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INFLATABLE SEAL FOR FLOATING ROOF

Filed Dec. 8, 1961

2 Sheets-Sheet 1

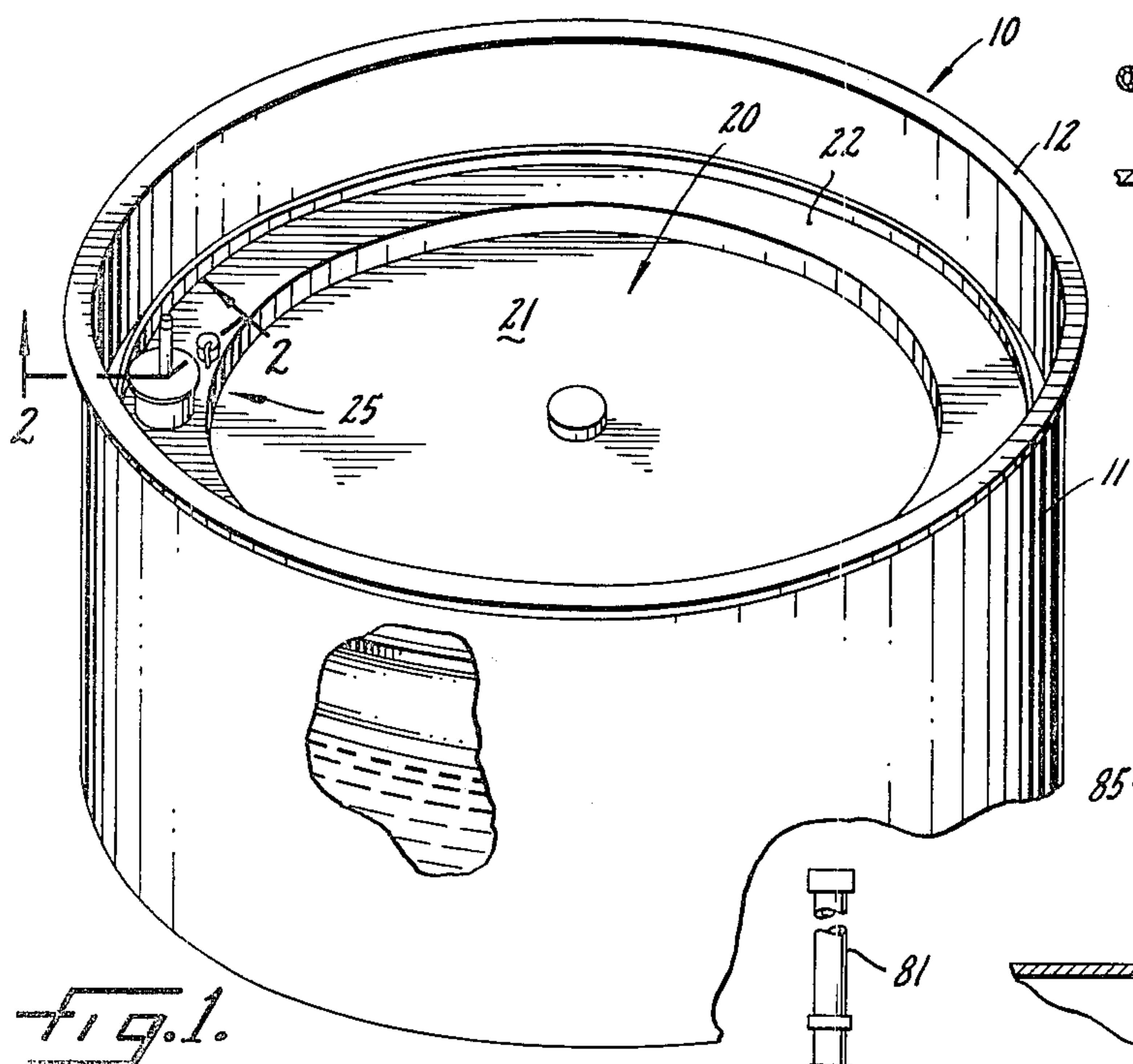


Fig. 1.

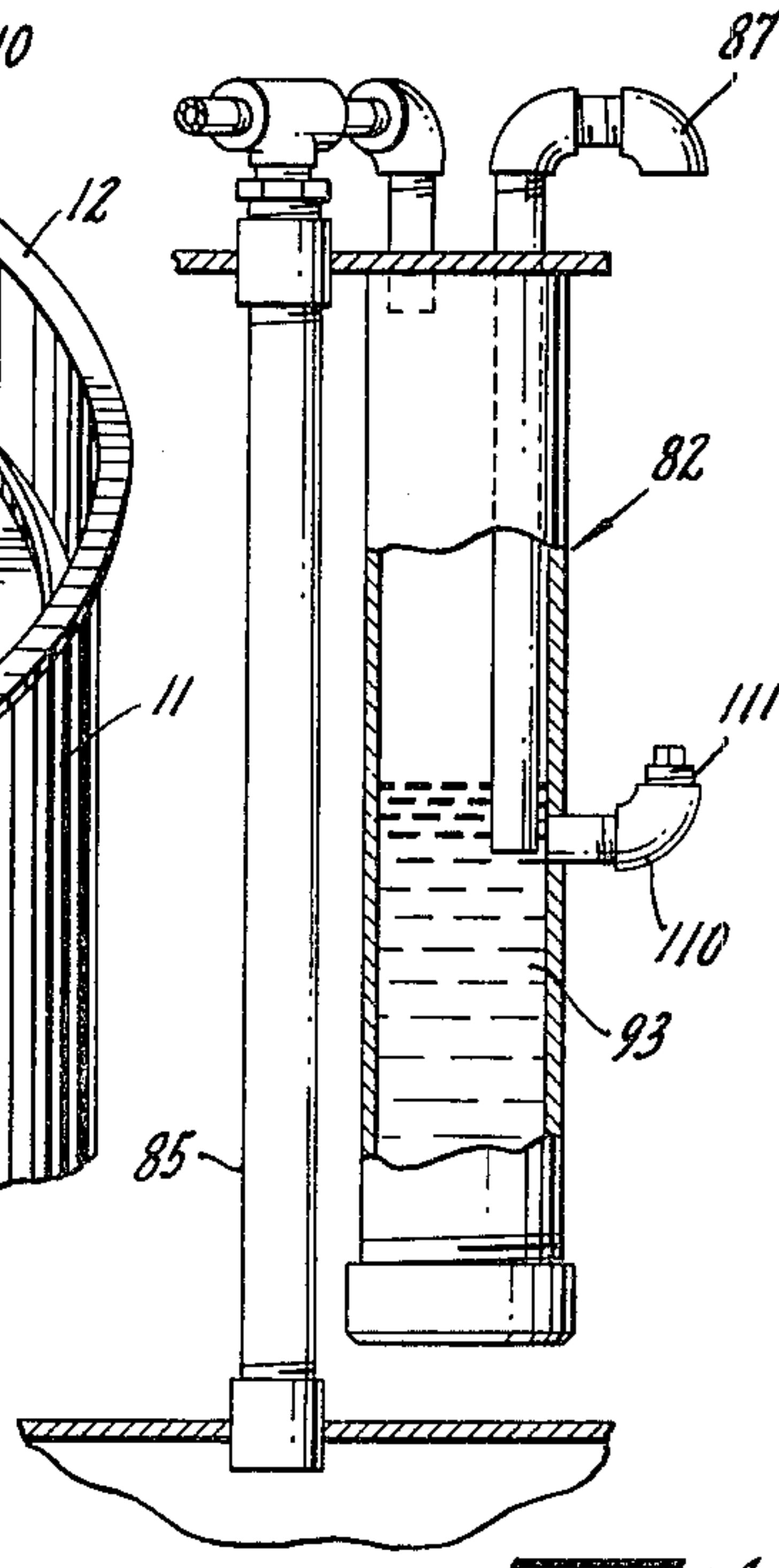


Fig. 4.

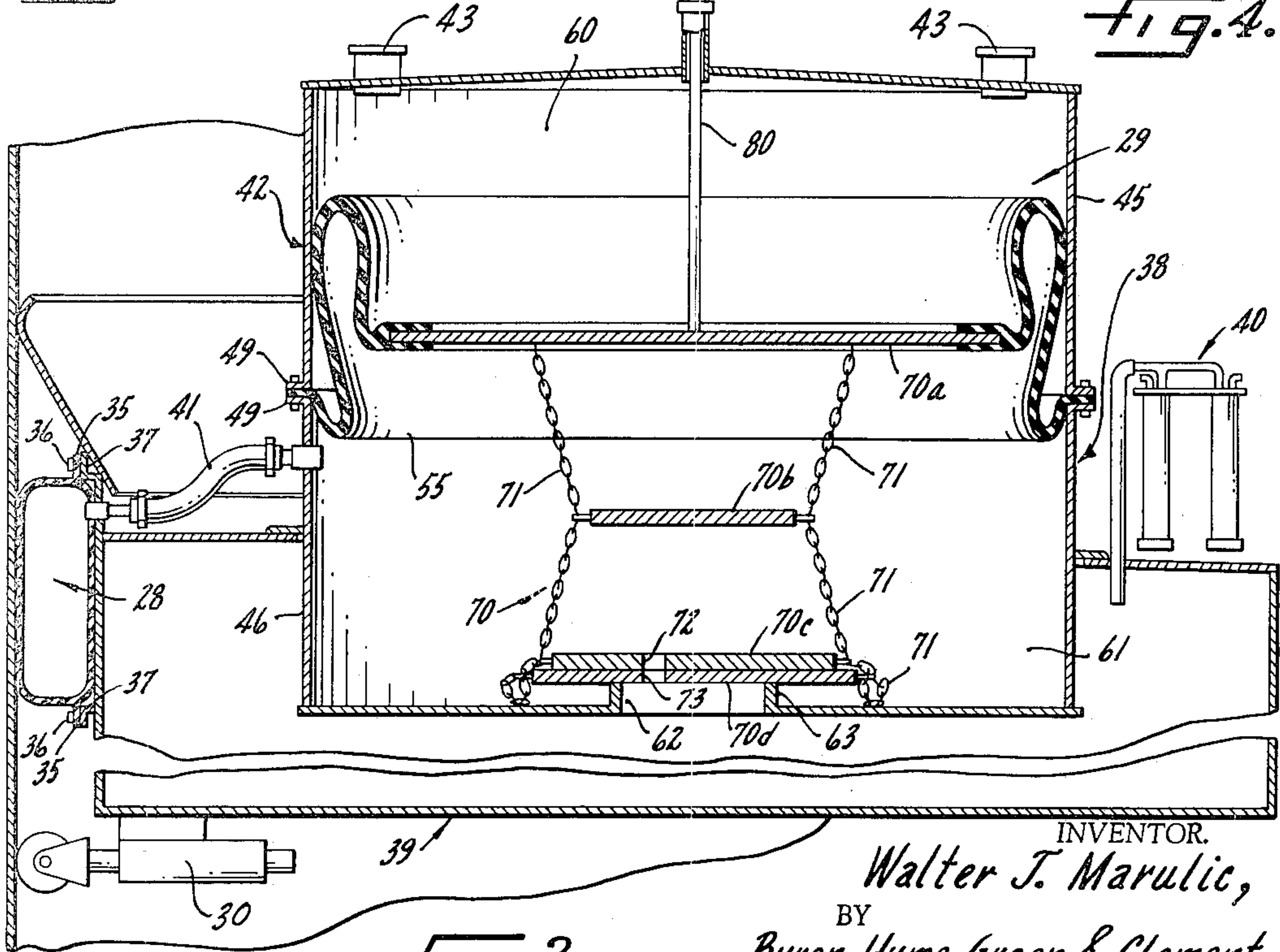


Fig. 2.

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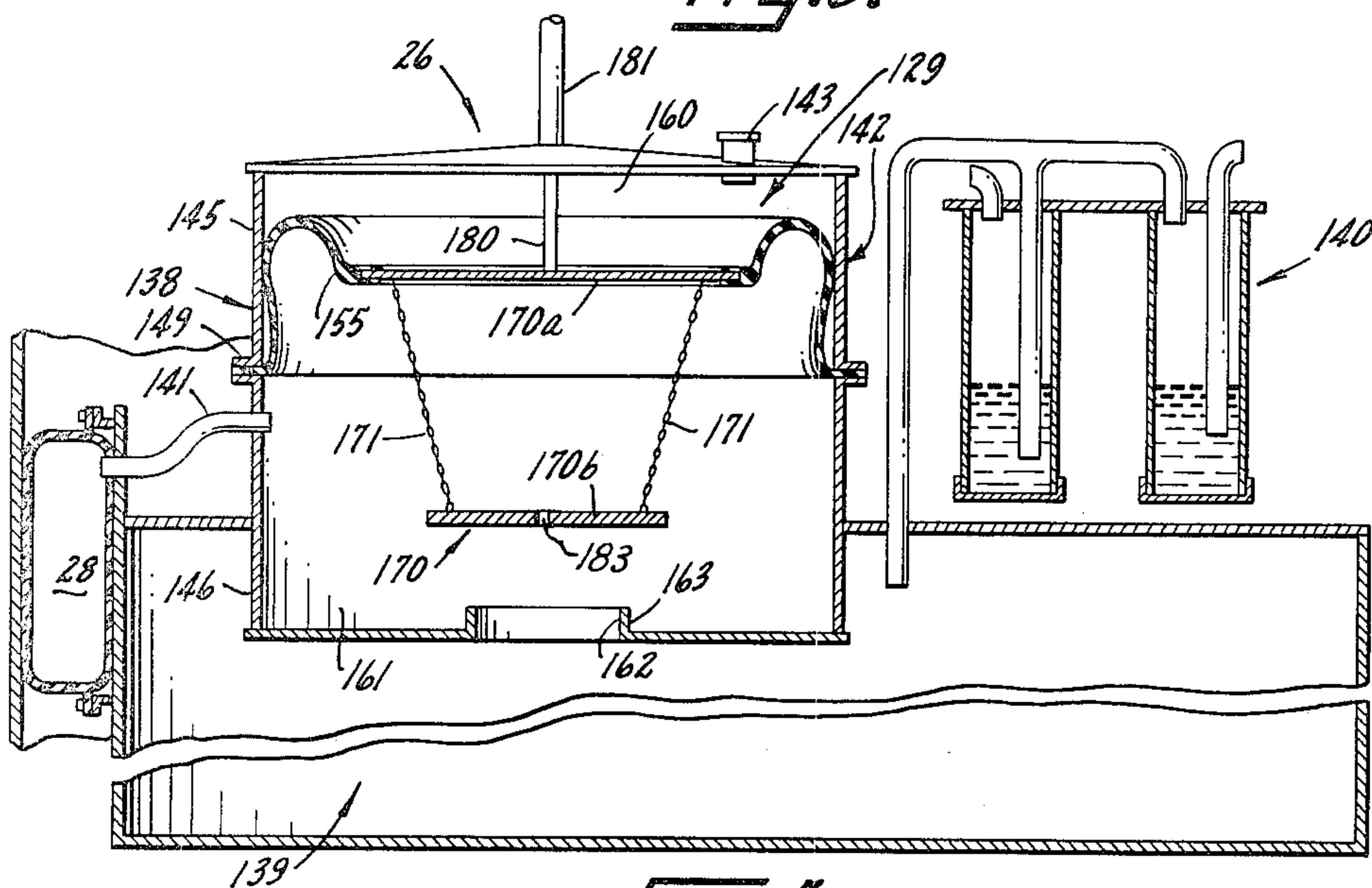
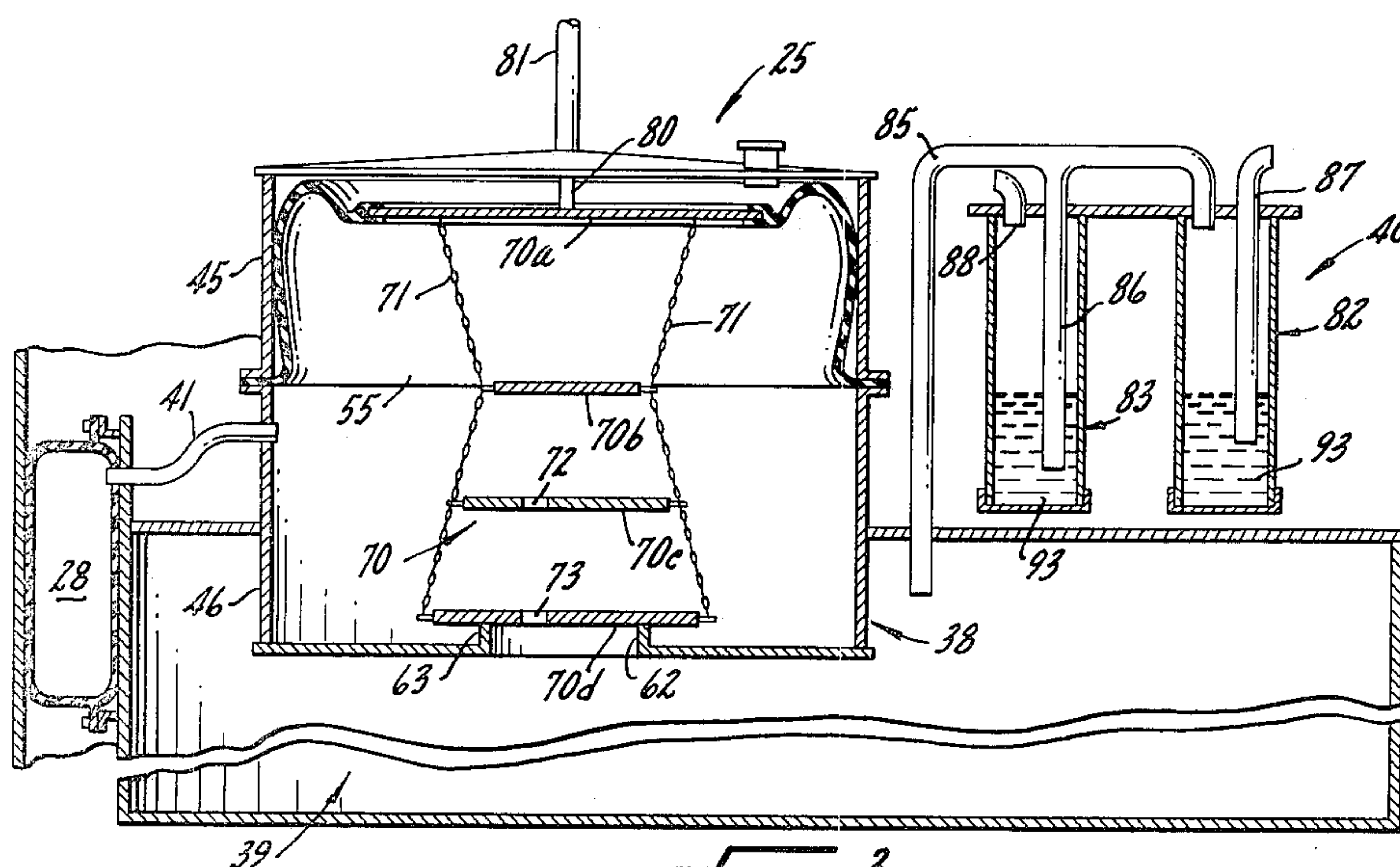
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1

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INFLATABLE SEAL FOR FLOATING ROOF

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11 Claims. (Cl. 220—26)

This invention relates in general to storage tanks and more particularly to a sealing arrangement for a storage tank of the floating roof type.

It is an object of this invention to provide a new and improved pressure seal system for a liquid storage tank having a floating roof.

It is another object to provide a pressure seal system which effects a superior vapor seal between a floating roof and the wall of a storage tank.

It is still another object to provide a pressure seal system which maintains an effective vapor seal between a floating roof and the wall of a tank irrespective of wide dimensional variations therebetween.

It is yet another object to provide a pressure seal system which normally maintains the seal pressure within a predetermined range irrespective of environmental temperature variations.

It is a further object to provide a pressure seal system of the aforescribed character which tends to maintain optimum seal pressures for varying atmospheric temperatures within a predetermined temperature range.

It is another object to provide a storage tank pressure seal system which develops substantially higher seal pressures within a predetermined pressure range as the rate of vaporization of a stored liquid increases and substantially lower seal pressures as the rate of vaporization of the stored liquid decreases.

It is still another object to provide a pressure seal system of the aforescribed character which is self-sustaining in operation and requires a minimum of maintenance.

The above and other objects are realized in accordance with the present invention by providing a new and improved pressure seal system for a floating roof storage tank. Briefly, the invention contemplates a seal system which operates to provide a resilient pressure seal between the floating roof and the wall of a storage tank. The seal system is carried by the floating roof and moves with the roof as the roof is carried vertically by changes in liquid level within the storage tank.

Two embodiments of the present invention are illustrated and described. In each of these embodiments, a tubular seal disposed between the floating roof and the tank wall is inflated with gas and the pressure is maintained within a predetermined range, irrespective of relatively wide changes in environmental temperature. The maintenance of pressure within the tubular seal is effected in such a manner that a controlled pressure build up, within the predetermined range, is induced when atmospheric temperatures are relatively high and consequently the rate of vaporization of the stored liquid is at a maximum, while a controlled pressure decrease, within the predetermined range, is induced as the environmental temperature decreases and the rate of vaporization of the stored liquid decreases. To assure that an adequate supply of gas is available to the seal, additional gas is automatically acquired in response to predetermined changes in atmospheric temperature. In addition, gas is vented to the atmosphere when the pressure within the seal exceeds a predetermined value.

In one of the embodiments, a relatively extensive range of gas pressure gradients is provided within the tubular seal to compensate for corresponding changes in atmospheric temperature. In another embodiment, a rela-

2

tively narrower range of gas pressure gradients is developed.

The invention, both as to its organization and method of operation, taken with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a fragmentary perspective view of a storage tank and pressure seal system embodying the features of the present invention;

FIGURE 2 is an enlarged fragmentary cross sectional view taken along line 2—2 of FIGURE 1;

FIGURE 3 is a fragmentary diagrammatic view of the seal system shown in FIGURE 1;

FIGURE 4 is an elevational view, partially in section, of an illustrative component valve in the seal system embodying the features of this invention; and

FIGURE 5 is a fragmentary diagrammatic view of another form of the pressure seal system embodying the features of this invention.

Referring now to the drawings and particularly to FIGURE 1, a storage tank is illustrated generally at 10. The tank 10 is designed to hold a liquid, such as a petroleum product, for example. It is constructed on a suitable foundation and comprises a vertical cylindrical wall 11 which terminates at its upper edge in a lip 12.

The storage tank 10 is of generally conventional construction and includes a floating roof 20 of well known construction. The floating roof is of the pontoon type and includes a main deck 21 and an annular pontoon chamber 22. In a well known fashion, the roof 20 remains on top of the stored liquid and moves vertically within the tank in accordance with the level of the liquid.

For the purpose of establishing a vapor seal between the floating roof 20 and the tank wall 11, one form 25 of the pressure seal system embodying the features of this invention is shown supported on the floating roof 20. In the alternative, as seen in FIGURE 5, another form 26 of the pressure seal system embodying the features of this invention might be utilized. In either case, the pressure seal system includes a tubular seal 28 and is designed to maintain the gas pressure within a predetermined range inside the tubular seal 28. Pressure maintenance inside the seal is such that an increased gas pressure, within the predetermined range, is developed when the atmospheric temperatures are relatively high and the tendency for vaporization of the stored liquid is correspondingly high, while lesser gas pressures are developed in a predetermined relationship as the environmental temperature decreases and the tendency for vaporization of the stored liquid also decreases.

The pressure seal system 25, on one hand, effects a relatively greater range of pressure gradients within its seal 28 while the pressure seal system 26 effects a relatively lesser range of pressure gradients. In either form of the invention, gas is periodically supplied to the tubular seal 28 under certain conditions and vented to the atmosphere when the pressure within the seal exceeds a predetermined value.

Referring now to FIGURE 2 and specifically to the first form 25 of the pressure seal system embodying the features of this invention, it will be seen that the seal 28 is in the fluid communication with a pressure control assembly 29 which maintains the pressure inside the seal within a predetermined range while effecting pressure changes within the seal as a function of corresponding changes in the atmospheric temperature and the tendency for vaporization of the stored liquid. The control assembly 29 also is effective to replenish the supply of fluid within the pressure seal system under predetermined conditions and vent the seal 28 to the atmosphere when the pressure therewithin exceeds a predetermined

value. The assembly 29 is suitably supported by the floating roof 20.

Referring to both FIGURE 1 and FIGURE 2, it will be seen that the floating roof 20 moves vertically within the tank 10 and at all times floats on top of the stored liquid, as has been pointed out. The seal 28 establishes a resilient seal between the floating roof 20 and the tank wall 11 irrespective of the position of the roof 20 within the tank. Through this relationship the loss of a stored product occurring through vaporization or through "wetting" or "wicking" is minimized.

The roof 20 is circular and its inner main deck is composed of steel plate or the like. It normally floats on the surface of the stored liquid much like a pie tin would, for example. The pontoon chamber 22 extends around the periphery of the main deck 21. It is air tight to provide additional buoyancy for the roof when snow or rain accumulates thereon. The diameter of the roof 20, defined by the pontoon chamber 22, is somewhat less than the diameter of the tank wall 11, thereby accommodating disposition of the seal 28 between the roof and the tank wall. In practice, this gap is approximately four to twelve inches, although it might vary to a greater or lesser extent. A plurality of spring biased centering wheel assemblies 30, of well known construction, extend outwardly from the periphery of the pontoon 22, as seen in FIGURE 2, to center the roof 20 and equalize the gap around the roof.

The tubular seal 28 extends entirely around the rim of the floating roof 20 and engages the wall 11 around its entire inner periphery. To this end, the seal 28 is generally cylindrical in cross section in free form and is maintained in an inflated condition with a suitable gas, preferably air, by the pressure control assembly 29.

The details of construction of the tubular seal 28 are disclosed in the copending application of Ulm et al., Serial No. 82,248, filed January 12, 1961, entitled, "Storage Tank," and assigned to the same assignee as the present invention. These details form no part of the present invention and consequently are not set out. Suffice it to say that the seal is made of resilient material and when inflated with air above atmospheric pressure it tends to assume an annular shape having a generally circular cross section. However, because of the limited space available between the floating roof 20 and the tank wall 11, the seal 28 adopts a generally oblong cross sectional configuration when it is inflated, as best seen in FIGURES 2 and 3.

As pointed out in the aforementioned copending application, the material used in the tubular seal 28 must be impervious to the product stored within the tank 10 as well as to the pressurized air used to inflate it. In addition, it must be fairly rugged to withstand the scuffing and other frictional forces offered by the tank wall. Consequently, in practice the seal preferably comprises an outer layer of a rugged abrasive-proof synthetic elastomer such as rubber or plastic over a synthetic fabric such as nylon, while an inner layer of vapor impervious material might be composed of a vinyl substance, for example.

In order to maintain an effective seal during the vertical movement of the floating roof, the seal 28 is supported from the rim of the floating roof at vertically spaced points around the periphery of the roof. In this connection, referring to FIGURE 2, the aforementioned outer layer of the seal is preferably provided with tabs 35. These tabs are secured by suitable fasteners 36 to corresponding pairs of outwardly extending brackets 37 secured to the rim of the roof 20. As a result, the inner portion of the seal flexibly engages the roof rim while the outer portion of the seal slidably engages a substantial area of the tank wall 11. Consequently, notwithstanding the fact that the space between the tank roof and the tank wall varies as the roof moves vertically, or that the inner surface of the tank wall 11 is uneven because of welded seams and the like, the seal 28 remains in engagement

with substantial peripheral areas of both the rim and the tank wall, thereby providing an effective vapor seal.

It should be appreciated that if the tubular seal 28 is inflated with too low a pressure, an effective seal may not be provided since the seal does not engage the roof rim and the tank wall with force adequate to prevent vapor leakage from the stored liquid. On the other hand, if the pressure is too high, the seal 28 applies a greater force than is desired and excessive stresses are built up in the connections 35-37 for the seal. In addition, uncontrolled build up of excessive pressure in the seal will result in harmful tensile stresses in the seal fabric plus harmful abrasion of the fabric and its coating due to the over-inflated seal rubbing against the tank shell. It has been found that it is desirable to maintain the pressure in the fluid seal somewhere within the range of one-half ounce to two and one-half ounces/in.² to prevent the foregoing consequences, as well as others.

In addition, it should be understood that as atmospheric temperature rises, the vapor pressure and consequently the propensity for vaporization of a volatile liquid increases accordingly. Conversely, as the atmospheric temperature decreases, the tendency for vaporization of a volatile liquid decreases also. As a result, of course, it will be seen that the controlled higher seal pressure is preferable when the atmospheric temperatures are at their peak, for example in the heat of the day, and controlled lesser seal pressures might be provided when the atmospheric temperatures are relatively low, for example at night.

The pressure control assembly 29 accomplishes each of the aforescribed ends. It maintains the pressure in the tubular seal 28 within a predetermined range. In addition, it varies the pressure in the seal, within this range, from relatively low pressures at low atmospheric temperatures to relatively higher pressures at correspondingly higher atmospheric temperatures.

The pressure control assembly 29, as seen in FIGURES 2 and 3, includes an expansion chamber unit 38, a heat pump chamber 39, and an air replacement and venting valve complex 40. The expansion chamber unit 38 is in free fluid communication with the seal 28 through a conduit 41 and also in fluid communication with the heat pump chamber 39. The heat pump chamber 39, in turn, is in fluid communication with the atmosphere through the air replacement and venting valve complex 40.

The expansion chamber unit 38 tends to establish and maintain a predetermined range of pressures within the seal 28 as the atmospheric temperature changes while the air replacement and venting valve complex 40 assures that air is periodically supplied to the expansion chamber unit 38 and further assures that air is vented to the atmosphere when the pressure in the seal 28 exceeds a predetermined value. The heat pump chamber 39 preferably comprises the pontoon 22 of the floating roof 20. As such, a substantial volumetric capacity is available to effect the influx of, and store, the air which replenishes the expansion chamber unit 38 under predetermined atmospheric conditions. It should be understood, however, that the heat pump chamber 39 might be a separate chamber from the pontoon and, of course, has to be separate where a floating roof other than the pontoon type is utilized.

The expansion chamber unit 38 comprises a completely enclosed vessel 42 having a pair of combination inspection ports and open atmospheric vents 43 on its upper end. The unit 38 is mounted on the heat pump chamber 39 (pontoon 22) and is in free communication with the heat pump chamber under predetermined conditions therewithin. This free communication is maintained until a predetermined minimum pressure exists within the expansion chamber unit 38 and the heat pump chamber 39. In this sense the expansion chamber unit 38 and the heat pump chamber 39 are, for practical purposes, an integral unit. The expansion chamber unit 38 acts as a heat pump itself, under these circumstances. A further drop in

pressure within the expansion chamber unit 38 and heat pump chamber 39 causes communication to be closed off. As a result, while the expansion chamber unit 38 continues to maintain the predetermined minimum pressure within the seal 28, the heat pump chamber 39 takes in air from the atmosphere to subsequently replace any air loss in the expansion chamber unit 38 itself.

Specifically, the vessel 42 comprises an upper inverted cup shaped portion 45 and a lower cup shaped portion 46 provided with annular flanges 49 which coact to form a clamping ring for a diaphragm 55. This clamping ring might be established by bolts (not shown) passing through both flanges 49 and the periphery of the diaphragm 55, or it might be maintained in any other well-known manner.

The diaphragm 55 is made of a resilient, air impervious material such as neoprene rubber coated nylon, for example, and has a configuration and size generally similar to the cup shaped portions 45 and 46. The periphery of the diaphragm 55 is disposed between the annular flanges 49, as has been pointed out, and thereby provides an upper chamber 60 defined by the inverted cup shaped portion 45 and the diaphragm 55, and further, a lower chamber 61 defined by the cup shaped portion 46 and the diaphragm 55. The lower chamber 61 might be referred to as the expansion chamber.

The expansion chamber 61 is in free fluid communication with the seal 28 through the conduit 41 and normally in communication with the heat pump chamber 39 through a relatively large port 62 surrounded by an upstanding rim 63. When the air pressure within the seal 28, the expansion chamber 61, and the heat pump chamber 39 reaches a predetermined minimum value under the influence of decreasing temperature, however, communication between the expansion chamber 61 and the heat pump chamber 39 is shut off so that a further decrease in temperature effects a decrease in pressure within the heat pump chamber without decreasing the pressure within the expansion chamber 61. Because of the action of the diaphragm 55, however, during a continued decrease in temperature the expansion chamber 61 functions normally to maintain pressure in the seal 28 for a substantial period of time while the heat pump chamber 38 is replenished with atmospheric air.

The diaphragm 55 is adapted to move vertically within the vessel 42 during normal operating of the pressure seal system 25 embodying one form of this invention. Accordingly, the pressure in the lower chamber 61 is controlled by the position of the diaphragm 55. The position of the diaphragm 55 is in turn influenced by a control weight assembly 70 which is suitably secured to the diaphragm 55 and functions to establish and maintain a predetermined range of operating pressure gradients within the seal 28 by establishing pressures which are a function of the atmospheric temperature. In addition, the control weight assembly 70 tends to balance the diaphragm 55 as it moves vertically in the vessel 42. In other words, the control weight assembly 70 maintains the diaphragm 55 in centered relationship in the vessel 42 with its closed end, of which the control weight assembly forms a part, substantially horizontal at all times. This insures that the diaphragm 55 does not twist or scrape the walls of the vessel 42.

More particularly, the control weight assembly 70 includes a superimposed series of metal pallets 70a, 70b, 70c, and 70d interconnected by an annularly spaced series of link chains 71. The upper pallet 70a is seated on the diaphragm 55 and secured thereto by any conventional means while the pallets 70b, 70c, and 70d depend therefrom. The lower pallets 70c and 70d have substantially large, aligned communication ports 72 and 73 extending therethrough for permitting communication between the heat pump chamber 39 and the expansion chamber 61 when the lower pallets 70c and 70d are seated on the rim 63 of the aperture 62. As a result, of course, as the diaphragm 55 moves downwardly in the chamber 42, fluid

communication between the heat pump chamber 39 and the expansion chamber 61 is not cut off until the pallet 70b rests on and closes the ports 72 and 73.

In operation, the diaphragm 55 moves vertically within the vessel and responds to changes in temperature of the air within the expansion chamber 61. In order to indicate the level of the diaphragm 55, and also to guide the diaphragm 55 during its vertical movement (in addition to the balancing effect of the control weight assembly 70), a rod 80 is attached at its lower end to the steel pallet 70a and the body of the rod is received within a sleeve 81 suitably secured to the top of the vessel 42. The sleeve 81 is open at the top to permit free communication between the upper chamber 60 and the atmosphere.

It will be appreciated that with a given quantity of air in the lower chamber 61, the diaphragm 55 will assume a position intermediate the top and bottom of the vessel 42, as seen in FIGURE 2. This might be expected under average atmospheric conditions when the outside temperature is neither exceedingly high nor exceedingly low. In such a position the two lower pallets 70c and 70d rest in superimposed relationship on the rim 63 surrounding the port 62 connecting the pump chamber 39 and the expansion chamber 61. Thus, the pressure within the expansion chamber 61 is dictated by the combined weight of the pallets 70a and 70b as well as the weight of the chains 71 between the pallets 70a and 70b and those portions of the chains 71 below the pallet 70b which are not lying on the pallet 70c. This combined weight is preferably such that a pressure of approximately one ounce/in.² is established within the lower chamber 61. Consequently, the pressure within the seal 28 is also approximately one ounce/in.², a pressure precalculated to provide optimum sealing when the vapor pressure of the stored liquid is at a moderate level, as might be expected when the atmospheric temperature is generally normal for the area.

If the atmospheric temperature increases, thereby tending to cause an increase in the rate of vaporization of the liquid, it also causes an expansion of the air in the expansion chamber 61 and the heat pump chamber 39. The diaphragm 55 moves upwardly to provide an increased volume in the expansion chamber 61 so as to abate a corresponding increase in pressure within the chamber. However, as the diaphragm 55 moves upwardly, it continually lifts chain links off the pallet 70c. Raising the links of the chains 71 slowly but continually increases the weight tending to hold the diaphragm 55 down and consequently slowly increases the pressure in the chamber 61 and the seal 28. As the diaphragm rises further, the weight of pallet 70c is brought to bear on it. A predetermined incremental pressure increase is then effected within the chamber 61 and the seal 28 before pallet 70c is lifted off the pallet 70d and the slow increase of pressure (effected by the weight of the chains 71 below the pallet 70c) begins again. The pressure in the chamber 61 and the seal 28 when the pallet 70c is lifted off the pallet 70d is preferably in the neighborhood of about one and one-quarter ounces/in.². This increased pressure is precalculated to provide optimum sealing for the incrementally increased vapor pressure of the stored liquid.

As the diaphragm 55 approaches its uppermost position, more chain is lifted off the lower pallet 70d and subsequently the pallet itself is lifted off the rim 63 surrounding the port 62 interconnecting the heat pump chamber 39 and the expansion chamber 61. Consequently, more weight is added to the diaphragm 55 and additional increments of pressure are developed within the lower chamber 61. This results also, of course, in incrementally increased pressures within the seal 28. The pressure induced by the weight of the entire control weight assembly 70 is in the neighborhood of one and one-half ounces/in.² and is precalculated to provide optimum seal-

ing for the correspondingly increased vapor pressure of the stored liquid.

If the atmospheric temperature continues to increase, the diaphragm 55 continues to move upwardly until it reaches its uppermost position. At this point there is a tendency for the pressure within the chamber 61 and seal 28 to rise above one and one-half ounces/in.². However, the expansion and venting valve complex 40 is effective to vent the seal 28 to the atmosphere whenever the pressure therewithin exceeds one and one-half ounces/in.². This is true, of course, since free communication between the seal 28, the expansion chamber 61 and the heat pump chamber 39 is maintained whenever the diaphragm 55 is in its uppermost position, as seen in FIGURES 2 and 3. Since the pressure within the seal 28 cannot exceed one and one-half ounces/in.², there is no danger of straining the connections 35-37 holding the seal to the roof 20 or causing damage to the surface of the seal itself by scuffing against the tank wall 11 while highly inflated.

During the time that the diaphragm 55 is moving upwardly from the aforescribed position midway between the top and bottom of the vessel 42, fluid communication between the expansion chamber 61 and the heat pump chamber 39 is maintained through the ports 72 and 73 in the pallets 70c and 70d, respectively. When the pallet 70c lifts off the pallet 70d, communication is maintained through the port 73 alone. In other words, communication is maintained between the chambers 61 and 39 regardless of whether one, or both, of the pallets 70c and 70d are seated on the rim 63 surrounding the port 62. Consequently, the benefit of the volumetric capacity of the pontoon 22 is available to the expansion chamber 61 as long as the pallet 70b remains out of contact with the pallet 70c. This eliminates the possibility of any pressure differential between the heat pump chamber 39 and the expansion chamber 61, as might be expected where a valve is situated between the two chambers (in the manner of generally similar systems presently utilized), and consequently the situation never arises where air is continually being pumped from the heat pump chamber 39 to the expansion chamber 61 regardless of whether the expansion chamber requires additional air or not.

Turning now to a decreasing temperature condition, it will readily be understood that the diaphragm 55 moves downwardly from its uppermost position and the pressure within the chamber 61 and the seal 28 decreases accordingly in a pattern which is exactly the inverse of the aforescribed increasing pressure pattern. When the diaphragm 55 is once more generally midway between the top and bottom of the vessel 42 (as seen in FIGURE 2) the pressure within the expansion chamber 61 and the seal 28 is again in the neighborhood of about one ounce/in.². When the atmospheric temperature decreases further, a programmed continuous decrease in pressure is effected within the expansion chamber 61 by the control weight assembly 70.

Initially, as the atmospheric temperature lowers, air within the expansion chamber 61 contracts and consequently the diaphragm tends to move downwardly to decrease the volumetric capacity of the chamber 61 and tend to maintain the seal pressure at the aforescribed one ounce/in.² level. However, as the diaphragm 55 moves downwardly, those lengths of the chains 71 between the pallet 70b and the pallet 70c deposit on the pallet 70c and the weight on the diaphragm 55 is slowly decreased, slowly decreasing the pressure in the chamber 61 and the seal 28. Subsequently, the pallet 70b comes to rest on the pallet 70c, which is in turn resting on the pallet 70d supported by the rim 63. This incremental reduction in weight on the diaphragm 55 causes a corresponding reduction in pressure within the chamber 61 and this incremental reduction is effective within the seal 28 also.

Since the pallet 70b does not have an aperture extending through it, the expansion chamber 61 and the heat pump chamber 39 are effectively sealed off once the diaphragm

55 reaches the point in its downward travel at which the pallet 70b is resting on the pallet 70c. A further decrease in atmospheric temperature will, of course, continue to cause the air within the expansion chamber 61 and that within the heat pump chamber 39 to contract and consequently tend to lower the pressure therewithin. However, the diaphragm 55 can continue to move downwardly for a distance equal to the distance between the pallets 70a and 70b. During this period of travel, those portions of the chains 71 depending from the pallet 70a continue to deposit on the pallet 70b and consequently the weight on the diaphragm continually decreases. The pressure within the chamber 61 and the seal 28 is consequently determined by the weight of the pallet 70a plus the weight contributed by those portions of the chains 71 which have not yet deposited on the pallet 70b. This pressure is preferably in the neighborhood of about three-quarters of an ounce/in.² and is calculated to provide optimum sealing for the decreases tendency for vaporization of the stored liquid which might be expected in the decreased atmospheric temperature condition.

Referring once more to the conditions within the heat pump chamber 39 after the pallet 70b has completely sealed the port 62 between the expansion chamber 61 and the heat pump chamber, the pressure within the heat pump chamber continues to drop with decreasing atmospheric temperature although the pressure within the seal 28 and the expansion chamber 61 is maintained at a higher value. When the pressure within the heat pump chamber 39 drops to the extent that a vacuum in excess of one-half ounce/in.² is developed therewithin, the air replacement and venting valve complex 40 operates to admit air from the atmosphere into the heat pump chamber 39 (pontoon 22).

As has previously been pointed out, the venting and replacement valve complex 40 is effective to vent expansion chamber 61 and seal 28 to the atmosphere when a pressure of in excess of one and one-half ounces/in.² exists within the seal 28. In addition, as has been pointed out immediately above, this same valve complex 40 is effective to admit air to the heat pump chamber 39 when the pressure therewithin drops to a point where a vacuum in excess of one-half ounce/in.² exists inside the pontoon. As a result, excess air pressure is abated under certain high temperature environmental conditions and lost air is replenished when predetermined lower temperatures exist.

Considering the air replacement and venting valve complex 40 in detail, attention is invited to FIGURE 3. The valve complex 40 comprises a differential pressure inlet valve 82 which is effective to admit air to the heat pump chamber 39 when a vacuum in excess of one-half ounce/in.² exists therewithin, and a pressure differential outlet valve 83 which is effective to vent air to the atmosphere from the seal 28 when the pressure therewithin exceeds one and one-half ounces/in.².

The valves 82 and 83 are in communication with the heat pump chamber 39 through a main conduit 85 having a branch conduit 86. The main conduit 85 extends into the inlet valve 82 while the branch conduit 86 extends into the valve 83. An air inlet conduit 87 connects the differential pressure inlet valve 82 to the atmosphere and an air outlet conduit 88 connects the differential pressure outlet valve 83 to the atmosphere.

A liquid, preferably oil or the like, is provided in each of the differential pressure valves 82 and 83, as at 93, and the conduit 86 as well as the conduit 87 extend a predetermined distance below the surface of the liquid 93. This predetermined distance or depth determines, in the case of the pressure differential inlet valve 82, that a pressure of equal to or more than one-half ounce/in.² lower than the atmospheric pressure must exist within the heat pump chamber 39 before air flows from the atmosphere into the heat pump chamber. In turn, the oil level within the differential pressure outlet valve 83 is established such that a pressure of equal to or more than one and one-half

ounces/in.² in excess of the atmospheric pressure must exist within the seal 28 before air flow from the seal 28 to the atmosphere takes place.

To understand specifically the construction of the oil filled valves 82 and 83, refer to FIGURE 4. In FIGURE 4, shown merely as an example, is the differential pressure inlet valve 82. As has been pointed out, a conduit 85 extends into it from the heat pump chamber 39 and an air inlet conduit 87 extends into it from the atmosphere. To establish the predetermined oil level within the valve 82, a filler pipe 110 is provided in the side of the valve at a predetermined level. As will be seen, if the valve 82 is filled with oil through the filler pipe 110, the oil will rise only to the level of the opening 111 in the filler pipe before it begins to spill out and indicate that the predetermined level has been reached. This level, of course, is precalculated to establish the pressure differential prescribed across the valve in question. To establish air flow through the valve, the air pressure in the branch conduit 87 must exceed the air pressure in the conduit 85 by a predetermined amount, in this case, one-half ounce/in.². If it is in such excess, air will push the oil down the branch conduit 87 and bubble out whereupon it passes out of the valve 82 and through the conduit 85 into the heat pump chamber 39.

The pressure seal system 25 embodying the features of one form of this invention and illustrated in FIGURES 1 through 4 maintains a highly effective seal between the roof 20 and the wall 11 of the storage tank 10 regardless of the atmospheric temperature of the environment. When the atmospheric temperature is relatively high, of course, the vapor pressure of the stored liquid is relatively high and vaporization tends to proceed at an increased rate. The system 25 maintains a seal pressure in the upper reaches of the optimum range (one-half ounce/in.² to two and one-half ounces/in.²) under such conditions. When the atmospheric temperature is substantially low, the tendency for vaporization of the volatile liquid is correspondingly lower. Consequently, the system 25 maintains a somewhat decreased seal pressure which is equally as effective and, more desirable, since it has less tendency to induce scuffing of the seal surface because the seal 28 is not forced against the tank wall 11 with as much force as it might be under higher pressures.

As the atmospheric temperature and consequently the tendency for vaporization of the stored liquid varies between high and low extremes, the pressure in the seal 28 is incrementally varied accordingly by the pressure seal system 25. Consequently, at virtually any atmospheric temperature, the most effective seal for the vapor pressure to be expected at that temperature is effected by the seal system.

If the pressure within the seal 28 and consequently within the lower chamber 61 exceeds one and one-half ounces/in.², the differential pressure outlet valve 83 tends to vent excess air to the atmosphere from the seal. Consequently, excessive pressure cannot be developed within the tubular seal 28 and excessive strains on the seal fastenings 35 through 37 are avoided as well as undue scuffing of the surface of the seal.

If the pressure in the heat pump chamber 39 drops more than one-half ounce/in.² below the atmospheric pressure, the differential pressure inlet valve 82 permits an influx of air into the chamber 39 from the atmosphere. During this period, the expansion chamber 61 is sealed off from the heat pump chamber 39 and continues to maintain a predetermined pressure or range of pressures in the seal 28 while the diaphragm 55 descends to the bottom of the vessel 42. When the atmospheric temperature rises again, the newly acquired air supply in the heat pump chamber 39 replenishes the air supply within the expansion chamber 61 and the seal 28.

The pressure seal system 26 embodying the features of another form of this invention is illustrated diagrammatically in FIGURE 5. The seal system 26 develops a

relatively narrower and less sophisticated range of pressure gradients within the seal 28 than does the seal system 25. However, the operation of the system 26 is generally similar to that described in relation to the pressure seal system 25, with specific exceptions. Basically, pressure is varied within the seal 28 as a function of the atmospheric temperature to maintain relatively higher seal pressures when the tendency for vaporization of the stored liquid is high during hot days, for example, and relatively lower pressures when the tendency for vaporization is lower during cooler nights, for example.

The pressure seal system 26 includes a pressure control assembly 129 which is in free fluid communication with the seal 28. The pressure control assembly 129 tends to maintain the pressure inside the seal 28 within a predetermined range. Within this range, the seal pressure is effectively varied incrementally as a function of the atmospheric temperature. Similar to the first embodiment of this invention, a relatively higher seal pressure is maintained during the period when the atmospheric temperature is high and the tendency for vaporization of the stored liquid is also relatively high, while a relatively lower seal pressure is maintained when the atmospheric temperature is lower and the tendency for vaporization of the stored liquid is correspondingly lower.

The control assembly 129 includes an expansion chamber unit 138, a heat pump chamber 139 and an air replacement and venting valve complex 140. The expansion chamber unit 138 is in fluid communication with the seal 28 through a conduit 141 and the heat pump chamber 139 is in communication with the atmosphere through the air replacement and venting valve complex 140.

The expansion chamber unit 138 comprises a vessel 142 having a combination inspection port and open vent provided in its upper end. It is mounted on the pontoon chamber 22 in a manner identical to that described in relation to the first embodiment of this invention. It comprises an upper inverted cup shaped portion 145 and a lower cup shaped portion 146 provided with opposed annular flanges 149 which coact to form a clamping ring for a diaphragm 155. The diaphragm 155 is preferably composed of neoprene rubber-coated nylon or the like.

An upper chamber 160 and a lower chamber 161 are defined by the diaphragm 155. Communication between the lower chamber 161, which might be referred to as the expansion chamber 161 and the heat pump chamber 139 is through a relatively large port 162 defined by an upwardly extending rim 163 in the lower end of the cup shaped portion 146. Communication between the heat pump chamber 139 and the atmosphere is through the air replacement and venting valve complex 140 which assures that air is periodically supplied to the heat pump chamber 139 and further assures that air is vented to the atmosphere when the pressure in the seal 28 exceeds a predetermined value.

As with the first embodiment of this invention, the pressure in the expansion chamber 161 is controlled by the position of the diaphragm 155. The position of the diaphragm 155 is, in turn, influenced by a control weight assembly 170 suitably secured to the bottom of the diaphragm 155. The weighted diaphragm 155 is effective to establish a predetermined range of operating pressures within the seal 28, as a function of atmospheric temperature. The control weight assembly 170 differs from the control weight assembly 70 described in relation to the first embodiment of this invention in that it provides a lesser number of weight increments for influencing the diaphragm 155.

More particularly, the control weight assembly 170 includes a superimposed pair of metal pallets 170a and 170b connected by a plurality of annularly spaced chains 171. The upper pallet 170a is suitably secured to the diaphragm 155 by any conventional means while the pallet 170b depends from the pallet 170a.

In operation, the diaphragm 155 moves vertically within the vessel 142 in response to changes in temperature of the air within the expansion chamber 161. In order to guide the diaphragm 155 during its vertical movement a guide rod 180 is attached at its lower end to the pallet 170a and the body of the guide rod is received within a guide sleeve 181 suitably secured to the top of the vessel 142. The guide sleeve 181 is open at the top to permit free communication between the upper chamber 160 and the atmosphere.

It will once more be appreciated that with a given quantity of air in the expansion chamber 161, the diaphragm 155 will assume a position midway between the top and the bottom of the vessel 142. This positioning might be expected when an average atmospheric temperature condition exists; that is the temperature is neither too hot nor too cold. In such a position, the lower pallet 170b rests on the rim 163 surrounding the aperture 162 which connects the heat pump chamber 139 and the expansion chamber 161. The pressure within the expansion chamber 161 is thus dictated by the weight of the pallet 170a plus the weight of those portions of the chains 171 depending from the pallet 170a and unsupported by the pallet 170b. This combination of weights preferably establishes a pressure of approximately one ounce/in.² within the lower chamber 161. A seal pressure of one ounce/in.² is precalculated to provide optimum sealing for the stored liquid at that particular moderate temperature.

If the atmospheric temperature increases, thereby tending to cause expansion of the air in the expansion chamber 161, the diaphragm 155 moves upwardly to provide an increased volume in the expansion chamber 161 and tends to forestall a pressure increase therewithin. However, as the diaphragm 155 moves upwardly, it lifts portions of the chains 171 off of the pallet 170b and soon lifts the pallet itself off its resting place on the rim 163 surrounding the aperture 162. Consequently, more weight is continually added to the diaphragm 155 and additional pressure is continually developed within the expansion chamber 161 and the seal 28. This increased pressure is at a predetermined optimum maximum value when the pallet 170b is off of its resting place on the rim 163 and this pressure might be in the neighborhood of one and one-half ounces/in.². It is precalculated to provide optimum sealing for the stored liquid at the increased rate of vaporization induced by the increased temperature.

Any further expansion of air within the seal 28 and consequently within the expansion chamber 161 and the heat pump chamber 139 results in the diaphragm 155 moving upwardly to its uppermost position to prevent the pressure from exceeding one and one-half ounces/in.². Once the diaphragm 155 has "backed-off" to its uppermost position, however, a further expansion of the enclosed air causes the entire system to be vented to the atmosphere through the air replacement and venting valve complex 140. This is true, of course, since the air replacement and venting valve complex 140 is preset so that an excess of pressure over one and one-half ounces/in.² within the heat pump chamber 139 causes air within the chamber to pass outwardly through the valve complex to the atmosphere.

Turning now to the condition where the atmospheric temperature is decreasing the pressure control assembly 129 correspondingly decreases the pressure within the seal 28. The pressure decreases generally as a function of the atmospheric temperature and consequently as a function of the decreasing rate of vaporization of the stored liquid.

Initially, of course, the diaphragm moves downwardly under the influence of the total weight of the weight assembly 170 while the air in chamber 161 contracts. During this period the pressure remains substantially at one and one-half ounces/in.². When the pallet 170b comes to rest on the rim 163, the weight on the diaphragm

155 decreases. Consequently, the diaphragm 155 develops less pressure in the chamber 161 and the seal 28.

When the pallet 170b is resting on the rim 163, the expansion chamber 161 is effectively sealed off from the heat pump chamber 139. In practice, a small aperture 183 is provided in the pallet 170b to prevent excessive pressure shock within the vessel 142 and the pontoon 22 when the pallet 170b seats on the rim 163. This aperture is not large enough, however, to permit more than a small passage of air therethrough and consequently the chambers 161 and 139 are, for all practical purposes sealed off.

A further decrease in atmospheric temperature, of course, the air within the expansion chamber 161 and that within the heat pump chamber 139 to contact further and consequently tends to lower the pressure therewithin. However, the diaphragm 155 continues to move downwardly for a distance equal to the distance between the pallets 170a and 170b. As the diaphragm moves through this distance, portions of the chain 171 continually deposit on the pallet 170b and a slight but continual decrease in pressure within the expansion chamber 161 and the seal 28 is effected. The pressure within the expansion chamber 161 and the seal 28 during this period is preferably in the neighborhood of one ounce/in.², the pressure precalculated to provide optimum sealing at the decreased vapor pressure of the stored liquid.

When the pallet 170b seals off the port 162 between the expansion chamber 161 and the heat pump chamber 139, the pressure within the heat pump chamber 139 continues to drop with decreasing atmospheric temperature although the pressure within the expansion chamber 161 is maintained substantially constant. Once the pressure within the heat pump chamber 139 drops to such an extent that a vacuum in excess of one-half ounce/in.² is developed, the air replacement and venting valve complex 140 is effective to admit air from the atmosphere to the heat pump chamber 139 (pontoon 22).

The air replacement and venting valve complex 140 of the seal system 26 is identical in construction and operation to the air replacement and venting valve complex 40 described in relation to the system 25 embodying the features of the first form of this invention. Consequently, it is not thought that the unit's construction need be described in detail again. However, it should be brought out at this point that although interconnected differential pressure inlet and outlet valves are illustrated with both forms of the present invention, the valves might be independently mounted and connected to the heat pump chamber (39 or 139) rather than being associated with each other in series as they are shown.

From the foregoing description, it will be seen that the seal system 26 embodying the features of the second form of this invention effectively establishes and maintains a seal pressure which is coordinated with the atmospheric temperature throughout a predetermined range to provide optimum sealing relationships for the vapor pressures of the stored liquid developed at these particular temperatures. In addition, pressure within the seal 28 is vented to the atmosphere when it exceeds a predetermined maximum pressure to prevent an excessive build up of pressure within the seal. Furthermore, the system 26 automatically replenishes air available to the seal 28 at periodic intervals.

Each of the pressure seal systems 25 and 26 hereinbefore described is self-sustaining in operation and requires a minimum of maintenance. Strain and wear on the seal 28 is considerably reduced over generally similar seal systems heretofore utilized while a superior seal is maintained throughout a substantial temperature range. The system is rugged and simple in construction and utilizes a minimum number of valve elements, reducing the cost extensively.

While several embodiments described herein are at present considered to be preferred, it is understood that

various modifications and improvements may be made therein, and it is intended to cover in the appended claims all such modifications and improvements as fall within the true spirit and scope of the invention.

What is desired to be claimed and secured by Letters Patent of the United States is:

1. In a cylindrical tank for the storage of a volatile liquid, a floating roof having a diameter less than the interior diameter of said tank and adapted to float on said liquid, an annular inflatable seal disposed between said floating roof and the interior of said tank, a system for regulating fluid pressure in said inflatable seal, said system including variable volume means in free fluid communication with said seal at all times, fluid communication means including a heat pump chamber between said variable volume means and the atmosphere, said variable volume means including pressure regulating means for varying the fluid pressure within said seal as a function of atmospheric temperature and controlling fluid communication between said variable volume means and said heat pump chamber.

2. In a cylindrical tank for the storage of a volatile liquid, a floating roof having a diameter less than the interior diameter of said tank and adapted to float on said liquid, an annular inflatable seal disposed between said floating roof and the interior of said tank, a system for regulating fluid pressure in said inflatable seal, said system including variable volume means in free communication with said seal at all times, a heat pump chamber, fluid communication means between said heat pump chamber and said variable volume means, said variable volume means including pressure regulating mean for varying the fluid pressure within said seal as a function of atmospheric temperature and shutting off fluid communication between said variable volume means and said heat pump chamber when the volume of said variable volume means decreases to a predetermined value.

3. The arrangement of claim 2 further characterized by and including another fluid communication means between said heat pump chamber and the atmosphere, said heat pump chamber being effective to acquire air from the atmosphere when the pressure within said heat pump chamber drops to a predetermined minimum value after fluid communication between said heat pump chamber and said variable volume means has been shut off.

4. The arrangement of claim 3 further characterized in that said variable volume means tends to maintain the pressure inside said seal within a predetermined range of pressures as the pressure in said heat pump chamber decreases after fluid communication between said heat pump chamber and said variable volume means has been shut off.

5. In a cylindrical tank for the storage of a volatile

liquid, a floating roof having a diameter less than the interior diameter of said tank and adapted to float on said liquid, an annular inflatable seal disposed between said floating roof and the interior of said tank, a system for regulating fluid pressure in said inflatable seal, said system including a variable volume diaphragm chamber and a heat pump chamber, said variable volume diaphragm chamber being in fluid communication with said seal and said heat pump chamber, said variable volume means including pressure regulating means for varying the fluid pressure within said seal as a function of atmospheric temperature and shutting off fluid communication between said variable volume means and said heat pump chamber when the volume of said variable volume means decreases to a predetermined value, said pressure regulating means comprising weight means carried by said diaphragm, said weight means being effective to vary the weight on said diaphragm to correspondingly vary the pressure in said seal as the atmospheric temperature varies.

6. The arrangement of claim 5 further characterized in that said weight means comprises a plurality of pallets depending one from the other, variations in atmospheric temperature causing predetermined combinations of said pallets to vary the weight acting on said diaphragm.

7. The arrangement of claim 6 further characterized in that said plurality of pallets includes at least two pallets.

8. The arrangement of claim 6 further characterized in that said plurality of pallets includes four pallets.

9. The arrangement of claim 6 further characterized in that said pallets are interconnected by chain means.

10. The arrangement of claim 6 further characterized in that the lowermost of said pallets is adapted to shut off fluid communication between said variable volume means and said heat pump chamber when the volume of said variable volume means decreases to said predetermined value.

11. The arrangement of claim 6 further characterized in that said plurality of pallets tend to balance and center said diaphragm as said diaphragm moves to vary the volume of said chamber.

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