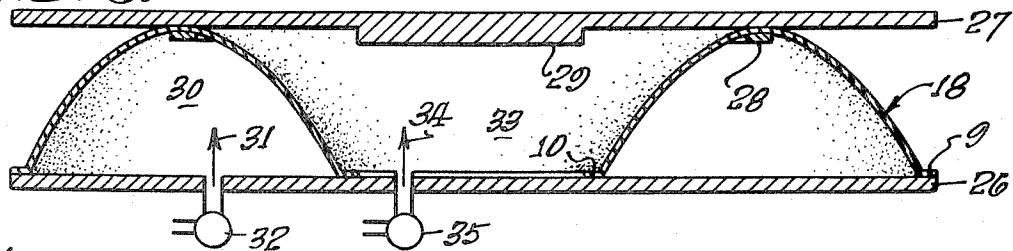


FIG. 4.

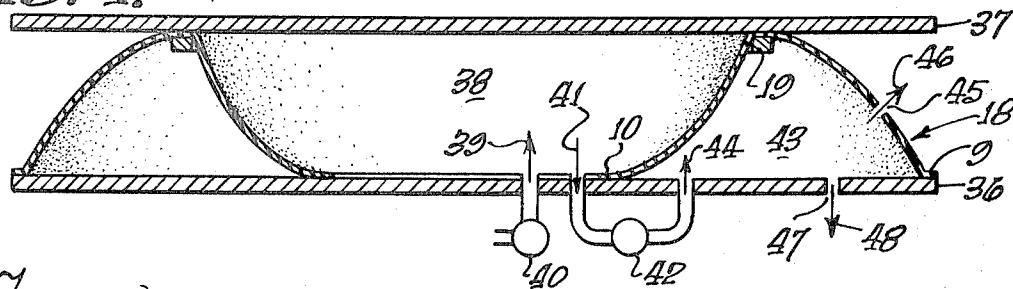
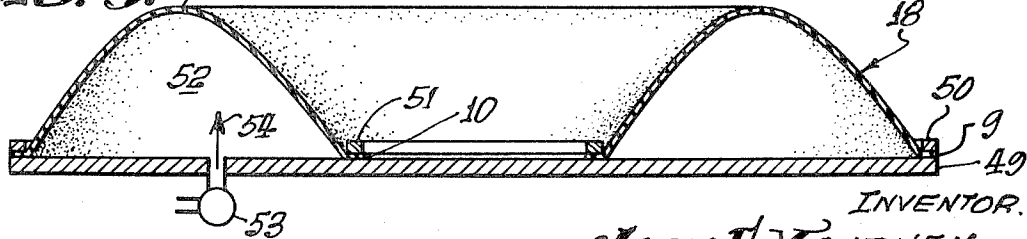


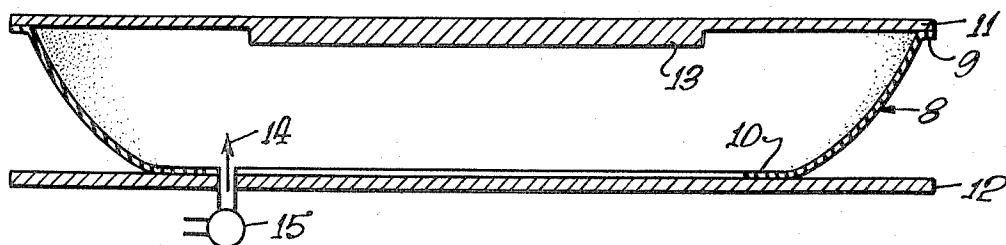
FIG. 5.



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Fig. 6.



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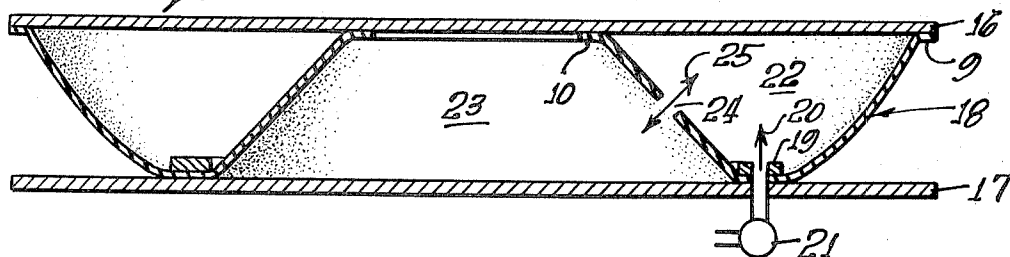


Fig. 8.

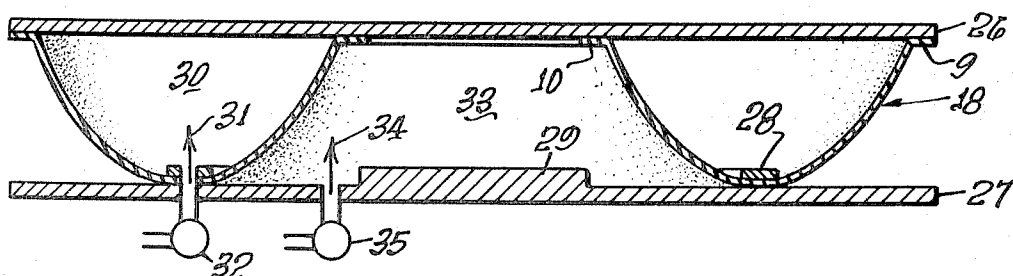
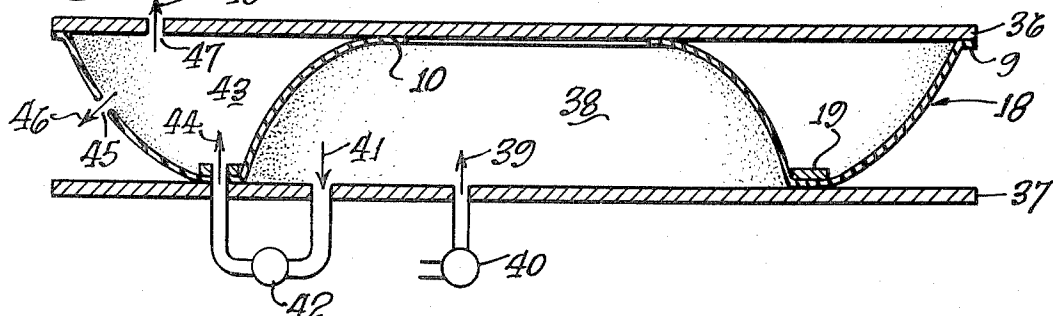


Fig. 9. — 48



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FIG. 10.

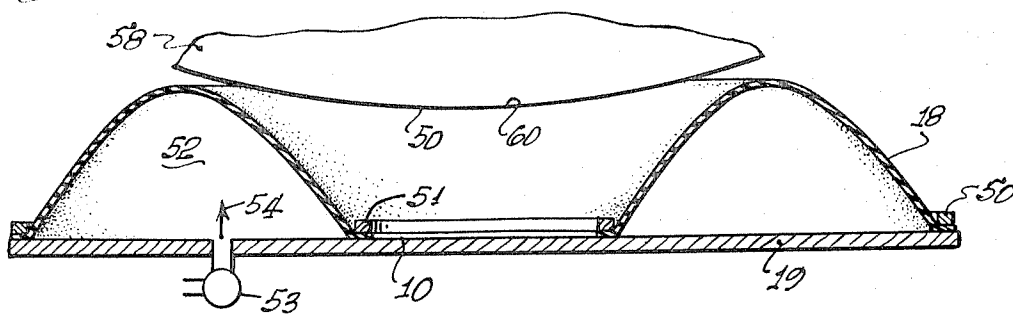


FIG. 11.

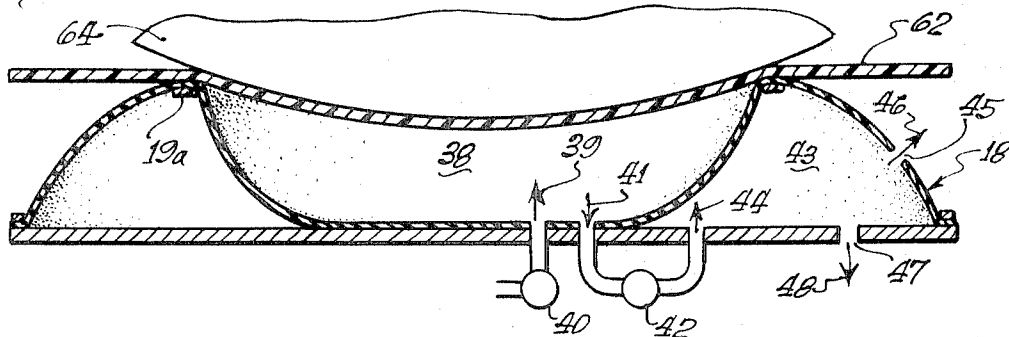


FIG. 12.

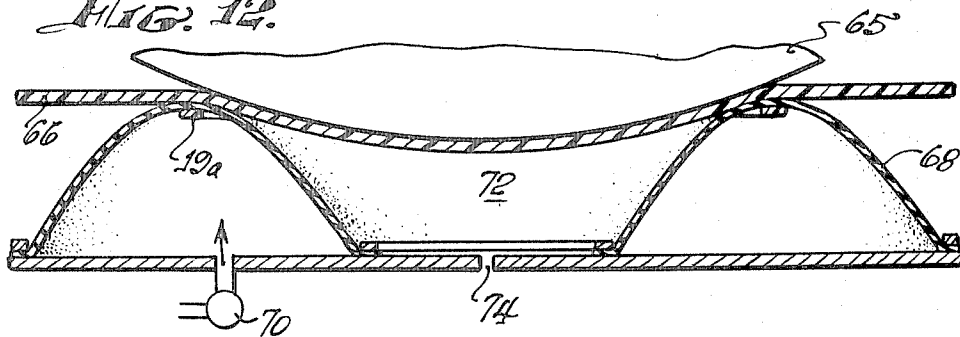
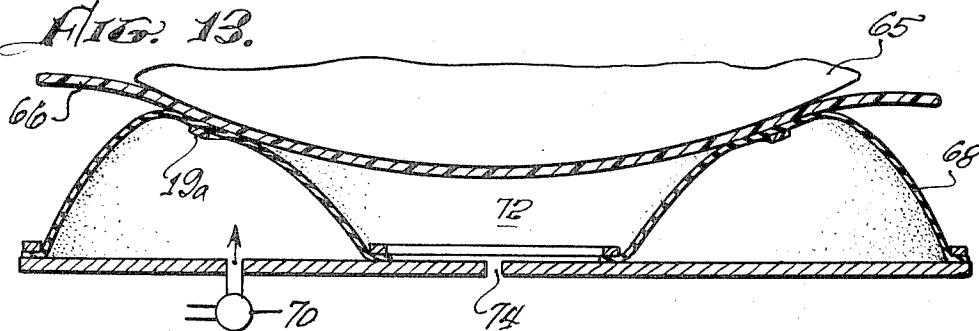


FIG. 13.



PNEUMATICALLY OPERATED LIFT DEVICE**CROSS REFERENCE TO RELATED APPLICATION**

This application is a continuation-in-part of my co-
pending application Ser. No. 183,554, filed Sept. 24,
1971, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to improvements in fluid pres-
surized lifting devices. Such lifting devices are typically
used instead of mechanical jacks when the object to be
lifted is massive, headroom underneath the object for
placement of jacks is limited, or the object has insuffi-
cient strength to withstand concentrated jacking
forces. Examples of objects commonly lifted by fluid
pressurized lifting devices include housing modules and
damaged aircraft. Fluid pressurized lifting devices are
used in these applications because they have a mini-
mum profile when collapsed and support the load over
a relatively large lifting area. Some types are also capa-
ble of freely distorting their shape to match the contour
of the underside of the load to be lifted.

Pressurized lifting devices currently available often
consist of one or more flexible bags which are con-
structed of rubberized fabric and may be filled under
pressure with any suitable working fluid such as air or
water. It is a common difficulty with such lifting devices
that although they can lift very heavy loads, they have
poor stability in shear and tilt once the load is sup-
ported by the lifting device. Sometimes elaborate inter-
nal networks of cross-ties are employed to stabilize
these units but their success is marginal because the
lifting bag must be stable over its total range of loads
and lifting heights. It is a primary object of my inven-
tion to provide a fluid pressurized lifting device of sim-
ple low cost construction which has a high degree of
stability in shear and tilt when supporting a wide range
of loads at all lifting heights within its working range.

SUMMARY OF THE INVENTION

In one practice of the invention an upper lifting plat-
form is superimposed on a lower base platform and a
circumferentially continuous diaphragm interconnects
the two platforms to form therewith a chamber that
may be inflated to lift a load. One of the circumferen-
tial edges of the diaphragm encompasses a relatively
large area on one of the two platforms and the other
edge of the diaphragm defines a smaller area on the
other of the two platforms, the two areas being sym-
metrical relative to each other. By virtue of this ar-
rangement, the diaphragm inclines inwardly from one
of the two platforms to the other and therefore tends
to keep the lifting platform from shifting laterally re-
lative to the base platform because on any diameter of
the device the opposite inclined walls of the diaphragm
oppose opposite horizontal shifts of the lifting platform.
In addition, since the confined pressurized fluid exerts
uniform pressure on the underside of the platform, the
diaphragm tends to prevent tilting of the lifting plat-
form out of horizontal. Thus, the arrangement stabi-
lizes the load and tends to cause the load to rise uni-
formly along a vertical lift axis.

A further feature of this arrangement is that when the
expansile chamber is inflated only slightly the relatively
slack diaphragm spreads over the surface of the plat-

form to which it is attached and, as the inflation is pro-
gressively increased for lifting action, the slack portion
of the diaphragm peels away to reduce the area of the
platform that is under fluid pressure. Thus, as the pres-
sure of the fluid is increased, the area of pressure appli-
cation is decreased with the consequence that the load
seeks an equilibrium level, there being for any given
load a given equilibrium level for a given fluid pressure
within the operating range. The load is stabilized at the
equilibrium level and may be raised or lowered to a
new equilibrium level by simply raising or lowering the
fluid pressure.

In some practices of the invention the envelope be-
tween the two platforms assumes what may be termed
a semi-toroidal configuration when inflated. The dia-
phragm assumes this configuration because it is made
from a truncated cone of sheet material with the outer
and inner circumferential edges of the cone attached to
one of the two platforms and with a continuous inter-
mediate portion of the cone attached to the other plat-
form to define therewith an area of the other platform
that is less than the area defined by the outer circum-
ferential edge of the diaphragm and greater than the
area defined by the inner circumferential area of the
diaphragm. The outer circumferential wall of the semi-
toroidal envelope or diaphragm functions in the same
manner as the outer circumferential wall in the above-
described embodiment of the invention and thus tends
to stabilize the load. In addition, the inner circumferen-
tial wall of the diaphragm functions in the same stabiliz-
ing manner because diametrically opposite portions of
the wall slope in opposite directions to oppose opposite
tendencies for the lifting platform to shift laterally re-
lative to the base platform.

Preferably the fluid to inflate the lifting device is sup-
plied through a pressure regulator to make it possible
to control and predetermine the fluid pressure. In the
forms of the invention that employ a semi-toroidal in-
flated diaphragm to form a semi-toroidal chamber, the
inner circumferential wall of the diaphragm defines a
second central chamber. These two chambers may be
separately supplied with controlled pressurized fluid or
the pressurized fluid source may be connected to only
one of the two chambers with suitable means provided
for fluid flow between the two chambers. In such an ar-
rangement, preferably the fluid flow between the two
chambers is controlled by an adjustable valve and the
chamber to which fluid is supplied by the other cham-
ber is preferably but not necessarily vented to the at-
mosphere by one or more bleeder ports. Thus, the in-
vention makes it possible to maintain equal pressures
in the two chambers or to maintain a higher pressure
in one chamber than in the other.

In another embodiment of the invention, a semi-
toroidal diaphragm is used but the upper lifting plat-
form is omitted so that the diaphragm is inflated di-
rectly against the load that is to be lifted. The semi-
toroidal diaphragm functions in the described load-
stabilizing manner but has the advantage of conforming
with the shape of the load where the diaphragm
contacts the load; thus, the fluid pressure is distributed
over the contacted portion of the load in a manner
which is impossible with a rigid, flat lifting platform.

In some practices of the invention, the upper plat-
form is flexible to conform to a load that is non-planar
on its underside. If desired, the central chamber that is
formed by the inner wall of a semi-toroidal envelope

may be at atmospheric pressure to favor downward bowing or downward dishing of the upper flexible platform for increase in the area of contact with a downwardly bulging load.

The various features and advantages of the invention may be understood from the following detailed description together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are to be regarded as merely illustrative:

FIG. 1 is a cross-sectional view of one inflatable lifting unit comprising an inflatable envelope mounted between two nominally parallel platforms;

FIG. 2 is a cross-sectional view of an alternate lifting unit comprising a semi-toroidal inflatable envelope mounted between two nominally parallel platforms;

FIG. 3 is a cross-sectional view similar to FIG. 2 with means for separately pressurizing the interior of the semi-toroidal envelope and the central cavity surrounded by the envelope;

FIG. 4 is a cross-sectional view similar to FIG. 2 with means for inflating the semi-toroidal envelope at lower pressure than the central cavity;

FIG. 5 is a cross-sectional view of an inflatable lifting unit comprising a semi-toroidal envelope mounted on a single base platform;

FIGS. 6-9 show how the structures illustrated by FIGS. 1-4, respectively, may be inverted if desired;

FIG. 10 shows how the semi-toroidal envelope of FIG. 5 conforms to a load having a non-planar bottom surface;

FIG. 11 shows how a flexible plate which is substituted for the rigid upper platform of FIG. 4 yields to conform to a load that has a bulging bottom;

FIG. 12 shows how a flexible plate supported solely by a semi-toroidal envelope conforms to a load having a bulging bottom;

FIG. 13 shows how reducing the pressure in the semi-toroidal envelope in FIG. 12 to lower the load increases the area of the envelope that is in pressure contact with the flexible plate.

DESCRIPTION OF SELECTED EMBODIMENTS OF THE INVENTION

FIG. 1 is a diametrical cross section through a single annular pressurized lifting unit which constitutes the first embodiment of my invention. This unit is shown in the fully inflated condition. A truncated conical diaphragm 8 forms an inflatable envelope between a first lower rigid base platform 11 and a second upper rigid lifting platform 12. The larger diameter edge 9 is attached by any suitable airtight means to the top surface of base platform 11 and the smaller diameter edge 10 is attached to the underside of the upper lifting platform 12. Base platform 11 is fitted with an integral circular raised portion 13 which serves as support for the upper lifting platform 12 when the unit is at collapsed height and no pressurized lifting fluid is being supplied to the interior of the lifting unit. This prevents the loaded upper platform 12 from crushing collapsed diaphragm 8 when the unit is at rest. Lifting fluid can be introduced into the interior of the unit as shown by arrow 14 through a pressure regulating valve 15. Any suitable working fluid can be employed including air, steam, gas, water or oil.

The weight which can be lifted by a unit like that shown in FIG. 1 is equal to the mathematical product of the pressure of the lifting fluid and the area over which the lifting fluid bears against the underside of load supporting platform 12. Since lower edge 9 of diaphragm 8 has a larger diameter than upper edge 10, the effective area of the underside of plate 12 over which the fluid pressure acts varies inversely with the height which the load is lifted. For example, if platform 12 is barely lifted free of the raised portion 13 of the base platform, diaphragm 8 is pressed up against the underside of platform 12 almost to the full diameter of its outer edge 9. On the other hand, if upper platform 12 is lifted to full height as shown in FIG. 1, the effective lift area extends only out to the smaller diameter edge 10. Therefore, in all embodiments of my invention, the effective lifting area decreases as lifting height increases. This means that with a given load supported on platform 12, pressure of the fluid inside the lifting unit must be increased to raise the load above a given equilibrium height. Conversely, the pressure must be reduced to lower the load below a given equilibrium position. Experience has shown that by using a pressure regulating valve to control pressure inside the unit, a very precise control of vertical position of the load can be achieved in this invention.

This lifting unit also possesses a very high degree of inherent static stability with respect to vertical height at all heights within the working range. If, for example, the unit were supporting a load at full height with upper platform 12 in the position shown in FIG. 1 and pressure regulator 15 were set to support the load in equilibrium; if the load suddenly increased it would attempt to settle toward the base platform 11. Due to the conical shape of diaphragm 8, however, the effective lifting area over which the lifting fluid bears against the underside of platform 12 would increase as soon as platform 12 moved downward. As a result, platform 12 would take up a new equilibrium position slightly below its original position without any change in setting of the pressure regulating valve 15 being required.

The conical construction of diaphragm 8 also contributes to the stability of upper platform 12 with respect to horizontal movement relative to the base platform 11. During operation, the lifting fluid inside the unit tends to force platforms 11 and 12 apart. This is resisted by the load supported by plate 12 and radial tension in diaphragm 8. If a diametrical slice were taken through the lifting unit in FIG. 1, that slice would constitute a bifilar pendulum consisting of parallel diametrical strips of platforms 11 and 12 connected together by two angularly disposed strips of diaphragm 8. These strips of diaphragm 8 are spaced further apart at their points of attachment to base platform 11 than they are at their points of attachment to upper platform 12. Also pressure inside the unit tends to force the two platforms apart and place the strips of diaphragm 8 in tension. It is well known to mechanical engineers that a bifilar pendulum with non-parallel tension members has a very strong tendency to center one rigid member above the other and to maintain them in parallel alignment with each other. In my lifting device this tendency to remain centered produces a high degree of horizontal shear stability and the tendency to remain parallel produces a high degree of tipping stability. These benefits result from the conical construction of the dia-

phragm employed in the first embodiment of my invention.

FIG. 2 is a diametrical cross section through a single annular pressurized lifting unit which constitutes the second embodiment of my invention. This unit is shown in the fully inflated condition. A truncated cone of sheet material formed into a semi-toroidal diaphragm 18 is mounted between a rigid base platform 16 and a rigid lifting platform 17. The larger diameter edge 9 is attached by any suitable airtight means to base platform 16 and the smaller diameter edge 10 is also attached to base platform 16. The annular portion of diaphragm 18 which lies midway between outer edge 9 and inner edge 10 is attached to the underside of lifting platform 17 by rigid mounting ring 19. Mounting ring 19 also serves to support lifting platform 17 when the unit is at collapsed height and no pressurized lifting fluid is being supplied to the interior of the lifting unit. This prevents loaded platform 17 from crushing collapsed diaphragm 18 when the unit is at rest. Lifting fluid can be introduced into the diaphragm as shown by arrow 20 through a pressure regulating valve 21. This fluid can flow freely between the interior of the diaphragm 22 and airtight chamber 23 at the center of the diaphragm through an arbitrary number of fixed diameter orifices 24 placed in the inner diaphragm wall as shown by the double headed arrow 25. Therefore, pressures in the interior of the diaphragm 22 and the center chamber 23 are equal in the second embodiment of my invention. Any suitable working fluid can be employed in the second embodiment including air, steam, gas, water or oil.

As previously explained for the first embodiment of my invention the conical construction of the diaphragm causes the effective lifting area to decrease as lifting height increases. This produces a very high degree of stability with respect to vertical position and very precise control of height can be achieved through adjustment of the pressure regulating valve 21. As previously explained the conical construction of the diaphragm also contributes to the horizontal stability of the lifting platform relative to the base platform. If a diametrical slice were taken through the lifting unit in FIG. 2, that slice would constitute a double bifilar pendulum consisting of diametrical strips of platforms 16 and 17 interconnected by two pairs of angularly disposed strips of diaphragm 18. Each pair of these strips of diaphragm 18 are spaced farther apart at their points of attachment to base platform 16 than they are at their points of attachment to load platform 17. Also pressure inside the unit tends to force the two platforms apart and place the radial strips of diaphragm 18 in tension thereby producing a truss-like structure during operation. A double bifilar pendulum of this type with non-parallel tension members has a very strong tendency to center one platform above the other and to maintain the platforms' parallel alignment with each other. Their tendency to remain centered produces a high degree of horizontal shear stability and their tendency to remain parallel produces a high degree of tipping stability. These benefits of the conical diaphragm construction are enhanced by the semi-toroidal shape of diaphragm 18 in the second embodiment of my invention. As shown in FIG. 2, this configuration effectively constitutes two concentric cones instead of the single cone employed in FIG. 1. Therefore, the shear and tipping stability of the second embodiment of my invention is

approximately twice as great as the stability of the first embodiment.

FIG. 3 is a diametrical cross-section through a single annular pressurized lifting unit which constitutes the third embodiment of my invention. This unit is shown in the fully inflated condition. A truncated cone of sheet material formed into a semi-toroidal diaphragm 18 is mounted between a rigid base platform 26 and a rigid lifting platform 27. The larger diameter edge 9 is attached by any suitable airtight means to base platform 26 and the smaller diameter edge 10 is also attached to base platform 26. The annular portion of diaphragm 18 which lies midway between outer edge 9 and inner edge 10 is attached to the underside of lifting platform 27 by a mounting ring 28. The underside of lifting platform 27 has an integral raised portion 29 which serves to support lifting platform 27 when the unit is at collapsed height and no pressurized lifting fluid is being supplied to the interior of the lifting unit. This prevents the loaded lifting platform 27 from crushing collapsed diaphragm 18 when the unit is at rest. Lifting fluid can be introduced into the interior 30 of the diaphragm as shown by arrow 31 through a pressure regulating valve 32. Lifting fluid can also be introduced into the chamber 33 in the center of the diaphragm as shown by arrow 34 through a second pressure regulating valve 35. Therefore, pressures in the interior of the diaphragm 30 and the center chamber 33 can be separately controlled in the third embodiment of my invention. If desired, pressure inside the diaphragm 30 may be set to be greater than, equal to or less than pressure in the center chamber 33. Any suitable working fluid can be employed including air, steam, gas, water or oil.

As previously explained for the second embodiment of my invention the conical construction of the diaphragm causes the effective lifting area to decrease as lifting height increases. This produces a very high degree of stability with respect to vertical position and very precise control of height can be achieved through adjustment of the pressure regulating valves 32 and 35. As previously explained the conical construction of the diaphragm also contributes to the stability of the lifting platform.

FIG. 4 is a diametrical cross section through a single annular pressurized lifting unit which constitutes the fourth embodiment of my invention. This unit is shown in the fully inflated condition. A truncated cone of sheet material formed into a semi-toroidal diaphragm 18 is mounted between a rigid base platform 36 and a rigid lifting platform 37. The larger diameter edge 9 is attached by any suitable airtight means to base platform 36 and the smaller diameter edge 10 is also attached to base platform 36. The annular portion of diaphragm 18 which lies midway between outer edge 9 and inner edge 10 is attached to the underside of lifting platform 37 by a rigid mounting ring 19. As in the second embodiment, this ring also serves to support the lifting platform when the unit is at collapsed height and no pressurized lifting fluid is being supplied to the interior of the lifting unit. Lifting fluid can be introduced into the center chamber 38 as shown by arrow 39 through a pressure regulating valve 40. Some portion of this lifting fluid can then bleed from cavity 38 as shown by arrow 41 and pass through adjustable valve 42 into the interior 43 of inflatable diaphragm 18 as indicated by arrow 44. The outer wall of diaphragm 18

is fitted with at least one orifice 45 through which lifting fluid can escape to the surrounding atmosphere as indicated by arrow 46. In addition, at least one orifice 47 is provided in base platform 36, through which fluid may bleed to the surrounding atmosphere as shown by arrow 48. Either the orifices 45 or the orifices 47 may be omitted. With such an arrangement, depending upon the setting of valve 42 relative to flow capacity of the bleeder orifice or orifices, the pressure inside diaphragm 18 can be set to some constant fraction of the pressure inside the center chamber 38. Although some small amount of lifting fluid is lost continually during operation through the bleeder orifice or orifices, this configuration produces lower stresses on the inner half of diaphragm 18 than the other embodiments of my invention. Any suitable working fluid can be used; but, since some fluid is bled off to atmosphere in the fourth embodiment, air or steam would normally be preferred.

As explained for previous embodiments of my invention the conical construction of the diaphragm produces a very high degree of stability with respect to height, horizontal shifting, and tipping of the lifting platform.

FIG. 5 is a diametrical cross section through a single annular pressurized lifting unit which constitutes the fifth embodiment of my invention. This unit is shown in the fully inflated condition. A truncated cone of sheet material formed into a semi-toroidal diaphragm 18 is mounted on a rigid base platform 49. The larger diameter edge 9 is attached to base platform 49 by mounting ring 50 and the smaller diameter edge 10 is attached by mounting ring 51. These mounting rings also serve to support the load when the unit is collapsed and no lifting fluid is being supplied to pressurize the lifting diaphragm. In FIG. 5, the annular portion 55 of diaphragm 18 which lies midway between outer edge 9 and inner edge 10 projects upward under the influence of pressurized lifting fluid in the interior 52 of diaphragm 18. This pressurized lifting fluid is introduced into the diaphragm through pressure regulating valve 53 as shown by arrow 54. During operation, annular portion 55 of diaphragm 18 presses against the underside of a load (not shown) which is to be lifted. The underside of the load should be free of sharp protrusions which might puncture diaphragm 18 but the load does not have to be flat bottomed since inflated diaphragm 18 can distort as required to match the contour of the load. Any suitable working fluid can be used to pressurize the diaphragm including air, steam, gas, water or oil.

As explained in previous embodiments of my invention the conical construction of the diaphragm produces a very high degree of stability with respect to vertical height, parallel horizontal relative movement of the load and tipping of the load.

The four embodiments of my invention in FIGS. 1 through 4 will operate in exactly the same manner if they are inverted. Thus, FIG. 6 is FIG. 1 inverted; FIG. 7 is FIG. 2 inverted; FIG. 8 is FIG. 3 inverted; and FIG. 9 is FIG. 4 inverted.

FIG. 10 shows how the semi-toroidal envelope or diaphragm 18 of FIG. 5 yields to a load 58 having a non-planar bottom surface. The load 58, for example, may be the hull of a boat. It is apparent that the semi-toroidal envelope 18 forms two diametrically opposite arcuate cradles 60 that snugly conform to the configu-

ration of the hull. The area of the diaphragm 18 that makes pressure contact with the load varies directly with the weight of the load and inversely with the magnitude of the fluid pressure inside the diaphragm.

FIG. 11 shows a flexible upper plate 62 substituted for the rigid upper platform 37 of FIG. 4 and a flexible mounting ring 19a substituted for the mounting ring 19. The flexible plate 62 may, for example, be made of alternate laminations of rubber or plastic and reinforcing cloth. With the flexible plate 62 carrying a load 64 such as a boat having a convex bottom surface, the flexible plate forms a cradle of arcuate cross section to support the load in a stable manner with low unit pressure against the load.

The structure shown in FIG. 12 for supporting a load 65 employs a flexible upper plate 66 which is supported by a semi-toroidal diaphragm 68. The semi-toroidal diaphragm 68 is maintained under fluid pressure by the pressure regulating valve 70 but the central chamber 72 that is surrounded by the semi-toroidal diaphragm is vented to the atmosphere through a port 74. The atmospheric pressure in the central chamber 72 facilitates the downward bowing of the flexible plate 66 to conform to the downward bulging of the load 65.

FIG. 13 shows how the level of the load 65 in FIG. 12 may be lowered by reducing magnitude of the fluid pressure in the semi-toroidal diaphragm 68. It is apparent that lowering the fluid pressure causes an increase in the area of the diaphragm that is in pressure contact with the flexible plate 66. Since the lifting area varies inversely with the magnitude of the fluid pressure, the load seeks an equilibrium level and any desired equilibrium level may be quickly established.

My description in specific detail will suggest various changes, substitutions, and other departures from my disclosure within the spirit and scope of the appended claims.

I claim:

1. In a device to lift a load, the combination of:
a base platform for positioning below the load;
a lifting platform overlaying the base platform;
generally semi-toroidal diaphragm means interposed between the two platforms and attached to the two platforms for inflation to raise the lifting platform; and

means to supply fluid under pressure to inflate the diaphragm means,

a first continuous portion of the diaphragm means being attached to one of the two platforms and defining a first area thereon,

a second continuous portion of the diaphragm means being attached to the other of the two platforms and defining a second area thereon,

a third continuous portion of the diaphragm means being attached to the first of the two platforms defining a third area thereon,

the first area being substantially larger than the second area and being positioned substantially symmetrically thereof with the outer circumferential wall of the diaphragm means sloping upwardly and inwardly of the two platforms from the first area to the second area, whereby the tensions in the diametrically opposite portions of the outer circumferential walls of the diaphragm means oppose lateral shifts of the lifting platform relative to the base platform to stabilize the load, and

the second area being substantially larger than the third area and being positioned substantially symmetrically thereof with the inner circumferential wall of the diaphragm means sloping upwardly and outwardly of the two platforms from the third area to the second area, whereby the tensions in diametrically opposite portions of the inner circumferential walls of the diaphragm means oppose lateral shifts of the lifting platform relative to the base platform to stabilize the load.

2. A combination as set forth in claim 1 in which the means to supply fluid under pressure includes pressure regulating means to control the fluid pressure between the two platforms.

3. A combination as set forth in claim 1 in which said one platform is the base platform and said other platform is the lifting platform.

4. A combination as set forth in claim 1 in which said one platform is the lifting platform and said other platform is the base platform.

5. A combination as set forth in claim 1 in which said one platform is the base platform and said other platform is the lifting platform.

6. A combination as set forth in claim 1 in which said one platform is the lifting platform and said other platform is the base platform.

7. A combination as set forth in claim 1 which includes means to bleed air from the space between the two platforms to reduce oscillations of the lifting platform.

8. A combination as set forth in claim 1 in which said diaphragm means and said lower platform define a single compartment to receive the pressurized fluid for the sole support of the lifting platform.

9. A combination as set forth in claim 1 in which the two platforms and the inner circumferential wall of the semi-toroidal diaphragm means form a central closed expansile chamber; and

which includes means to supply fluid under pressure to said central chamber to create additional force to lift the load.

10. A combination as set forth in claim 9 in which the means to supply fluid under pressure to said central chamber includes pressure regulator valve means.

11. A combination as set forth in claim 9 in which the means to supply fluid under pressure communicates with the semi-toroidal chamber and the semi-toroidal chamber communicates with the central compartment to supply fluid under pressure thereto.

12. A combination as set forth in claim 9 in which the means to supply fluid under pressure is in direct communication with the semi-toroidal chamber and is in direct communication with the central chamber.

13. A combination as set forth in claim 9 in which the means to supply fluid under pressure communicates with the central chamber and the central chamber is in flow communication with the semi-toroidal chamber.

14. A combination as set forth in claim 13 which includes means to bleed air from the semi-toroidal chamber to reduce oscillations of the lifting platform.

15. A combination as set forth in claim 13 which includes means to adjust the rate of fluid flow from the central chamber to the semi-toroidal chamber.

16. A combination as set forth in claim 9 in which the means to supply fluid to the central chamber and the semi-toroidal chamber maintains the same fluid pressure in both chambers.

17. A combination as set forth in claim 9 in which the means to supply fluid to the two chambers maintains higher pressure in the central chamber than in the semi-toroidal chamber.

18. A combination as set forth in claim 9 in which the means to supply fluid to the two chambers maintains higher pressure in the semi-toroidal chamber than in the central chamber.

19. A combination as set forth in claim 1 which includes spacer means to protect the diaphragm means by limiting the approach of the lifting platform to the base platform when the diaphragm means is deflated.

20. A combination as set forth in claim 19 in which said spacer means projects upward from the base platform.

21. A combination as set forth in claim 19 in which said spacer means comprises means to anchor the diaphragm means to one of said two platforms.

22. In a device for lifting a load wherein diaphragm means is mounted on a base for upward expansion by inflation to lift the load with an upper portion of the inflated diaphragm means pressing against the load and conforming to the shape of the load,

the improvement comprising:

said envelope when inflated being of semi-toroidal configuration;

an outer peripheral edge of the envelope being attached to the base and defining a relatively large area on the base;

an inner peripheral edge of the envelope being attached to the base and defining a relatively small area on the base,

said two areas being located substantially symmetrically relative to each other,

the outer circumferential wall of the inflated diaphragm means sloping upwardly and inwardly whereby the tensions in the diametrically opposite portions of the outer circumferential wall of the diaphragm means oppose lateral shift of the elevated load relative to the base to tend to stabilize the load relative to the base,

the inner circumferential wall of the inflated diaphragm means sloping upwardly and outwardly whereby the tensions in the diametrically opposite portions of the inner circumferential wall of the diaphragm means also oppose opposite lateral shift of the elevated load relative to the base to stabilize the load.

23. A combination as set forth in claim 22 which includes pressure regulator means to maintain selected magnitudes of pressure inside the diaphragm means.

24. A combination as set forth in claim 1 in which said lift platform is flexible for deformation in response to the weight of the load to conform in art to the configuration of a load that has a non-planar bottom surface.

25. A combination as set forth in claim 1 in which the transverse cross-sectional configuration of the semi-toroidal diaphragm means is upperwardly convergent toward the lifting platform.

26. A combination as set forth in claim 25 in which the two platforms and the inner circumferential wall of the semi-toroidal diaphragm means form a central closed expansile chamber; and

which includes means to supply fluid under pressure to the central chamber to create additional force to lift the load.

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27. A combination as set forth in claim 1 in which the two platforms and the inner circumferential wall of the semi-toroidal diaphragm means form a central chamber and the central chamber is vented to the atmosphere to facilitate downward bulging of the central portion of the flexible lifting platform by a downwardly bulging load.

28. A combination as set forth in claim 1 in which the cross-sectional configuration of the diaphragm means

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is convergent toward the lifting platform so that the area of the diaphragm means in pressure contact with the lifting platform increases with depression of the diaphragm means by the lifting platform, whereby the magnitude of the area of the diaphragm means in pressure contact with the lifting platform varies directly with the weight of the load and inversely with the magnitude of the fluid pressure in the diaphragm means.

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