Jan. 11, 1966 R. C. ULM ETAL 3,228,702

INFLATABLE SEAL FOR FLOATING ROOF

Filed Nov. 2, 1961 2 Sheets-Sheet 1

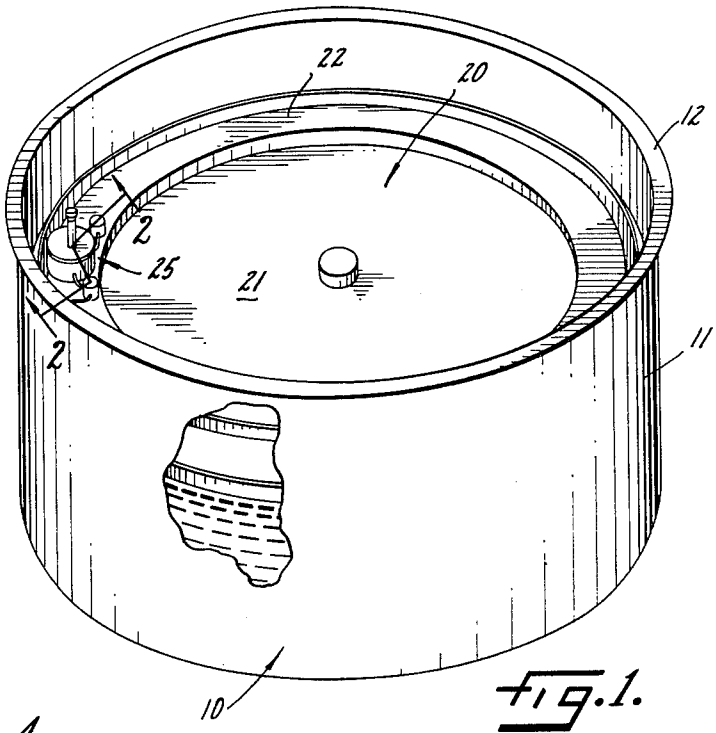


Fig. 1.

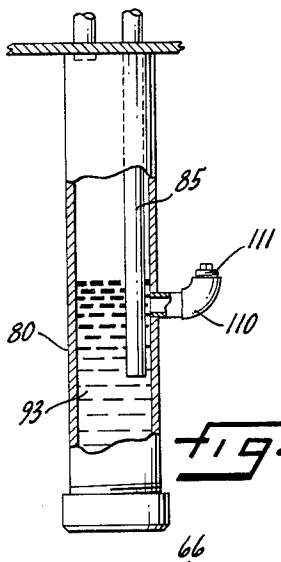


Fig. 4.

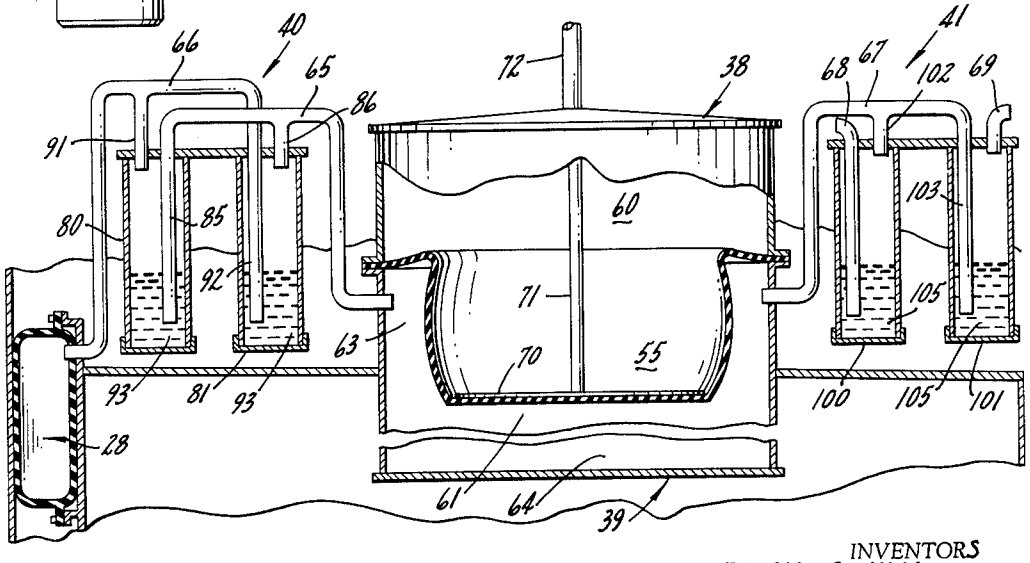


Fig. 3.

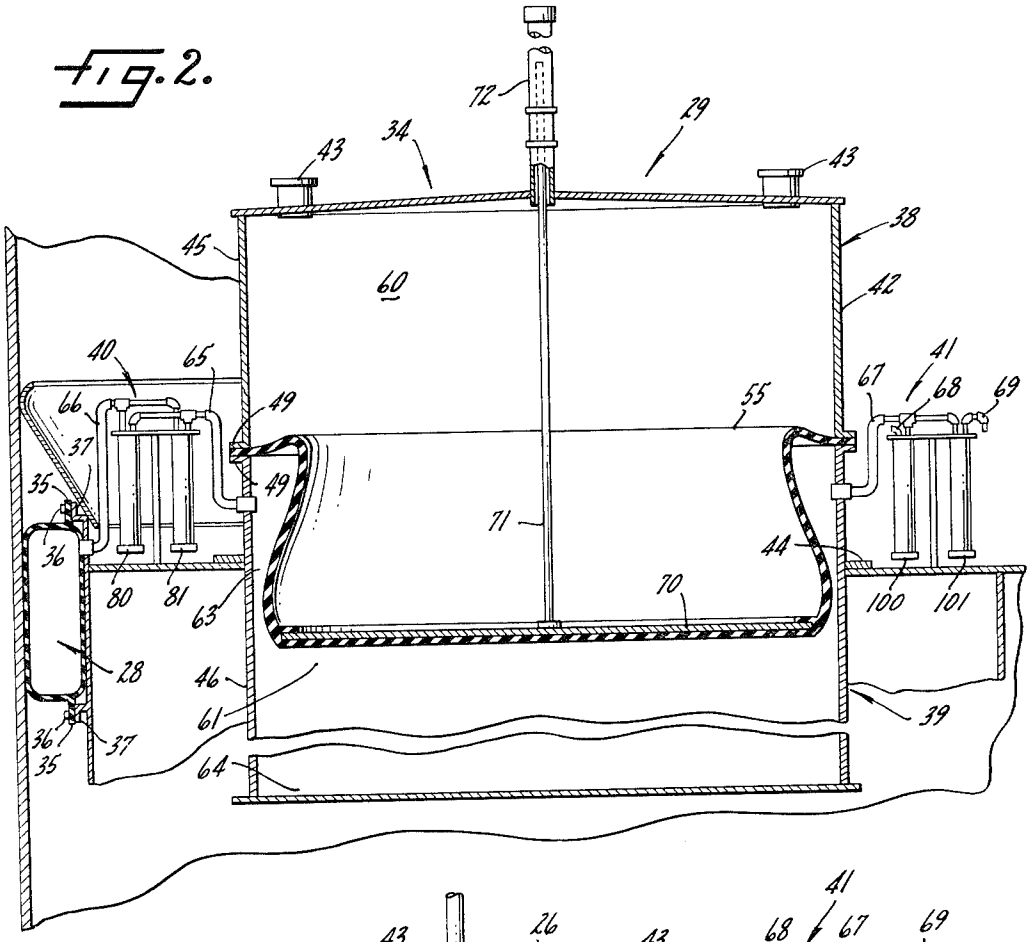
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Fig. 2.



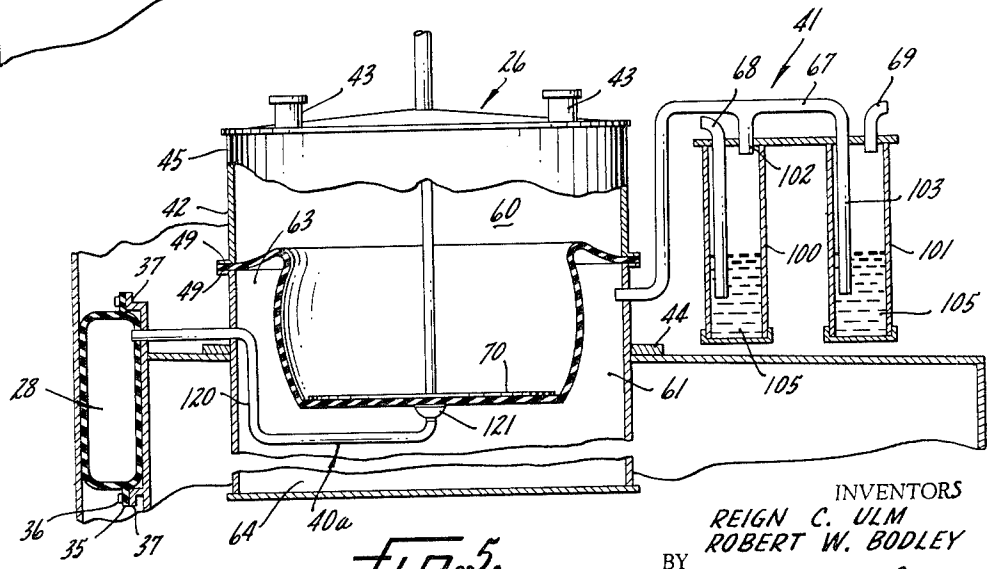


Fig. 5.

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3,228,702

INFLATABLE SEAL FOR FLOATING ROOF

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2 Claims. (Cl. 277—29)

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

It is an object of the present 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 highly efficient vapor seal between the 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 the floating roof and the wall of a tank irrespective of wide dimensional variations therebetween.

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

It is yet another object to provide such a pressure seal system for storage tanks which reduces evaporation losses from volatile liquids stored in the tank.

It is another object to provide a pressure seal system for a volatile liquid storage tank having a floating roof which substantially eliminates the danger of fire around the periphery of the floating roof.

It is still another object to provide a pressure seal system for a storage tank which is readily adaptable for use with any type of floating roof.

It is still another object to provide a pressure seal system of the aforedescribed 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 sealing system which operates to provide a resilient pressure seal between the floating roof and the wall of a storage tank. The sealing 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 wide changes in environmental temperature. In one embodiment the pressure within the tubular seal is normally maintained at a predetermined level below a control pressure. In the other embodiment disclosed, seal pressure and control pressure are coincidental. In each embodiment, to assure that an adequate supply of gas is available to the seal, additional gas is automatically supplied to the tube in response to changes in the atmospheric temperature. In addition, gas is vented to the atmosphere when the pressure within the tube exceeds a predetermined value.

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 sealing system shown in FIGURE 1;

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

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

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

The storage tank **10** is of the floating roof type and, for purposes of illustration, embodies a pontoon type floating roof, seen generally at **20**. It should be understood, however, that the use of a pontoon type roof is merely exemplary and any conventional type of floating roof might be utilized.

The floating roof **20** has an outside diameter which is slightly less than the inside diameter of the cylindrical wall **11** of the tank **10**. The roof **20** includes a main deck **21** and an annular pontoon chamber **22** and remains on top of the stored liquid while it moves vertically within the tank in accordance with the level of the liquid. The inherent buoyancy of the roof normally supports it on top of the liquid while the pontoon chamber **22** provides additional buoyancy when the roof loads up with snow or rain, for example.

For the purpose of establishing a vapor seal between the floating roof **20** and the tank wall **11**, one embodiment **25** of the pressure seal system incorporating the features of this invention is provided and is supported by the floating roof **20**. In the alternative, another embodiment **26** of the pressure seal system incorporating the features of this invention, as seen in FIGURE 5, might be utilized and, in a similar manner, is supported by the floating roof **20**. In either case, the pressure seal system is designed to maintain the gas pressure inside a tubular seal **28** within a predetermined range. While the pressure seal system **25** maintains a seal pressure at a predetermined level lower than a control pressure, however, the system **26** normally maintains the seal pressure equal to a control pressure. With regard to either form of the pressure seal system embodying the features of this invention, gas is periodically supplied to the tubular seal **28** under certain conditions and gas is vented to the atmosphere when the pressure within the seal **28** exceeds a predetermined value.

Referring now to FIGURE 2 and specially to the first embodiment **25** of the pressure seal system incorporating the features of this invention, it will be seen that the seal **28** is in fluid communication with a constant pressure assembly **29** which maintains the pressure inside the seal within a predetermined range. The constant pressure assembly **29** is suitably supported by the floating roof **20** and assures that gas is periodically supplied to the seal **28** and, further assures, that gas is vented to the atmosphere when the gas pressure within the seal exceeds a predetermined value.

Referring now to FIGURES 1 and 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 (ordinarily a volatile liquid) occurring through volatilization or through "wetting" or "wicking" is minimized.

The roof **20** is circular and its inner main deck **21** is composed of steel plate or the like as is the pontoon chamber **22** extending around the periphery of the main

deck 21. The pontoon chamber 22 is air tight and, as shown in FIGURE 1, is in engagement with the surface of the stored liquid within the tank. As is readily seen, 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 floating roof 20 and the tank wall 11. In practice, this gap is ordinarily in the vicinity of approximately 4 to 12 inches, although it could vary more under certain circumstances.

Considering now in particular the tubular seal 28, it will be understood that it extends entirely around the rim of the floating roof 20 and engages the entire inner periphery of the tank shell 11. To this end, the seal 28 is generally cylindrical in cross section in its free form and is maintained in an inflated condition with a suitable gas, preferably air or the like, by the constant pressure assembly 29.

The specific details of construction of the tubular seal 28 are disclosed in the co-pending application to Ulm et al., Serial No. 82,248, filed January 12, 1961, entitled "Storage Tank," and assigned to the same assignee as the present invention. Since these details form no part of the present invention, they are not set out here. Suffice it to say that the seal is made of a 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, when inflated, assumes a generally oblong cross-sectional configuration, as best seen in FIGURES 2 and 3.

It will be appreciated that the material used in the 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, because the tubular seal engages a substantial area of the inner tank wall 11 and, further, because the seal 28 must move vertically within the tank 10 and yet maintain engagement with the wall 11, the material of the seal must be fairly rugged to withstand the scuffing and other frictional forces offered by the tank wall.

In practice, the tublar seal 28 preferably comprises an outer layer of a rugged abrasive-proof material such as a rubber or elastomeric plastic coated nylon which has been suitably vulcanized, for example. The use of such a material is merely exemplary of a number of similar materials which might be utilized, however. The seal 28 might have an inner layer of vapor impervious material such as a vinyl substance, for example. As has been pointed out, the details of such a seal are disclosed in the aforementioned co-pending application, however, and form no part of this invention.

In order to assure that an effective seal is maintained during vertical movement of the floating roof, the seal 28 is supported from the rim of the floating roof at vertically spaced apart points around the periphery of the roof. In this connection, referring to FIGURE 2, the aforementioned outer layer of the seal 28 is preferably provided with flaps 35. These flaps are secured by suitable fasteners 36 to corresponding pairs of outwardly extending brackets 37 secured to the rim or periphery of the roof 20. As a result, as will be seen in FIGURE 2, the inner portion of the seal 28 flexibly engages all of the roof rim between the brackets 37 while the outer portion of the seal 28 slidably engages a substantial area of the tank wall 11. Thus, notwithstanding the fact that the space between the roof 20 and the tank wall 11 varies as the roof 20 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 roof rim and the tank wall 11, thereby providing an effective vapor seal.

It will be appreciated that if the tubular seal 28 is inflated with too low or too high a pressure, an effective seal may not be provided as the seal 28 moves along the uneven surface of the tank wall during vertical movement of the roof. If the pressure is too low, the seal does not engage the roof rim and the tank wall 11 with a 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 with the consequent result that excessive stresses are imparted to both the seal and the connections 35–37 for the seal. It has been found that it is desirable, for optimum operation, to maintain the pressure in seal 28 somewhere within the range of one-half ounce to two and one-half ounces/in.^{2} irrespective of wide temperature variations and, to this end, the constant pressure assembly 29 is employed.

The constant pressure assembly 29, as seen in FIGURES 2 and 3, includes air expansion chamber and heat pump unit 34, an air supply valve unit 40, and an air replacement and venting valve unit 41. The unit 34 is in fluid communication with the seal 28 through the air supply valve unit 40 and in fluid communication with the atmosphere through the air replacement and venting valve unit 41. The unit 34 includes an expansion chamber 38 which tends to establish the predetermined pressure which is to be maintained within the seal 28 while the air supply valve unit 40 controls the influx and outflow of air under pressure to and from the seal 28. The unit 34 also includes a heat pump 39 which cooperates with the air replacement and venting assembly 41 to assure that air is periodically supplied to the expansion chamber 38 and further assure that air is vented to the atmosphere when the pressure in the expansion chamber exceeds a predetermined value.

The unitary expansion chamber and heat pump unit 34 comprises a completely enclosed vessel 42 having inspection ports 43 provided in its upper end. The vessel 42 is recessed into the pontoon chamber 22, as will readily be seen, and to this end an annular flange 44 extends radially outward of the wall of the vessel 42 and is suitably secured by welding or the like to the pontoon chamber 22, as seen in FIGURE 2. It should be understood, however, that the vessel 42 might rest equally as well on top of the pontoon chamber 22, or in the case where another type of floating roof is utilized, might be supported structurally in any well known manner.

Specifically, the vessel 42 comprises an upper inverted cup-shaped portion 45 and a somewhat deeper 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 in any other well known manner.

The diaphragm 55 is made of a resilient, air impervious material such as neoprene rubber, for example and has a configuration and size generally similar to the upper cup-shaped portion 45. As shown, the periphery or open end of the diaphragm 55 is disposed between the annular flanges 49 in clamped relationship 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 is divided, in effect, into that portion 63 of the chamber 61 into which the diaphragm 55 extends in its lowermost position and the portion 64 of the chamber 61 below it. The lower portion 64 of the chamber actually comprises the heat pump 39. As readily seen, fluid communications is maintained between the lower chamber 61 and the air supply valve unit 40 by a suitable conduit 65 while fluid communication is maintained between the valve unit 40 and the seal 28 by a suitable conduit 66. In addition, the lower chamber 61 is in communication with the air replacement and venting valve unit 41 through a suitable conduit 67 while the valve unit 41 is in communication

with the atmosphere through an air inlet pipe 68 and an air discharge pipe 69.

The diaphragm 55 is adapted to move vertically within the vessel 42 during normal operation of the pressure seal system 25 embodying the one form of this invention. Accordingly, the pressure in the lower chamber 61 is controlled by the position of the diaphragm 55. A steel plate 70 of disc-like construtcion and having a diameter somewhat less than the diameter of the vessel 42 is suitably secured to the bottom of the diaphragm 55 and functions as a control weight for establishing a predetermined operating pressure for the expansion chamber 38 by establishing a designated pressure within the lower chamber 61. It should be appreciated, of course, that the weight of the plate 70 can be varied to vary the prescribed operating pressure of the expansion chamber 38.

In operation, the diaphraghm 55 moves vertically within the vessel 42 in response to changes in the temperature of the air within the lower chamber 61. In order to guide the diaphragm 55 during its vertical movement, a guide rod 71 is attached at its lower end to the steel plate 70 and the body of the guide rod is received within a guide sleeve 72 suitably secured to the top of the expansion chamber 38 and 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 assumes a position intermediate the top and bottom of the vessel 42. If the atmospheric temperature increases, thereby tending to cause an increase in pressure in the lower chamber 61, the diaphragm 55 moves upwardly to provide an increased or additional volume whereby the tendency toward increasing pressure is abated and the pressure within the lower chamber 61 is maintained at the desired level. Conversely, if the atmospheric temperature decreases, thereby tending to decrease the pressure within the lower chamber 61, the diaphragm moves downwardly, thereby decreasing the volume and maintaining the pressure within the lower chamber 61 at the desired level.

The diaphragm 55 moves vertically up and down within the vessel 42 in response to changes in atmospheric temperature and maintains substantially constant pressure within the lower chamber 61. In this way, through the facility of the air supply valve unit 40, the expansion chamber 38 maintains an effective control over the pressure in the seal 28. This is true even though the displacement capacity of the expansion chamber 38 is only approximately 20 percent of the volume of the seal 28.

As has previously been pointed out, the air supply valve unit 40 through which the seal 28 communicates with the lower chamber 61 of the vessel 42 is so constructed as to tend to maintain the pressure in the seal within a predetermined range. This range is preferably between one-half ounce/in.^{2} and two and one-half ounces/in.^{2}. At the same time, the air replacement and vent valve unit 41, through which the lower chamber 61 communicates with the atmosphere, is so constructed as to prevent the pressure in the chamber 61 from rising above one and one-half ounces/in.^{2} and insuring that it never falls to less than one-half ounce/in.^{2} below the atmospheric pressure.

Considering the air supply valve unit 40 in greater detail, attention is invited to FIGURE 3. The valve unit 40 comprises a pressure differential inlet valve 80 and a pressure differential outlet valve 81. The pressure differential inlet valve 80 is connected to the conduit 65 through branch conduit 85 while the pressure differential outlet valve 81 is connected to the conduit 65 through branch conduit 86. In turn, the conduit 66, which is in communication with the seal 28, is also in communication with the pressure differential inlet valve 80 through branch conduit 91 and with the pressure differential outlet valve 81 through branch conduit 92.

A liquid, preferably oil or the like, is provided in each of the pressure differential valves 80 and 81, as at 93, and the corresponding branch conduits 85 and 92 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 80, the excess of pressure in the lower chamber 61 of the vessel 42, over the pressure in the seal 28, which must exist before air flow is established from the chamber 61 to the seal 28, and in the case of the pressure differential outlet valve 81, the excess in pressure in the seal 28, over the pressure in the lower chamber 61, which must exist before air flow is established from the seal 28 back into the chamber 61. Since a minimum of about one-half ounce/in.^{2} of pressure within the seal 28 is desirable, and the pressure which tends to be maintained in the lower chamber 61 is one ounce/in.^{2} (as preset), it follows that the branch conduit 85 will extend below the level of the liquid 93 in the pressure differential inlet valve 80 to an extent which requires that the presure in the lower chamber 61 exceed the pressure in the seal 28 by one-half ounce/in.^{2} before air flow from the lower chamber 61 to the seal 28.

In turn, since a maximum pressure of approximately two and one-half ounces/in.^{2} is desirable within the pressure seal 28, it will be seen that any pressure in excess of two and one-half ounces/in.^{2} which builds up in the seal must be caused to flow through the pressure differential outlet valve 81 back into the lower chamber 61 of the vessel 42. This is effected in the system embodying this invention by assuring, through the medium of the air replacement and venting valve unit 41, that the air pressure within the lower chamber 61 never exceeds one and one-half ounces/in.^{2} and establishing the level of the liquid 93 in the valve 81, relative to the branch conduit 92, in such a manner that any pressure in the seal 28 in excess of one ounce/in.^{2} more than the pressure within the lower chamber 61 will cause a flow of air from the seal 28 back to the lower chamber 61.

Considering now the air replacement and venting valve unit 41 in greater detail, it comprises a differential pressure inlet valve 100 and a differential pressure outlet valve 101. The conduit 67, which communicates with the lower chamber 61 of the vessel 42, communicates in turn with the differential pressure inlet valve 100 through branch conduit 102 and with the differential pressure outlet valve 101 through branch conduit 103. As has been previously pointed out, the differential pressure inlet valve 100 has an air inlet pipe 68 while the differential pressure outlet valve 101 has an air outlet pipe 69. A liquid 105, preferably in the form of oil or the like, is provided in each of the valves 100 and 101 and a predetermined oil depth is established relative to the inlet pipe 68, in the case of the differential pressure inlet valve 100, and relative to the branch conduit 103, in the case of the differential pressure outlet valve 101.

Specifically with regard to the differential pressure outlet valve 101, the oil 105 level is established such that a pressure of equal to or more than one and one-half ounces/in.^{2} must exist within the lower chamber 61 relative to the atmospheric pressure before air flow from the chamber 61 to the atmosphere takes place. In turn, the oil level within the differential pressure inlet valve 100 is established such that the pressure within the lower chamber 61 must be at least one-half ounce/in.^{2} lower than the atmospheric pressure before air flow from the atmosphere into the lower chamber 61 begins to take place.

To understand specifically the construction of the various oil-filled valves 80 and 81 of the air inlet valve unit 40 and valves 100 and 101 of the air replacement and vent valve unit 41, refer to FIGURE 4. In FIGURE 4, shown merely as an example, is the differential pressure inlet valve 80 of the air inlet control valve unit 40. The valve 80 has, as has been pointed out, a branch conduit

85 extending into it from the conduit 65 which communicates with the lower chamber 61 and a branch conduit 91 extending into it which communicates with the conduit 66 (which in turn communicates with the tubular seal 28). To establish the predetermined level of the oil 93 within the valve 80, a filler pipe 110 is provided in the side of the valve 80 at a predetermined level. As will then be seen, if the valve 80 is filled with oil through the filler pipe 110, the oil will rise only to the level of the opening 111 of the filler pipe 110 before it begins to spill out of the filler pipe and thus indicate to personnel that the predetermined level has been reached. This level, of course, has been predetermined to establish the pressure differential prescribed across the valve in question. To establish air flow through the valve, the air pressure in branch conduit 85 must exceed the air pressure in branch conduit 91 by a predetermined amount, in this case, one-half ounce/in.^{2}. If it is in such excess, air will push the oil down in the branch conduit 85 and bubble out whereupon it passes out of valve 80 through branch conduit 91.

Turning now to the operation of the system 25 embodying one form of this invention and illustrated in FIGURES 1 through 4, it has been found that a pressure of in the range from about one-half ounce/in.^{2} to two and one-half ounces/in.^{2} within the seal 28 will maintain a highly satisfactory seal between the roof 20 and the walls 11 of the storage tank 10. To maintain the pressure within the seal 28 in this predetermined range, it is preferable to maintain a substantially constant pressure of approximately one ounce/in.^{2} within the lower chamber 61 of the vessel 42. To this end, the steel plate 70 is provided on the diaphragm 55 within the vessel 42. The steel plate 70 is of a predetermined weight as has been pointed out, which weight is just sufficient to cause the diaphragm 55 to impress a pressure of one ounce/in.^{2} in the chamber 61. With a differential inlet pressure valve 80 set at one-half ounce/in.^{2}, it will now be seen that air from the lower chamber 61 will course through the conduit 65, the branch conduit 85, the fluid 93 within the valve 80, out the branch conduit 91 and down through the conduit 66 into the seal 28 until the pressure within the seal 28 reaches one-half ounce/in.^{2}. At this point, since the pressure within the lower chamber 61 is continually readjusting and consequently is maintained at one ounce/in.^{2}, a balance will be struck between the pressure within the seal 28 and the pressure within the lower chamber 61, as effected by the one-half ounce/in.^{2} pressure differential set up in the pressure differential inlet valve 80.

If now, for example, the atmospheric temperature should rise, the pressure within the lower chamber 61 of the vessel 42 will remain at one ounce/in.^{2} because the diaphragm 55 will rise to accommodate the increase in volume decreed by the increase in atmospheric temperature. However, since the seal 28 has no such compensating device, the pressure in the seal 28 will rise accordingly. While the pressure in the seal increases, the diaphragm 55 in the chamber 61 rises and the pressure therein is maintained at one ounce/in.^{2}. Soon, it will be apparent, that the pressure within the seal 28 will exceed the pressure within the lower chamber 61. When it exceeds it by more than one ounce/in.^{2}, air begins to flow out of the seal 28, through the conduit 66, the branch conduit 92, the liquid 93 in the differential control outlet valve 81, out through the branch conduit 86 and the conduit 65 and back into the lower chamber 61. This is true, of course, because the differential control outlet valve 81 has been preset, by means of the liquid level therein, so that the pressure within the tubular seal 28 will never exceed the pressure within the lower chamber 61 by more than one ounce/in.^{2}.

Suppose now that the atmospheric temperature has risen to such an extent that the diaphragm 55 in the vessel 42 can no longer rise; in other words, it has reached the upper limit of its travel. In such case, the pressure within the lower chamber 61 also begins to rise. When it reaches one and one-half ounces/in.^{2}, however, due to the setting of the differential pressure outlet valve 101 of the air replacement and venting valve unit 41 the air begins to flow out of the lower chamber 61 through the conduit 67, the branch conduit 103, the liquid 105 in the valve 101, and out through the outlet pipe 69 to the atmosphere. This is true, of course, because of the differential pressure setting pre-established by the level of the liquid 105 within the differential pressure outlet valve 101. This setting is for one and one-half ounces/in.^{2}, as has hereinbefore been pointed out.

Noting now that the pressure within the lower chamber 61 of the vessel 42 can never exceed one and one-half ounces/in.^{2}, it will be obvious that the pressure with the seal 28 can never exceed one ounce/in.^{2} more than that one and one-half ounces/in.^{2}, or two and one-half ounces/in.^{2}.

Turning to another possibility, suppose that a great cooling of the atmospheric air takes place, as might be expected in the desert at night, for example. In such case, the air in the seal 28 and the lower chamber 61 contracts and the normal tendency, obviously, is for the pressure to fall. However, the pressure in the lower chamber 61 is maintained at substantially one ounce/in.^{2}, regardless of the atmospheric pressure as long as the diaphragm 55 does not reach its lowest point and the pressure in the seal 28 is consequently maintained at substantially one-half ounce/in.^{2}.

It is only under particularly cool conditions that the diaphragm 55 does reach its lowest point. When it does, it will readily be seen that the expansion chamber portion 63 of chamber 61 is no longer effectively operable. At this point, the heat pump portion 64 of the chamber 61 is, in effect, the entire chamber. As the night gets still cooler, for example, the pressure within the heat pump portion 64 drops below one ounce/in.^{2}. A continued drop in pressure soon creates a vacuum in the chamber and when this vacuum is in excess of one-half ounce/in.^{2}, the air begins to flow through the inlet pipe 68, the liquid 105 in the differential pressure inlet valve 100, the branch conduit 102 and the conduit 67 and into the heat pump portion 64. This is true, of course, since the differential pressure control valve 100 is set at one-half ounce/in.^{2}. It will thus be seen that on cold nights, for example, the heat pump will replenish itself with air from the atmosphere to be utilized by the expansion chamber in establishing the predetermined ideal pressure range within the seal 28 when the temperature begins to rise.

A pressure seal system 26 embodying the features of another form of this invention is illustrated diagrammatically in FIGURE 5. The operation of the system 26 is generally similar to that described in relation to the pressure seal system 25, with certain specific exceptions. The pressure within the tubular seal 28 varies directly with and is normally the same as the pressure within the lower chamber 61 of the vessel 42, within prescribed limits. This is basically a result of the elimination of the air inlet supply valve unit 40 and its replacement with a simple air shut-off unit 40*a*. The system generates a maximum pressure in the seal 28 of one and one-half ounces/in.^{2} in contrast to the two and one-half ounces/in.^{2} maintained within the seal in the pressure seal system 25.

The pressure seal system 26 includes the unitary expansion chamber and heat pump unit 34, the air shut-off unit 40*a*, and an air replacement and venting valve unit 41. The chamber and heat pump unit 34 is in fluid communication with the seal 28 through the air shut-off unit 40*a* and in communication with the atmosphere through the air replacement and venting valve unit 41.

The unit 34 includes the expansion chamber 38 which tends to maintain a pre-established pressure which it im-

parts directly to the seal **28**. The seal pressure, in turn, can vary within a predetermined range as controlled by the air shut-off unit **40***a* and the air replacement and venting valve unit **41**. The air shut-off unit **40***a* cuts off communication between the expansion chamber **38** and the seal **28** when the pressure within the expansion chamber **38** reaches a predetermined lower value. The unit **34** also includes the heat pump **39** which cooperates with the air replacement and venting valve unit **41** to assure that air is periodically supplied to the expansion chamber **38** and further assure that air is vented to the atmosphere when the pressure in the expansion chamber **38** exceeds a predetermined value.

The unitary expansion chamber and heat pump unit **34** comprises the completely enclosed vessel **42** having inspection ports **43** provided in its upper end. It is mounted on a pontoon chamber in a manner identical to that described in relation to the first embodiment of this invention. In that light, it comprises an upper inverted cup-shaped portion **45** and a lower, substantially deeper, cup-shaped portion **46** provided with opposed 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 established in any well known manner. The diaphragm is preferably composed of neoprene rubber or the like, for example.

An upper chamber **60** and a lower chamber **61** are defined by the diaphragm **55**. Communication between the lower chamber **61** and the seal **28** is through the air shut-off unit **40***a*. In addition, the lower chamber **61** is in communication with the air replacement and vent valve unit **41** through a suitable conduit **67** while the valve unit **41** is in communication with the atmosphere through an air inlet pipe **68** and an air discharge pipe **69**.

A predetermined operating pressure for the expansion chamber **38** is established by suitably securing a steel plate **70** of disc-like construction to the bottom of the diaphragm **55**. The steel plate **70** functions as a control weight for maintaining this pre-established pressure. It should be appreciated, of course, that the weight of the plate **70** might be varied to vary the prescribed operating pressure of the expansion chamber **38**.

Considering the air shut-off unit **40***a* in greater detail, it comprises a conduit **120** and a conventional shut-off valve **121**. The conduit **120** is in communication with the seal **28** and extends into the lower chamber **61** of the vessel **42** where it terminates in the shut-off valve **121**. The shut-off valve **121** is mounted in such a manner that communication between the lower chamber **61** and the seal **28** is sealed off by the diaphragm **55** when the diaphragm **55** is in its lowermost position within the vessel **42**, as seen in FIGURE 5.

Since the pressure which tends to be maintained in the lower chamber **61** is approximately one ounce/in.^{2} (as preset), and the diaphragm **55** is approximately midway between the top and bottom of the vessel **42** under normal operating conditions, it follows that the pressure within the seal **28** will also be one ounce/in.^{2}. As long as the diaphragm **55** does not reach its lowermost position and close the shut-off valve **121**, preventing communication through conduit **120** with the seal **28**, this pressure will be maintained.

The air replacement and vent valve unit **41** in the system **26** is identical in construction and operation to the valve unit **41** 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 again.

Turning now to the operation of the system **26** embodying the features of an alternate form of this invention and illustrated in FIGURE 5, it should still be understood that a pressure range in the seal **28** of greater than one-half ounce/in.^{2} and less than two and one-half ounces/in.^{2} is considered desirable. To maintain the pressure within the seal **28** somewhere within this range, it is preferable to maintain a substantially constant pressure of approximately one ounce/in.^{2} within the lower chamber **61** of the vessel **42**. To this end, the steel plate **70** is provided on the diaphragm **55**.

Since, of course, there is free communication between the lower chamber **61** and the seal **28** as long as the diaphragm **55** does not cut off the shut-off valve **121**, it will readily be seen that the one ounce/in.^{2} pressure which tends to be maintained within the lower chamber **61** will also tend to be maintained within the seal **28**.

If the atmospheric temperature rises, the pressure within the lower chamber **61** of the vessel **42** remains at one ounce/in.^{2} because the diaphragm **55** rises to accommodate the increase in volume decreed by the increase in atmospheric temperature. Since the seal **28** and the chamber **61** are in communication, the pressure in the seal **28** also remains substantially at one ounce/in.^{2}.

If the atmospheric temperature rises to such an extent that the diaphragm **55** in the vessel **42** can rise no further; in other words it has reached the upper limit of its travel, the pressure within the lower chamber **61** will also begin to rise. When it reaches one and one-half ounces/in.^{2}, however, due to the setting of the differential pressure outlet valve **101** of the air replacement and venting valve unit **41**, the air begins to flow out of the chamber **61**, through the conduit **67**, the branch conduit **103**, the liquid **105** and the valve **101**, and out through the outlet pipe **69** to the atmosphere. This is true, of course, because of the differential pressure setting pre-established by the level of the liquid **105** within the differential pressure outlet valve **101**. This setting of one and one-half ounces/in.^{2} has been hereinbefore described.

Knowing now that the pressure within the lower chamber **61** of the vessel **42** can never exceed one and one-half ounces/in.^{2}, it will be obvious that the pressure within the seal **28** can never exceed one and one-half ounces/in.^{2}. This is true, of course, because the seal **28** and the chamber **61** are in direct communication as long as the diaphragm **55** does not contact the shut-off valve **121**.

If, on the other hand, atmospheric cooling takes place, in the manner which has hereinbefore been described, for example, both the pressure in the seal **28** and the pressure in the lower chamber **61** begin to fall. Since the pressure in the lower chamber **61** will be maintained at substantially one ounce/in.^{2}, regardless of the atmospheric pressure, as long as the diaphragm does not reach its lowest point of travel, the pressure in the seal **28** will obviously also be maintained at substantially one ounce/in.^{2}. However, a continued drop in pressure within the lower chamber **61** soon causes it to reach its lowermost position whereupon it contacts the shut-off valve **121**, of the air cut off unit **40***a*, and shuts off communication between the lower chamber **61** and the seal **28**. When the diaphragm **55** reaches this lowermost position, it will readily be seen that the expansion chamber portion **63** of chamber **61** is no longer effectively operable. At this point, the portion **64** of the chamber **61** forming the heat pump **39** is, in effect, the entire chamber.

A further drop in the pressure with the heat pump portion **64** of the lower chamber **61** soon creates a vacuum therein and when this vacuum is in excess of one-half ounce/in.^{2}, the air begins to flow through the inlet pipe **68**, the liquid **105** in the differential pressure inlet valve **100**, the branch conduit **102** and the conduit **67**, and into the lower chamber **61**. This is true, of course, since the differential pressure control valve **100** is set at one-half ounce/in.^{2} as a consequence of the pre-established liquid level within the valve **100**.

It will thus be seen that on cold nights, for example, the vessel **42** and specifically the heat pump portion of the lower chamber **61** will replenish itself with air from the atmosphere. This air is then utilized in establishing the predetermined ideal pressure range within the seal **28** again when the temperature begins to rise.

From the foregoing description it should be appreciated that there have been provided several new and improved pressure sealing systems embodying tubular seals adapted to provide an effective vapor seal between a floating roof and a tank wall. Notwithstanding variations in the distance between the roof and the tank wall produced by the lack of concentricity of the roof with the tank and by the uneven inner surface of the tank wall resulting from welding and the like and from shifting of the tank foundations, an excellent seal is obtained. The tubular seal is sensitive to pressure and is maintained in good sealing contact with the floating roof and the tank wall when it is inflated to a pressure in the neighborhood of between one-half ounce/in.^{2} and two and one-half ounces/in.^{2}, for example. This relatively low pressure permits high flexibility of the seal, good surface contact between the seal and the roof and the tank wall and a minimum of abrasive action and wear of the seal as a result of contact with the inner wall of the tank, with the result that the useful life of the tubular seal is increased substantially.

Each system unitarily combines an expansion chamber and heat pump to maintain the pressure in the seal within a predetermined range and replenish fluid (air in this case) lost through normal leakage and the like. A unique valve arrangement in each system facilitates the maintenance of seal pressure within this predetermined range and the replenishment of air in the system. Because of of its unitary expansion chamber and heat pump construction, each system is readily adaptable to utilization with all types of floating roof constructions, unlike generally similar arrangements presently in use. A substantially simpler and less expensive system than those presently known is the result. The valve unit arrangement in each instance also lends to the simplicity and inexpensive qualities of this invention, as opposed to its relatively more complicated and, accordingly, costly counterparts.

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. A system for regulating fluid pressure in an inflatable seal comprising variable volume means, first fluid communication means between said variable volume means and said seal, said first fluid communication means including first valve means responsive to predetermined pressure differentials between the fluid in said seal and the fluid in said variable volume means for controlling the flow of fluid between said variable volume means and said seal means, second fluid communication means between said variable volume means and the atmosphere, said second fluid communication means including second valve means for controlling the flow of fluid between said variable volume means and the atmosphere, said variable volume means and said first and second valve means operating in response to predetermined pressure differentials between the seal and the variable volume means and between the variable volume means and the atmosphere, respectively, to tend to maintain the fluid pressure in said seal within a predetermined range irrespective of the normal atmospheric temperature changes effected in said fluid.

2. A system for regulating fluid pressure in an inflatable seal comprising variable volume means, first fluid communication means between said variable volume means and said seal, said first fluid communication means including a valve unit for controlling the flow of fluid between said variable volume means and said seal means, said valve unit comprising one differential pressure valve adapted to cut off fluid communication between said seal and said variable volume means when the pressure within said seal exceeds a predetermined value relative to the pressure within said variable volume means and another differential pressure valve adapted to open communication between said seal and said variable volume means when the pressure within said seal exceeds the pressure within said variable volume means by a predetermined amount, second fluid communication means between said variable volume means and the atmosphere, said second fluid communication means including valve means for controlling the flow of fluid between said variable volume means and the atmosphere, said variable volume means tending to maintain a predetermined fluid pressure in said seal irrespective of normal atmospheric temperature changes in said fluid.

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