

Oct. 31, 1961

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3,006,149

PRESSURIZED STORAGE SYSTEM AND METHOD OF OPERATING

Filed Jan. 3, 1956

3 Sheets-Sheet 1

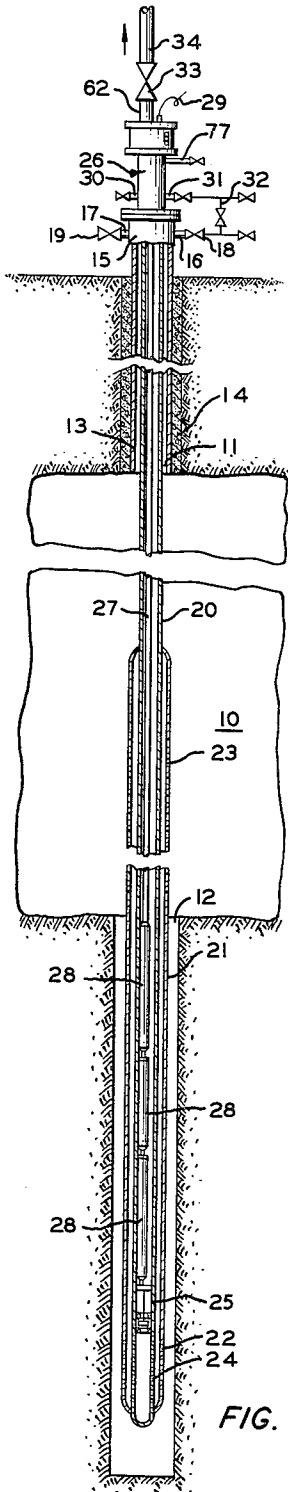


FIG. 1

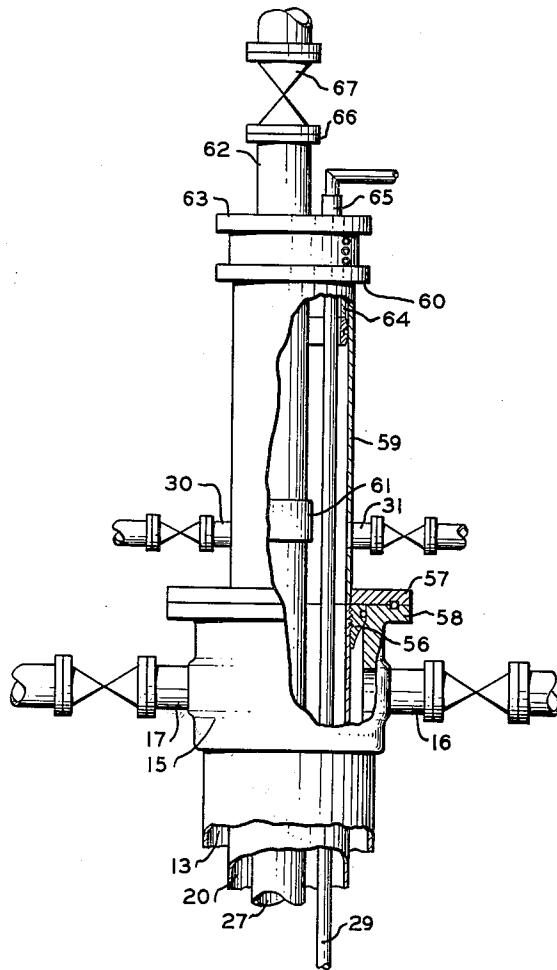


FIG. 4

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3 Sheets-Sheet 2

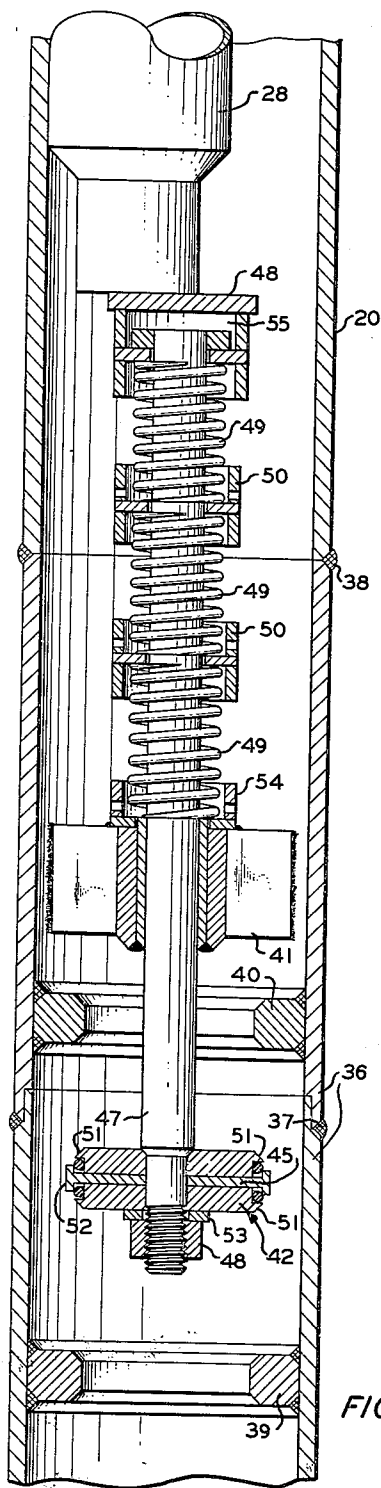


FIG. 3

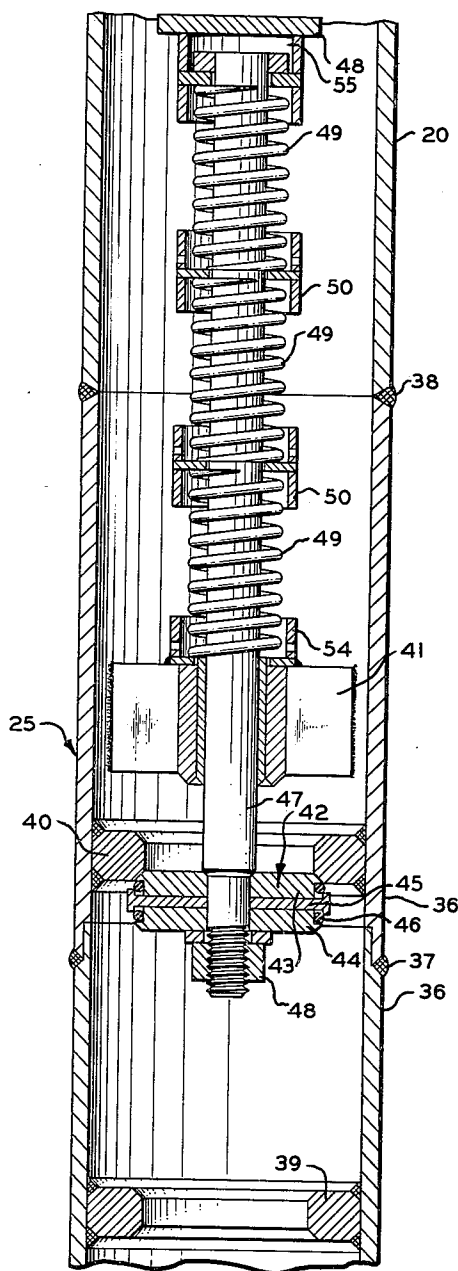


FIG. 2

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3 Sheets-Sheet 3

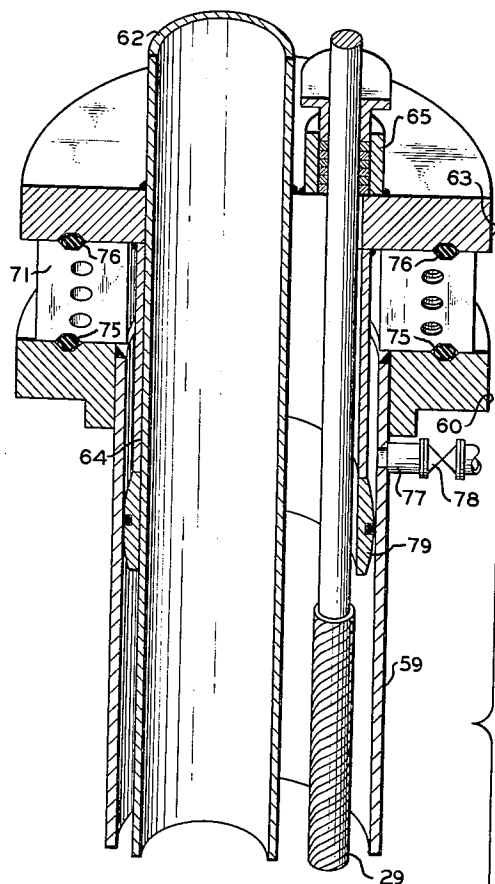


FIG. 5

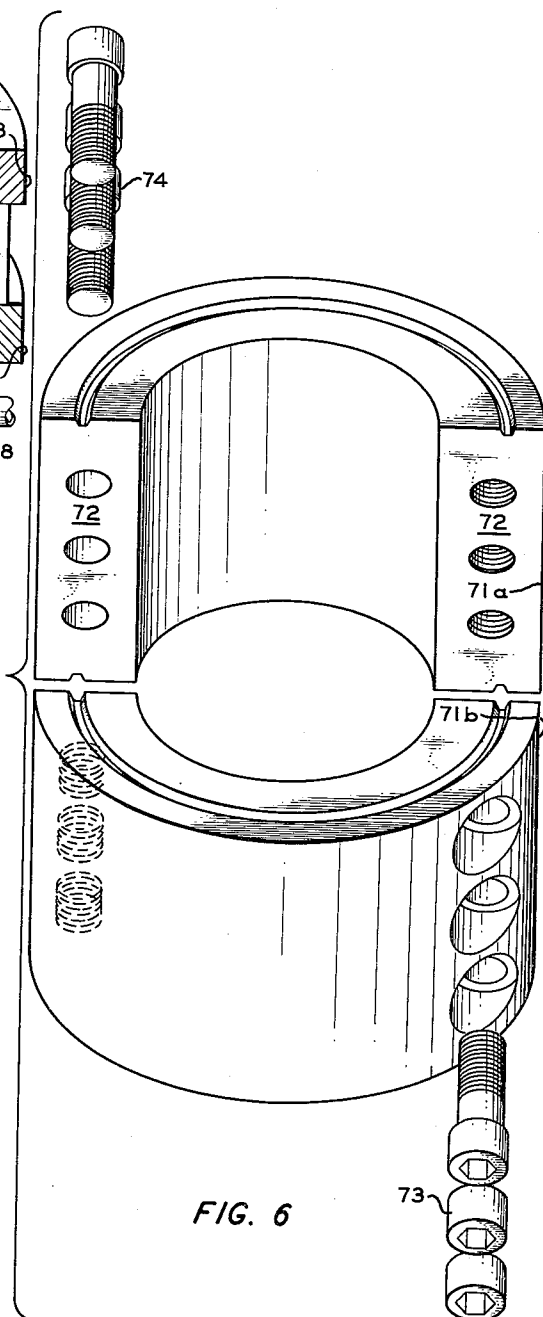


FIG. 6

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1

3,006,149

PRESSURIZED STORAGE SYSTEM AND METHOD OF OPERATING

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Filed Jan. 3, 1956, Ser. No. 556,853
11 Claims. (Cl. 61—.5)

This invention relates to an improved pressurized storage system and method of operating same.

Constantly expanding production of liquefied petroleum gas has created a definite problem in providing suitable storage facilities for this material. Due to the high vapor pressure of liquefied petroleum gas, particularly propane, the cost of storage in surface equipment, such as steel tanks, becomes excessive due to the massive construction required to withstand the vapor pressure of the stored material in a safe manner. The problem becomes extremely acute where it is necessary to store large quantities of such materials during the off-season. In addition to the expense involved, the use of steel tanks is limited by shortages in production.

In order to overcome some of these difficulties, it has been proposed to store liquefied petroleum gas in porous water bearing formations, in water-leached caverns in salt formations or in abandoned mines in impermeable shale or in limestone formations. Further, underground concrete storage tanks and buried sections of pipe have been used to limited extent in the storage of liquefied petroleum gas.

In my copending application, Serial No. 348,344, filed April 13, 1953, now Patent No. 2,901,889 entitled "Pressurized Storage System," there is disclosed and claimed an underground storage system for liquefied petroleum gas which is capable of storing extremely large quantities of this material at a very small cost. The present invention relates to a method and means for sealing such a system against product losses during equipment changes and is an improvement over the invention disclosed and claimed in my said copending application. The storage system of my said copending application and the storage system and method of operating given herein are not limited to the storage of liquefied petroleum gas, but are applicable to the storage of any liquefiable gas such as ammonia, carbon dioxide, and the like. Further, the present invention is not necessarily limited to underground storage systems and can be employed where steel tanks are used as the pressurized containers.

There are many methods of removing liquefied gas from a storage container. For example, it is well known that a liquefied gas can be forced from a chamber by introducing compressed gas above the liquid. In other instances, displacement by a second non-contaminating liquid of greater density can be employed. One method, and a more generally preferred method, for removing a liquefied gas from storage is by means of a centrifugal pump. The pump is usually contained within the pressurized container and can be one wherein the motor driving the pump is also submerged, or of the type driven by a rotating shaft attached to a motor outside of the container. It is recognized that such pumps will have to be pulled from the container from time to time for repair or replacement. To do this, some means must be provided to prevent the loss of large quantities of vapor from the container. There is disclosed in my said copending application Serial No. 348,344, mentioned above, an apparatus and method to insure that the container can be tightly sealed during the time the pump is being operated or being inserted or withdrawn.

In particular, there is disclosed and claimed in said Serial No. 348,344, a spring-operated, normally-closed valve at the bottom of a casing providing communication

2

between the surface of the earth and the caverns. The valve stem of said valve is displaced by the pump body disposed within said casing, and thereby the valve is opened when the pump is lowered into operating position. Accordingly, when the pump body is raised the valve closes, thereby sealing the cavern or storage container.

I have found that water flooding of the casing, in which the pump is normally disposed, during the removal and reinstallation of the pump is a desirable safety feature. Water flooding of said casing has the advantages of (1) providing a higher pressure in the casing than in the storage container, and, (2) a decelerator for the pump should it be dropped while being reinstalled. From a safety standpoint, when inflammable liquids are stored in the storage container, water flooding has the advantage of completely removing the inflammable liquid and vapors thereof during the pump withdrawal and reinstallation. However, the use of water flooding in conjunction with the bottom hole valve of my above referred to copending application Serial No. 348,344, is not completely satisfactory because the valve will open when the head of water in the casing exceeds the container pressure and allow water to enter the storage container. I have now developed a two-seated shutoff and check valve which can be employed as a bottom-hole valve and which eliminates the above described difficulty. Said new valve, discussed further hereinafter, is one of the subcombinations of the present invention.

An object of this invention is to provide an improved pressurized storage system and method of operating same. Another object of this invention is to provide an improved underground storage system for storing liquefied gases under pressure. A further object of this invention is to provide an underground storage system capable of storing liquefied gases having a high vapor pressure for an extended period with a minimum of operating difficulties. Still another object of this invention is to provide a method for withdrawing and reinstalling a pump in a pressurized storage container without loss of vapors of the products stored therein. A further object of this invention is to provide an improved shutoff and check valve. Still another object of this invention is to provide an improved means for sealing one tubing within another tubing. Still other aspects, objects, and advantages of the invention will be apparent to those skilled in the art upon reading this disclosure.

Thus according to the invention, there are provided a method and apparatus for withdrawing a pump from a pressurized container without loss of pressure from said container. The container is provided with a conduit extending through a boundary thereof and closely communicating with the container. A submersible pump is positioned within the conduit adjacent the region of communication of said conduit with said container. When it is desired to remove the pump, said pump is moved, as by lowering, to a non-operating position within the conduit. Concomitantly with the moving of the pump the conduit is closed off from the container. The pressure in the conduit is released and said conduit is filled with an inert liquid, such as water, so as to maintain said conduit in a closed condition. Thereafter the pump is withdrawn. After the pressure is released from the conduit the contents thereof may be vented off or said contents can be displaced with said inert liquid as the conduit is filled.

When reinstallation of the pump is desired said pump, suspended from a discharge tubing connected thereto, is run into the conduit to an operating position therein adjacent the region of communication of said conduit with said container. Pressure between the conduit and the container is equalized and water is pumped from the conduit. As the head of water in the conduit is decreased the

valve will concomitantly open and provide communication between the conduit and the container. An alternative procedure is to lower said pump to a non-operating position, pump the water from the conduit, and then raise the pump to an operating position, which raising will concomitantly open the conduit in communication with the container.

Further according to the invention, there is provided apparatus for carrying out the method of the invention and attaining the above mentioned objects. The apparatus of the invention includes a combined shutoff and check valve, means for sealing one tubing within another tubing, and an improved pressurized storage system.

While water has been given as an example of an inert liquid, other liquids can be employed. Any liquid which is inert, i.e., non-reactive under condition of use with the material being stored, has a specific gravity greater than said stored material, and is substantially immiscible with said stored material, can be used. Non-inflammable liquids are preferred. Water is the presently preferred liquid and is used herein for illustrative purposes.

FIGURE 1 is a vertical elevation, partially in section, of part of an underground storage system constructed in accordance with this invention.

FIGURE 2 is a sectional view, partially in elevation, of a shutoff and check valve according to the invention.

FIGURE 3 is another view of the valve shown in FIGURE 2.

FIGURE 4 is an elevation, partly in section, of the well head apparatus employed at the surface of the earth for sealing the underground storage cavern.

FIGURE 5 is a sectional view, partially in elevation, of a slip joint sealing means employed to seal one tubing within another tubing.

FIGURE 6 is a disassembled isometric view of a split bushing which forms a part of the apparatus illustrated in FIGURE 5.

Referring now to the drawings, the invention will be more fully explained as employed in connection with the storage of liquefied petroleum hydrocarbons such as propane and/or butane. In the drawings, like reference numerals are employed to denote like elements. In FIGURE 1, there is shown a cavern 10 connected by means of a vertical shaft 11 to the surface of the ground. Cavern 10 can comprise more than one cavern and said caverns can be connected by suitable tunnels. Said caverns can be constructed in a number of different ways as illustrated in the copending application of L.P. Meade, Serial No. 314,541, filed October 13, 1952. Said shaft 11 extends below the floor of cavern 10 to form a sump or well 12 below the floor of said cavern. A metal liner 13 lines the shaft from the surface of the earth to the roof of the cavern and is held firmly in place by means of cement 14. A well head 15 closes liner 13 and seals the contents of the cavern from the atmosphere. Access lines 16 and 17 provide communication through the side of liner 13 below the seal point of well head 15. Valves 18 and 19 control said access lines. A first conduit or tubing 20 is suspended from well head 15 and extends through cavern 10 into well or sump 12. Surrounding said tubing 20 is an outer tubing 21 which is attached at its upper and lower ends to said tubing 20 as shown. Said outer tubing 21 contains a series of perforations 22 near the bottom end thereof and another series of perforations 23 near the top end thereof. The lower end of tubing 20 has a series of perforations 24, below the valve 25, which perforations extend to a point higher than the perforations 22 in outer pipe 21. Perforations 22, 23, and 24 together with the outer tubing 21 comprise collectively a pump inlet means which is disclosed and claimed in copending application Serial No. 441,244, filed July 6, 1954, by E. S. Miles and E. W. Porter.

Mounted above well head 15 is a slip joint assembly, denoted generally by 26, which provides means for sealing a discharge tubing 27 within said first tubing 20. Said

slip joint assembly is described further hereinafter. A pump 28 is suspended from tubing 27, which serves as a discharge tubing for said pump, and is disposed within tubing 20 at a point adjacent the region of communication of said tubing 20 with cavern 10. Said pump 28 comprises three main parts, i.e., a lower part or motor, a protector unit mounted above said motor, and a top unit which comprises the pumping unit itself. However, herein and in the claims, the term "pump," unless otherwise specified, will be employed generally to include all three parts of said pump, as well as other suitable pumps which can be employed in this service. Submersible pumps of this type are well known to those skilled in the art. Although not shown, it will be understood that a cable 29 extends from the motor section of said pump, within the inner space between tubings 27 and 20, to the surface of the earth as shown in FIGURES 4 and 5. Said cable attaches to a source of electric power (not shown) for energizing said motor. Said cable has been omitted from FIGURE 1 for the sake of clarity.

FIGURES 2 and 3 illustrate one modification of the improved valve of the invention. As shown in FIGURE 2, said valve is closed at its upper seat. Said valve, denoted generally by 25, comprises a valve body 36 which can be divided into two parts and sealed as shown at 37. However, it will be understood that said valve body can be comprised of one continuous piece of cylindrical tubing. As shown here, valve body 36 is connected to the lower end of tubing 20 by welding as at 38. Obviously other means such as threads can be employed in connecting said valve body and said tubing. Likewise, said valve body 36 can be an extension of tubing 20. Mounted within valve body 36 and secured to the inner wall thereof is a first or lower valve seat 39. Spaced apart from and also secured to the inner wall of said valve body is a second or upper valve seat 40. Spaced apart from said upper valve seat 40 on the opposite side thereof from said valve seat 39 is a perforated guide member 41 which is secured to the inner wall of said valve body 36. Disposed within the chamber between said valve seats 39 and 40 is a valve head 42. Said valve head is comprised of a first or upper disc 43 and a second or lower disc 44, separated by a spacer plate 45. Spacer plate 45 is a flat metal disc having a perforation in the center thereof and is provided with a lip 52 extending above the surface on both sides at the outer circumference thereof. Discs 43 and 44 are flat metal discs having a perforation in the center thereof. Each of said discs is provided with an outer beveled edge 51 adapted to cooperate with and seat in the corresponding beveled seating surface in valve seats 39 and 40. Said discs are recessed at their outer circumference on the side opposite said beveled edge 51 for receiving O-rings 46 between said beveled edge and said lip 52. Said O-rings are preferably fabricated from a suitable resilient material such as an oil-resistant rubber, for example neoprene. Said valve head 42 by being provided with the upper and lower discs 43 and 44 is thus adapted to seat in either valve seat 39 or valve seat 40. The split construction of the valve head together with the resiliency of O-rings 46 provide a very desirable flexibility in fabrication and operation of the valve and it is not necessary to machine and position the valve seats 39 and 40, with respect to each other, with the accuracy which would otherwise be necessary if valve head 42 were otherwise constructed, as for example a one piece disc. It is to be noted there is a double seal between the beveled seating surfaces of valve seats 39 and 40 and the valve head 42, i.e., there is a metal to metal seal between beveled edges 51 and said beveled edge seating surfaces of valve seats 39 and 40, and a rubber to metal seal between O-rings 46 and said seating surfaces. Thus small pieces of foreign matter in valve seats 39 and 40 will not prevent valve head 42 from effecting a seal.

One end of a valve shaft 47 extends through the perforations in the members of valve head 42 which are held

5

in their illustrated assembled positions by means of nut 48 and washer 53. The other end of valve shaft 47 extends through valve seat 40, the perforation in guide member 41, and terminates with a combined contact member and spring guide 48. Coil springs 49 are mounted around valve shaft 47 between contact member 48 and a spring guide 54 mounted on guide member 41. A single coil spring can be employed if desired. Spring guides 50 are employed to maintain said springs in proper vertical alignment.

It is a feature of the invention that when springs 49 are compressed, spring guides 50 and 54, together with combined contact member and spring guide 48, will form a solid stack when valve head 42 has moved a sufficient distance to seat in valve seat 39. Valve shaft 47 backs up into space 55 in combined contact member and spring guide 48. All compression loading is thus taken off valve shaft 47 and cannot be transmitted to valve seat 39. For example, in a vertical installation, should the pump be lowered too far or dropped during reinstallation (described further hereinafter) the weight or force will be borne by guide member 41. The advantage of this feature will be readily appreciated by those skilled in the art.

FIGURE 3 shows the valve head 42 of FIGURE 2 disposed in an open position between valve seats 39 and 40. Said valve has been opened by lowering pump 28 into contact with contact member 48.

FIGURE 4 illustrates in detail the well head assembly employed to seal the liner 13, tubing 20, and tubing 27. Liner 13 is connected to well head 15 by threaded engagement as shown. If desired, a seal weld can be provided between said liner 13 and well head 15. Tubing 20 is suspended within well head 15 by means of threaded engagement with hanger 56. Hanger 56 is sealed to well head 15 by means of the O-rings shown or other suitable sealing means. Flange 57 is removably attached to flange 58 of well head 15. Said flanges are sealed by means of an O-ring therebetween as shown or other suitable sealing means. Mounted within and sealed to flange 57 is an outer tubing or casing 59, a flange 60 sealed to its other end. Discharge tubing 27 extends upwardly through tubing 20, casing 59, and is attached by means of a coupling 61 to a pipe 62 which extends through flanges 63 and 60. Said pipe 62 is attached as by welding, at its circumference to flange 63 but extends freely through flange 60. Inner cylindrical member 64 is sealed to and extends downwardly from flange 63 and surrounds said pipe 62. The lower end of cylindrical member 64 terminates in shoulder 79 (FIGURE 5) which bears against the inner wall of casing 59 and is provided with suitable sealing means such as the O-ring shown. Cable 29 extends upwardly within the inner space between tubing 27 and tubing 20 and out through stuffing box 65. While a coupling 61 has been shown as connecting tubing 27 to pipe 62 within casing 59, it will be realized by those skilled in the art that if desired tubing 27 could be extended upwardly through flanges 60 and 63 as described to take the place of pipe 62 within casing 59 and the coupling effected above flange 63. However, the use of coupling 61 and pipe 62 provides a convenient short length of equipment which is more conveniently handled. Similarly, pipe 62 could be extended to a lower level and connect with tubing 27 in well head 15 or lower. However, it is usually more convenient to make the connection between pipe 62 and tubing 27 within casing 59 as shown.

Flange 66 is attached to the upper end of pipe 62. A suitable flanged valve 67 is attached to flange 66. A suitable discharge pipe 34 (FIG. 1) is attached to the upper end of valve 67 for conducting liquid pumped from the cavern to any desired point.

FIGURES 5 and 6 illustrate in detail the slip joint assembly which forms one subcombination of the invention. Said slip joint assembly was shown generally in FIGURE 4. It will be noted that a split bushing or spacer 71 is provided between the flanges 60 and 63. Said split bush-

6

ing or spacer is shown in detail in FIGURE 6. Said bushing or spacer comprises two members 71a and 71b. Said members each have a lapped or other machine surface 72 at their interface and when drawn together by means of bolt members 73 and 74 form a sealed engagement at said interface. O-rings 75 and 76 provide a sealing means between said spacer 71 and the flanges 60 and 63. The position of cable 29 is shown clearly in FIGURE 5. It will be noted that the metal sheathing has been stripped from said cable at the portion thereof which passes through stuffing box 65. Stuffing box 65 is a conventional packing gland assembly and any type of suitable packing can be employed therein. A vent 77 controlled by valve 78 extends from casing 59 at a point above the highest point of shoulder 79 of cylindrical member 64. Said vent thus provides means for venting the space between flange 63 and the lower end 79 of cylindrical member 64 before disassembling the apparatus.

It will be understood that all cooperating flanges such as flanges 57-58, 60-63, 66 and valve 67, are held together in their assembled positions by means of suitable bolts and nuts. Said bolts and nuts have not been illustrated so as to simplify the drawings.

In assembling and operating the apparatus, well head 15 is placed on liner 13 and tubing 20, having outer tubing 21 positioned thereon as described, is lowered through shaft 11 and into well 12. It will be understood that the portion of tubing 20 having outer tubing 21 thereon is assembled at the surface prior to lowering in the shaft and the remainder of tubing 20 is lowered section by section until it has reached the desired position in well 12. Hanger 56 is then installed on the upper end thereof and the seal is effected between hanger 56 and the well head 15. It will be understood that valve 25 is attached to the lower end of tubing 20, which valve 25 is normally closed so that once tubing 20 is inserted and sealed into well head 15 no material can pass through tubing 20 to the surface or between said tubing and liner 13. Casing 59 having flanges 57 and 60 on the lower and upper ends respectively is then attached to flange 58 of well head 15. Tubing 27, having pump 28 secured to the lowermost section thereof, is lowered through casing 59, section by section, until the approximate proper length has been installed. While the upper end of tubing 27 is still above flange 60, pipe 62 which extends through flange 63 but is attached to said flange 63 at its outer circumference is attached to the upper end of said tubing 27 by means of coupling 61. It will be remembered that cylindrical member 64 is also attached to flange 63 and extends downwardly from the under side of said flange. The assembled tubing 27, pipe 62, and flange 63 is then lowered until the pump 25 has reached its approximate normal operating position. At this time, split bushing 71 is installed around pipe 62 between flanges 60 and 63 and the pump is lowered to its normal operating position. The lowering of said pump to its normal operating position will concomitantly open valve 25 through the action of the lower end of pump 28 on contact plate 48 which moves valve head 42 downward from upper valve seat 40 until said valve head 42 is disposed in the chamber between said valve seat 40 and valve seat 39. The system is now ready to receive the material to be stored therein. Said material can be introduced through lines 16 or 17. Any suitable type of filling mechanism can be employed at the surface of the earth for introducing the liquid to be stored into lines 16 or 17.

When it is desired or necessary to remove the pump for service, the vent 77 is checked by opening valve 78 and any pressure which may have accumulated in the space above seal 79 is vented to the atmosphere. Flange 63 is then raised sufficiently to permit the removal of split bushing 71. After removal of said bushing, flange 63 is lowered until it abuts flange 60 which lowering will concomitantly close valve 25 by moving valve head 42 into contact with lower valve seat 39. The contents of

casing 20 are then vented through lines 30 or 31 to the atmosphere. After venting the contents, said casing 20 is filled with water through either lines 30 or 31. Thereupon, flange 63 is raised until the coupling 61 clears flange 60. Coupling 61 is uncoupled, and pipe 62, flange 63, etc. are moved out of the way, tubing 27 is then raised section by section until the pump has been completely withdrawn from tubing 20. Alternative to venting the contents of tubing 20 after valve 25 has been closed at its lower position, said contents can be displaced by water admitted through line 31. The entering water will cause the lighter hydrocarbons to be floated upwardly and said lighter hydrocarbons can be removed through line 30, or if desired, through a higher connection in casing 59 (not shown).

It is to be noted that the hydrostatic head of water in casing 20 holds the valve head 42 against lower valve seat 39 thus maintaining said valve in a closed position during the time the pump is being withdrawn and is removed from the hole. If by some circumstance the water head should be lost or the pressure in cavern 10 should exceed said hydrostatic head of water, then valve head 42 will be forced upwardly against upper valve seat 40 and the valve is still maintained in a closed position. Thus my invention not only eliminates inflammable vapors from the tubing 20 during the pump removal and reinstallation operations but it also provides the additional safety feature of the check valve, because valve 25 is normally closed at its upper seat and will close at said upper seat due to the action of spring 49 when the valve is not held open.

When the pump is reinstalled, pump 25, attached to the lower end of tubing 27, is lowered through casing 59 of slip joint assembly 26 until the approximate proper length has been installed. Pipe 62, flange 63 and cylindrical member 64 are installed as previously described and the assembly is lowered to the approximate normal operating position of pump 25. At this time, the pressure within the cavern 10 and the pressure within tubing 20 are equalized by means of lines 16, 32 and 31. It will be remembered that equalization is possible because seal 79 by bearing on casing 59 seals tubing 20. After the pressures have been equalized, split bushing 71 is installed as previously described, the pump is lowered to its normal operating position, and the water in casing 20 is pumped out through lines 62, valve 33 and line 34. When the head of water in casing 20 becomes less than the pressure in cavern 10 plus the force of spring 49, valve 25 will open and admit liquid from cavern 10 into casing 20. At this point a mixture of water and propane will be discharged by the pump. Said mixture of water can be discharged through line 34 to any kind of conventional separating means (not shown) at the surface of the earth. When effluent from said separating means shows all of the water has been removed the propane stream can then be switched to surface storage or other means as desired.

An alternate procedure in reinstalling the pump 28 is to lower said pump to its bottom position after pipe 62, flange 63, and cylindrical member 64 have been installed. Said lowering to the bottom position will concomitantly close valve 25 by moving valve head 42 into contact with lower valve seat 39. All the water in casing 20 is then pumped out. The pressure in casing 20 and the pressure in cavern 10 are then equalized as previously described. Flange 63 is then raised sufficiently to permit insertion of split bushing 71, which raising will concomitantly open valve 25. Flange 63 is then lowered onto the bushing and pump 28 is now in its normal operating position.

The invention is not limited to employing a well or sump 12 illustrated in FIGURE 1. If desired, said well or sump can be omitted in which case tubing 20 would only extend to a point near the bottom of cavern 10. Herein and in the claims, unless otherwise specified, the

term "bottom region" is employed generically to include the bottom region of cavern 10 and any point within sump 12.

As will be understood by those skilled in the art, various other modifications of the invention can be made in the light of the foregoing disclosure and discussion without departing from the spirit or scope of the said invention.

I claim:

1. An underground storage system for the storage of liquids under pressure which comprises, in combination: a cavern; a first tubing extending into said cavern and establishing communication between said cavern and the surface of the earth; a second tubing within said first tubing; a pump suspended from said second tubing and disposed within said first tubing at the region of communication of said first tubing with said cavern; a pump-actuated double-seated valve disposed below said pump in the lower end portion of said first tubing, said valve comprising a valve head disposed between and adapted to seat in either of spaced apart upper and lower annular valve seats but being normally closed at said upper valve seat and being moved to an open position when a valve stem attached to said valve head and extending through said upper valve seat is contacted by the pump body when said pump is lowered to an operating position, and being moved to a closed position at said lower valve seat when said pump is moved to a point below said operating position; means forming a seal at the surface of the earth at the point of entry of said first tubing; means including a slip joint for sealing said second tubing within said first tubing, said slip joint permitting limited vertical movement of said second tubing and said pump within said first tubing without breaking the seal between said tubings; means for introducing fluid to be stored into the cavern; and means for actuating said pump whereby said stored fluid can be removed from said cavern.
2. A bottom hole shutoff and check valve adapted to be mounted in a vertical position in the lower end portion of a first tubing extending to the bottom region of a bore and actuated by a pump suspended from the lower end of a second tubing disposed within said first tubing when said pump and said second tubing are lowered into said bore, which comprises: a cylindrical valve body; a lower annular valve seat secured to the inner wall of said body member; an upper annular valve seat secured to said inner wall of said valve body at a point spaced apart and above said lower valve seat and forming a chamber within said body member and between said valve seats; a perforated guide member secured to the inner wall of said body member at a point above said upper valve seat; a single valve head disposed in said chamber between said valve seats, said valve head being adapted to seat in either of said valve seats; a valve stem attached at one end to one side of said valve head, the other end extending through said upper valve seat and the perforation in said guide member, and terminating in a contact member; and a coil spring mounted around said valve stem between said guide member and said contact member biasing said valve head to a normally closed position at said upper valve seat; said valve stem being adapted to move said valve head into open position between said seats when said pump is lowered against said contact member and into closed position at said lower valve seat when said pump is lowered farther into said bore.
3. Apparatus for removing liquid stored under pressure from an underground storage cavern, which comprises, in combination: a first tubing extending into a bottom region of said cavern and establishing communication between the surface of the earth and said region of said cavern; a second tubing suspended within said first tubing; a pump suspended from said second tubing and disposed within said first tubing at the region of communication of said first tubing with said cavern; said second tubing also being a discharge conduit for said pump; a

lower annular valve seat secured to the inner wall of said first tubing below the normal operating position of said pump; an upper annular valve seat secured to the inner wall of said first tubing above said lower valve seat and below the normal operating position of said pump; a guide member secured to the inner wall of said first tubing above said second valve seat and below said pump; said guide member having a perforation therein; a valve head disposed between said valve seats and adapted to seat in either of said valve seats; a valve stem attached at one end to said valve head, the other end extending through said second valve seat, the perforation in said guide member and terminating in a contact member; and a spring mounted around said valve stem between said guide member and said contact member biasing said valve head to a normally closed position at said upper valve seat; said valve stem being adapted to move said valve into open position between said valve seats when said pump is lowered into normal operating position and contacts said contact plate, and into closed position at said lower valve seat when said pump is lowered farther to a position below said operating position.

4. Apparatus according to claim 3 including means for introducing water into said first tubing so as to establish a head of water therein to maintain said valve head in closed position at said lower valve seat when said pump is withdrawn from said first tubing.

5. Apparatus for sealing a second tubing within a first tubing so as to permit said second tubing to be moved from a first position to at least one other predetermined position without breaking the seal between said tubings, which comprises, in combination: a first flange surrounding and fixed to one end of said first tubing; a second flange surrounding and fixed to said second tubing; a cylindrical member attached to one side of said second flange, surrounding said second tubing and extending into said first tubing between said first tubing and said second tubing; sealing means mounted in the end portion of said cylindrical member away from said second flange and bearing against the inner wall of said first tubing; a split bushing of predetermined thickness adapted to be inserted between said flanges around said second tubing when said flanges are parted, said bushing being comprised of two parts the adjoining faces of which are adapted for sealing engagement with each other and means for securing said parts together; and sealing means between said flanges and said bushing.

6. In a pressurized storage system, in combination: a closed container for holding a volatile fluid under pressure; a first tubing passing through an upper wall of said container and extending into a bottom region thereof; means comprising a first head for sealing said container at the point of entry of said first tubing, said first head also supporting said first tubing; a second tubing disposed within said first tubing; a second head comprising a slip joint mounted on said first head for supporting said second tubing within said first tubing and forming a seal between said first and said second tubings, said slip joint permitting limited longitudinal movement of said second tubing within said first tubing; a pump attached to the end of said second tubing and disposed within said first tubing adjacent the region of its communication with the interior of said container, said pump being movable with said second tubing; a double-seated valve mounted within the lower end portion of said first tubing below the normal operating position of said pump; said valve comprising a valve head disposed between and adapted to seat in either of spaced apart first and second annular valve seats but normally biased to closed position at said second valve seat, and a valve stem attached to said valve head and extending through said second seat into the path of said pump so that said valve head is moved to open position between said valve seats when said pump is moved into said normal operating position by moving said second tubing a first distance within the distance per-

mitted by said slip joint, and is moved into closed position at said first valve seat when said second tubing is moved a farther distance within the distance permitted by said slip joint.

7. An underground storage system for the storage of a volatile liquid under pressure which comprises, in combination: an underground cavern; a shaft extending from the surface of the earth to below the floor of said cavern to form a well below said floor; a first tubing suspended within said shaft and establishing communication between said well and the surface of the earth; means comprising a first head for suspending said first tubing, sealing said shaft, and forming a seal between said shaft and said first tubing suspended therein; a second tubing suspended within said first tubing from a second head mounted on said first head; said second head comprising a slip joint and forming a seal between said first and said second tubings, said slip joint permitting limited vertical movement of said second tubing within said first tubing; a pump attached to the lower end of said second tubing and disposed within said first tubing adjacent the region of its communication with the interior of said cavern, said pump being movable with said second tubing; a double-seated valve mounted within said first tubing below said pump; said valve comprising a valve head disposed between and adapted to seat in either of spaced apart first and second annular valve seats but normally biased to closed position at said second valve seat, and a valve stem attached to said valve head and extending through said second valve seat into the path of said pump so that said valve head is moved to open position between said valve seats when said pump is moved into normal operating position by moving said second tubing a first distance within the distance permitted by said slip joint and is moved into closed position at said first valve seat when said second tubing is moved a farther distance within the distance permitted by said slip joint; conduit means in communication with said first head for introducing liquid to be stored into said cavern; and conduit means in communication with said second head for introducing an inert liquid having a specific gravity greater than, and which is substantially immiscible with, said stored liquid into said first tubing so as to maintain said valve head in closed position at said first seat.

8. An underground storage system for the storage of a volatile liquid under pressure, which comprises, in combination: an underground cavern; a shaft extending from the surface of the earth to below the floor of said cavern to form a well below said floor; a first tubing suspended within said shaft and establishing communication between said well and the surface of the earth; means comprising a first head for suspending said first tubing, sealing said shaft, and forming a seal between said shaft and said first tubing suspended therein; a second tubing suspended within said first tubing from a second head mounted on said first head; said second head comprising a slip joint and forming a seal between said first and said second tubings, said slip joint permitting limited vertical movement of said second tubing within said first tubing; a pump attached to the lower end of said second tubing and disposed within said first tubing adjacent the region of its communication with the interior of said cavern, said pump being movable with said second tubing; a double-seated valve mounted within said first tubing below said pump; said valve comprising: a lower annular valve seat secured to the inner wall of said first tubing; an upper annular valve seat secured to the inner wall of said first tubing at a point spaced apart and above said lower valve seat and forming a chamber between said valve seats; a perforated guide member secured to the inner wall of said first tubing at a point above said upper valve seat; a valve head disposed in said chamber between said valve seats, said valve head being adapted to seat in either of said valve seats; a valve stem attached at one end to said valve head, the other end extending through said upper

11

valve seat and the perforation in said guide member, and terminating in a contact member; a coil spring mounted around said valve stem between said guide member and said contact member biasing said valve head to a normally closed position at said upper valve seat; said valve stem extending into the path of said pump so that said valve head is moved to open position between said valve seats when said pump is moved into normal operating position by moving said second tubing a first distance within the distance permitted by said slip joint, and is moved into closed position at said lower valve seat when said second tubing is moved a farther distance within the distance permitted by said slip joint; conduit means in communication with said first head for introducing liquid to be stored into said cavern; and conduit means in communication with said second head for introducing an inert liquid having a specific gravity greater than, and which is substantially immiscible with, said stored liquid into said first tubing so as to maintain said valve head in closed position at said lower valve seat.

9. The apparatus of claim 8 wherein said coil spring comprises a plurality of coil springs and a spring guide is disposed between each of said coil springs, said spring guides together with said contact member and another spring guide mounted on said guide member being adapted to form a solid stack upon contact of said contact member by said pump with a force greater than the force necessary to seat said valve head in said lower valve seat.

10. Apparatus according to claim 7 wherein said second head comprising a slip joint comprises, in combination: a first flange surrounding and fixed to the upper end of a third tubing, said third tubing surrounding said second tubing; a second flange surrounding and fixed to said second tubing; a cylindrical member attached to the lower side of said second flange, surrounding said second tubing and extending into said third tubing between said second tubing and said third tubing; sealing means mounted in the end portion of said cylindrical member which is disposed away from said second flange and bearing against the inner wall of said third tubing; a split bushing of predetermined thickness adapted to be inserted between said first and second flanges and around said second tubing when said flanges are parted, said bushing being comprised of two parts the adjoining bases of which are machined and adapted for sealing engagement with each other and means for securing said parts together; sealing means between said flanges and said bushing; a third flange surrounding and fixed to the lower end of said third tubing, said third flange being adapted to rest on and coact with a fourth flange seal-

12

ingly engaged to said first tubing and forming a part of said first head; and sealing means between said third and fourth flanges.

11. A shutoff and check valve comprising: a cylindrical valve body; a first annular valve seat secured to the inner wall of said valve body; a second annular valve seat secured to said inner wall of said valve body at a point spaced apart from said first valve seat and forming a chamber within said cylindrical valve body and between said valve seats; a valve head disposed between said valve seats in said chamber and adapted to seat in either of said valve seats; a guide member secured to the wall of said valve body at a point spaced apart from said second valve seat on the opposite side from said first valve seat, said guide member having a perforation therein; a valve stem attached at one end to said valve head, the other end extending through said second valve seat, the perforation in said guide member, and terminating in a contact member; a plurality of coil springs mounted around said valve stem between said guide member and said contact member for biasing said valve head to a normally closed position at said second valve seat; a plurality of spring guides, each disposed between an adjacent pair of said springs; another spring guide mounted on said guide member; said valve stem being adapted to move said valve head into an open position between said valve seats upon application of a force to said contact member and into a closed position at said first valve seat upon an increase in said force; and said spring guides, together with said contact member, being adapted to form a solid stack upon application of a force to said contact member greater than the force necessary to seat said valve head in said first valve seat.

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