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C. S. KELLEY

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HEAT-INSULATED TANK HAVING TANK CONTENTS
REFRIGERATING, FOUNDATION WARMING, AND
LOADING AND UNLOADING SYSTEMS

Filed Dec. 23, 1963

3 Sheets-Sheet 1

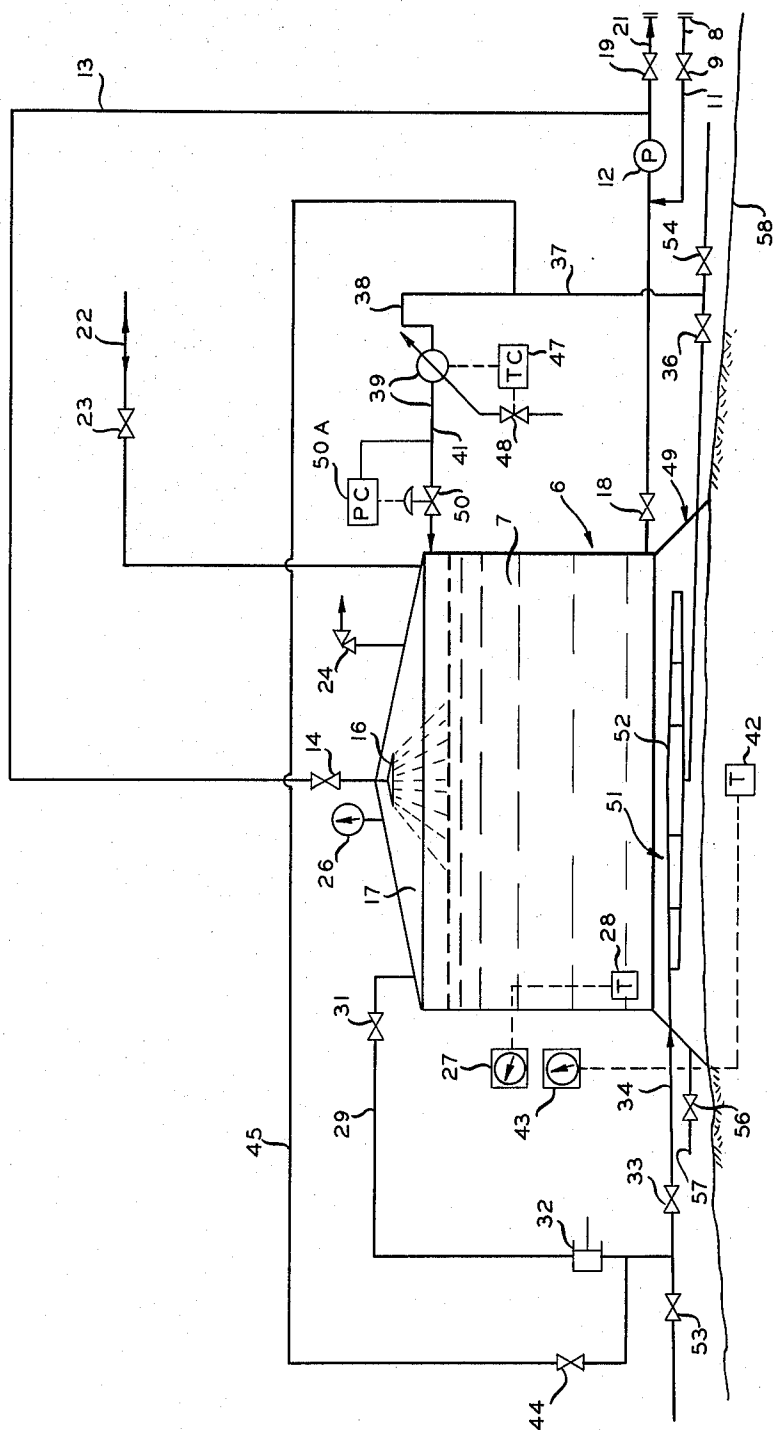


FIG. 1

INVENTOR
C. S. KELLEY

BY *Young & Frigg*
ATTORNEYS

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3 Sheets-Sheet 2

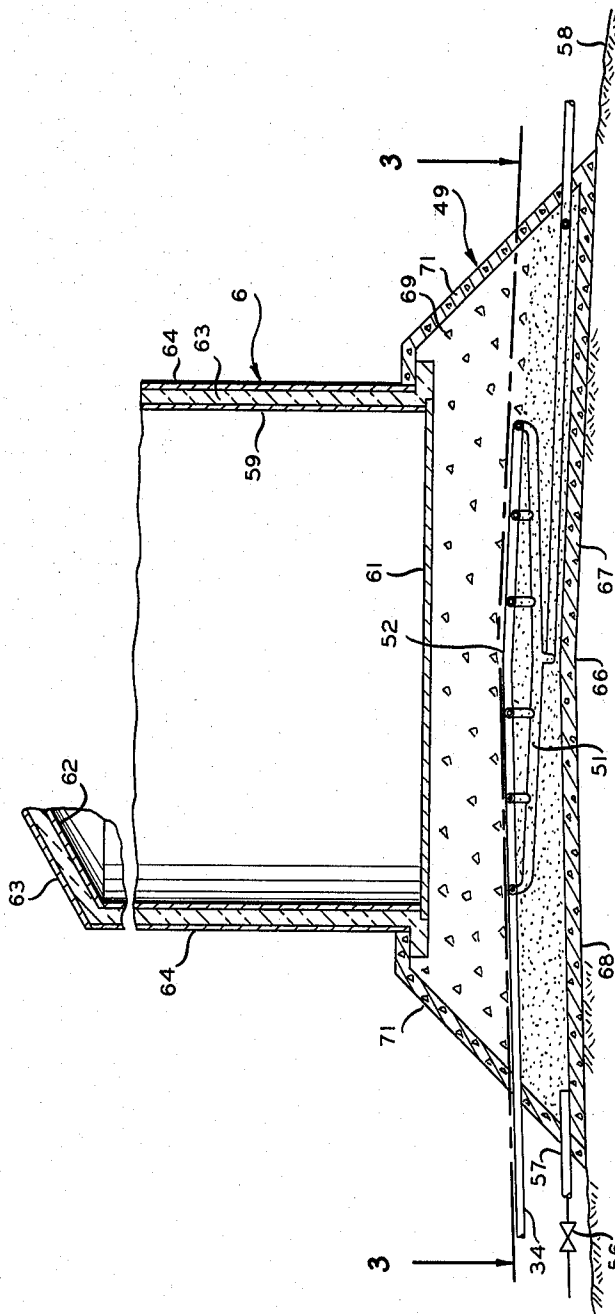


FIG. 2

INVENTOR.

C. S. KELLEY

BY

Young & Quigg

ATTORNEYS

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3 Sheets-Sheet 3

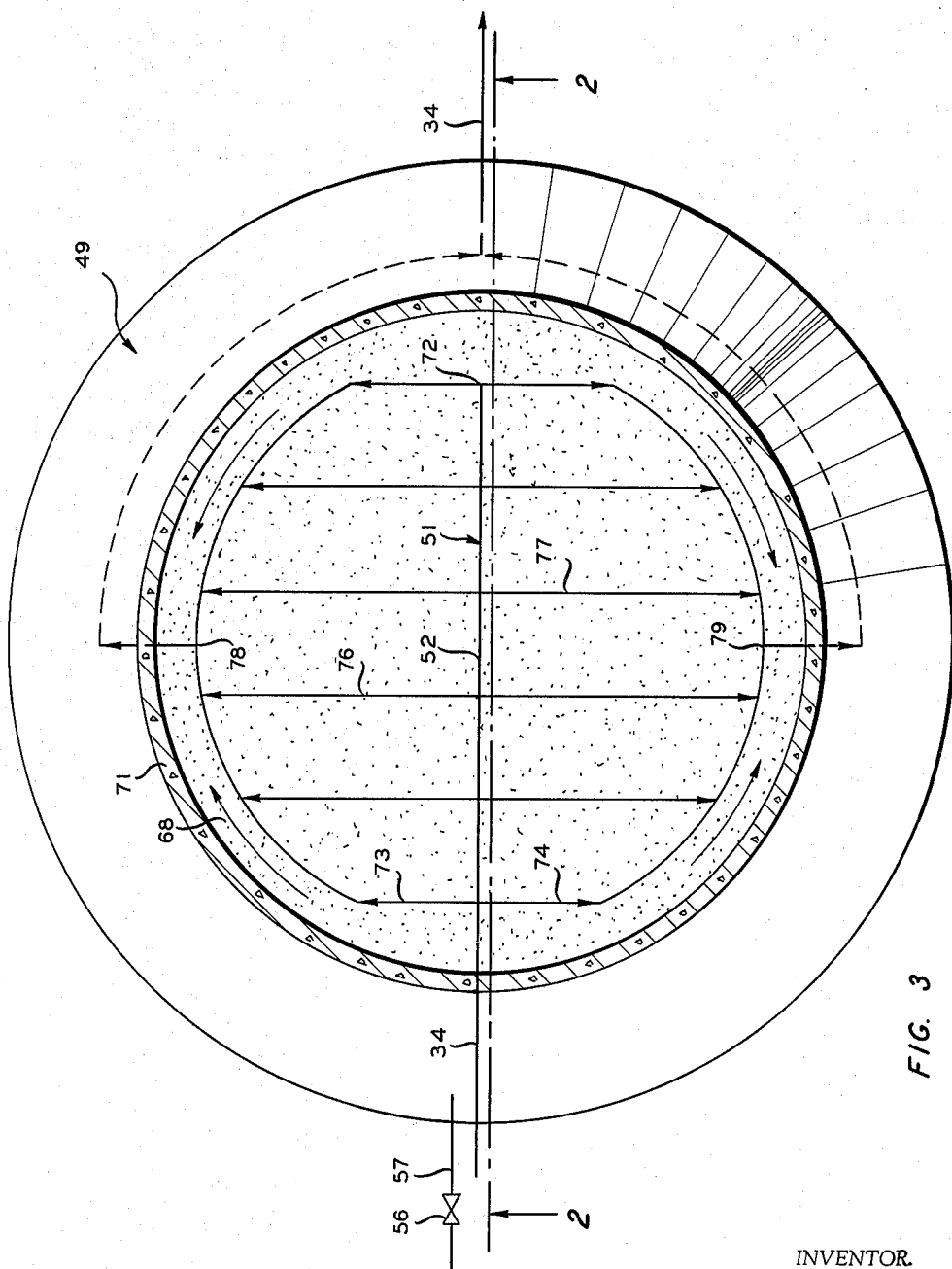


FIG. 3

INVENTOR.
C. S. KELLEY

BY *Young & Quigg*
ATTORNEYS

ATTORNEYS

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HEAT-INSULATED TANK HAVING TANK CONTENTS REFRIGERATING, FOUNDATION WARMING, AND LOADING AND UNLOADING SYSTEMS

Carl S. Kelley, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware
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5 Claims. (Cl. 62—45)

This invention relates to a heat-insulated tank for the storage of volatile liquids or normally gaseous liquefied gases in refrigerated conditions at a reduced pressure because of said refrigeration. It relates also to means for refrigeration of the liquid contents of such a storage tank. It relates also to means for warming the foundation of such a storage tank to reduce freezing and resulting heaving of the ground under said foundation. It relates also to means for loading and unloading such tanks. It relates also to novel economical construction and operation of such tanks and such means, and novel construction of a base for such tanks.

In the prior art, some attention has been paid to the problem of the ground freezing and heaving under such cold tanks, as evidenced by Jackson 2,332,227 of October 19, 1943, by passing steam, hot water, or other extraneous heated fluid heat exchange medium through pipes in the foundation. This requires expensive heating equipment in addition to the refrigeration equipment (neither being shown by Jackson) and involves extra expense for power, heating, and cooling.

The present invention lies in the discovery that sufficient heating for preventing the freezing of the ground under the foundation of a refrigerated tank can be supplied by the same system needed to supply refrigeration to the volatile liquid being stored to keep it at reduced pressure in said tank. At the same time, further economies in the construction, insulation, and loading and unloading means for the tank have been developed by producing a tank and operating system which are novel, useful and superior to those of the prior art.

One object of the present invention is to provide a novel and economical tank and systems for operating said tank for the storage of volatile liquids or liquefied gases in refrigerated state at a reduced vapor pressure.

Another object is to provide means for warming the foundation of such a tank enough to reduce freezing and heaving of the ground, which is economical because it utilizes the heat removed from the stored fluid in the refrigeration cycle of cooling the fluid being stored in said tank.

Another object is to provide means for loading and unloading said tank that will cooperate with the general construction of said tank and refrigerating means.

Numerous other objects and advantages will be apparent to those skilled in the art upon reading the accompanying specification, claims and drawings.

In the drawings:

FIGURE 1 is an elevational, cross-sectional view of a tank and system embodying the present invention, with minor details of construction shown in the other figures omitted in order to give a clearer picture of the entire liquid refrigerating, ground warming, loading and unloading systems.

FIGURE 2 is an enlarged elevational, cross-sectional view of the same tank in the same position as in FIGURE 1, but showing details of construction of the tank, tank insulation, foundation, and foundation-warming heat exchanger system, and omitting showing the other systems shown in FIGURE 1. FIGURE 2 is taken along the line 2—2 of FIGURE 3 in the direction indicated, except that

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some of the sand in the foundation has been removed to expose the foundation-warming piping system completely.

FIGURE 3 is a plan cross-sectional view of the construction of FIGURE 2 taken along 3—3 looking in the direction indicated, except that some of the sand in the foundation has been removed to expose the foundation-warming piping system completely.

In FIGURE 1, a tank generally designated as 6, the heat insulation of which is not shown (see FIGURE 2 for heat insulation details), contains a volatile liquid 7 which may be of any volatile liquid. Minor obvious engineering design changes have to be made for each volatile liquid to be stored, namely, thickness of heat insulation, size of pumps, and type of metal used in the tank, pipes and valves, all of which are within the prior art knowledge of those skilled in the art, such as any chemical or mechanical engineer, as they all depend on boiling point, vapor pressure, and other well known properties of the volatile liquid for which the system is designed. The system shown for illustrative purposes is for storing a volatile liquid known as L.P.G., that is, propane, butane, or mixtures of these two normally gaseous hydrocarbons. With only obvious modification as to pressure and temperature being maintained, anhydrous ammonia can be stored in this identical installation. With heavier pumps and more heat insulation, and using nickel steel as the inner tank, valves and flow lines, the volatile liquid stored may be liquefied and refrigerated methane, ethane, ethene, propene, or other liquefied gases common in industry at corresponding suitable pressures and temperatures. This invention can also be applied to storing butadiene, pentane, pentene, or other volatile liquids less volatile than butane. By volatile liquid it is intended to include all liquefied, normally-gaseous substances, as well as all fluid materials having a high vapor pressure except in freezing weather.

In the storage of such volatile liquids, the pressure under which they are stored, and therefore the weight and cost of the tank, can be greatly reduced by refrigeration of the liquid to a subatmospheric temperature suitable for each liquid to be stored, which temperature and resulting pressure can be obtained from a handbook by any engineer, and the selection of which depends on how strong and heavy it is necessary or desired to build the tank. I have found, for example, that liquefied propane is most economically stored in a system embodying my invention at -45° F. and a resulting gauge vapor pressure of 5 inches of water. Butane may be stored at a higher temperature and similar pressure, and methane, of course, should be stored at a much lower temperature to obtain similar gauge vapor pressures on the roof of the tank. Methane boils at about -259° F., propane at about -43.7° F., butane at about 31° F., and ammonia (anhydrous) at about -28° F., all at atmospheric pressure.

Ordinary fine-grain carbon steels can be used for storage tanks operating at temperatures down to -55° F., as is used for L.P.G. and ammonia, but nickel steels must be used for real cryogenic storage of liquefied natural gas, known as L.N.G., which is almost all methane and which involves temperatures down to -260° F. Any large steel company will be glad to specify the steel to be used. Furthermore, cryogenic storage involves considerably more power, as a rule of thumb is that for every horsepower (H.P.) needed to cool to 40° F., $1\frac{1}{2}$ H.P. is needed at -40° F. and 20 H.P. at -260° F.

Additional amounts of liquid 7 may be added to tank 6 from a source, such as a tank truck or other tank (not shown), which is at substantially the same temperature and pressure as in tank 6 through connection 8, valve 9, line 11, pump 12, liquid loading line 13, valve 14, and spray head 16. The liquid spray from head 16 absorbs

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some of the vapor in the space 17 above the liquid 7 in tank 6 and thereby reduces any build-up in pressure as liquid replaces vapor space in said tank. Liquid 7 may be dispensed from tank 6 by closing valves 11 and 14 and opening valves 18 and 19 and pumping the liquid with pump 12 through dispensing line 21. Vapor may be added or dispensed through line 22 after opening valve 23. Tank 6 may be provided with the usual safety means, such as a vapor pressure relief valve 24 which opens at a predetermined pressure greater than it is desired to maintain in space 17 but less than the maximum pressure the tank is designed for, and vapor pressure gauge 26 indicates and may record that pressure. A thermometer 27 indicates and may record the temperature taken at one point 28 or more points (not shown) of the liquid 7 in said tank.

The system for maintaining the fluid stored as liquid 7 and at the same time reducing the freezing and heaving of the ground under tank 6 will now be described. Vapor is drawn from space 17 through line 29 and valve 31 into compressor 32. With propane, the temperature of liquid 7 is about -45° F. and the vapor in 17 is only slightly higher at a gauge pressure of about 5 inches of water. In line 29 the temperature rises to about -40° F. at the inlet of compressor 32. The latent heat of vaporization (or condensation) of propane is about 183 B.t.u./lb. The compressor exhaust is about 190 p.s.i.a. at 150° F. Assuming that all the compressed vapor from compressor 32 passes through valve 33 and foundation warming pipes 34 and valve 36, it reaches return line 37 at a temperature of about 100 to 120° F. and a slightly lower pressure and passes as a compressed vapor through a point 38 above condenser 39 where it is cooled to about 70° F. and 170 p.s.i.a. and becomes a liquid in line 41.

The temperature at a selected point 42 (or points not shown) under the foundation of tank 6 may be indicated or recorded at 43 and a decision made as to how much of the vapor is sent through valve 33 and warming pipes 34 and how much is by-passed through valve 44 and by-pass line 45 to return line 37. By-pass line 45 is shown going over the top of tank 6, which it could, but obviously in an economic installation line 45 would go around tank 6 on the ground, and it is just shown schematically to avoid confusion in the drawing. Vapor entering line 37 from valve 44 is not much below 150° F. and 190 p.s.i.a., but temperature controller 47 may adjust the flow of cooling fluid, preferably water, through valve 48 so that the temperature is still about 70° F. and the pressure about 170 p.s.i.a. in line 41, regardless of what proportion comes through line 34 and line 45. While not shown, it is obvious that compressor 32 could be automatically controlled to maintain the pressure at 26 or the temperature at 27 within close limits, and the temperature at 43 could be used to automatically control valves 33 and 44 to proportion the flow of compressed vapor through these valves and still practice the present invention.

Liquid propane at about 170 p.s.i.a. and 70° F. in line 41 is flashed through valve 50, which opens in response to the pressure control 50A connected with it whenever the pressure in line 41 reaches 170 p.s.i.a. As this liquid flashes into tank space 17 at about 5 inches of water pressure gauge, a large part of it vaporizes and cools down to about -49 to -50° F., and together with the unevaporated remaining liquid which has been cooled by this vaporization to about -50° F. and which enters liquid 7, the temperature of liquid 7 is maintained at about -45° F. even though heat is constantly leaking in through the insulation 63 of tank 6.

At the same time, the tank is not permitted to draw heat through its bottom 61 out of the ground 58 at a fast enough rate to cause substantial freezing and heaving of the ground, because of the heat-insulating layer of broken slag 69 and heat exchanger 51 interposed between the tank bottom 61 and the ground 58. Excess heaving of the ground has caused flexure and finally rupture to

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metal tank bottoms of refrigerated tanks placed directly on the surface of water-saturated soil, which action is avoided by the present invention, without the addition of equipment and added expense of special additional extraneous ground heating systems.

The boiling points given above are the average boiling points of commercial supplies and not the absolute boiling point of 100 percent pure hydrocarbons. Commercial propane may contain up to 5 percent ethane and/or 5 percent butane, and the same is true for other hydrocarbons or volatile liquids such as ammonia which can contain up to 5 percent N_2 and/or H_2 . When the critical temperature of the gas being stored is below 32° F., then water cannot be used to cool 39, but obviously the cooling coil of a suitable external refrigeration system employing SO_2 , H_2 , N_2 , CO_2 or "Freon 12" (difluorodichloromethane) can be used (not shown). Methane has a critical temperature of -117° F. and when stored as a liquid the coolant in line 84 has to be selected from a refrigerant gas that is a gas or a liquid considerably below that temperature and not a solid at any point in its cycle.

In order to spread the warming effect of line 34 over the entire area of foundation 49, it contains a manifold section 51 having a high point 52. For purposes of periodic drainage, valves 53 and 54 can be temporarily opened as system 34 slopes downward from high point 52 to both of valves 53 and 54. Valve 56 in foundation drainage line 57 is not essential, but is preferred as a precautionary measure to drain foundation 49 if necessary at periodic periods. Foundation 49 is support on the ground surface 58.

The details of preferred construction of the tank 6, foundation 49, and foundation-warming system 34 are shown on an enlarged scale in FIGURE 2. For propane, tank 6 comprises an inner tank wall 59, floor 61 and roof 62 which may be made of the usual fine-grain carbon steel. A suitable layer of heat insulation surrounds the inner tank and its thickness depends on the type of insulation chosen. It is preferred to use 4 inches of "Foamglas," a rigid cellular glass insulating material for service down to -50° F. with propane as recommended by the manufacturer, Pittsburgh Corning Corporation, and corresponding greater thicknesses for lower temperature service, but other well known types of insulation of suitable thickness can be substituted. They recommend covering the insulation 63 with one or two coats of asphalt-base aluminum paint (not shown) or a thin coating of glass-fibred asphalt cutback covered with light-gauge metallic foil or sheet metal, such as aluminum covering 64, for heavier service. Tank 6 is supported on foundation 49.

Foundation 49 is preferably constructed in the following manner. The ground surface 58 is smoothed in the form of a slightly protruding cone with its apex 66 in the center of the proposed tank. A water-sealing blanket of asphalt 67, preferably that known as asphalt cement preferably having a penetration of 50 to 250 at 77° F. in 5 seconds using a 100-gram needle as specified in ASTM designation D-5-61, pages 1144-1147, of the 1961 book of ASTM standards, is laid over the conical ground. Manifold 51 with high point 52 is approximately centered above apex 66 and secured in place by supporting sand 68. While any sand can be used, it is preferable to use a fast water-draining sharp sand with substantially preponderately angular grains, known as sand bank sand, rather than river or beach sand. Sand of 20-30 mesh (U.S. Standard sieve) is preferred. On top of the sand and manifold 51, it is preferred to pile broken rock, preferably lumps of blast furnace slag 69 of up to $1\frac{1}{2}$ to 2 inches diameter, which acts as heat insulation and a firm support for the bottom of tank 6. Suitable slag or cinder from iron-making blast furnaces are available on the market. While sand 68 is not very heat conductive, it is more so than slag layer 69.

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After tank 6 is constructed on foundation 49 and emergency drain pipe 57 is inserted in sand 68, a water-sealing layer of asphalt cement 71 is formed welded to blanket 67 and against the outer wall of tank 6 to keep rain out of the foundation 49.

The preferred form of foundation-warming, indirect heat exchange element 51 is shown in FIGURES 2 and 3. Pipe 34 rises to a high point 52 and then drops to an intermediate elevation at 72. At substantially equispaced points along pipe 34 are connected outwardly-extending, downwardly-sloping pipes, only a few of which are numbered. Of these pipes 73 and 76 extend in one direction from central pipe 34 and others, such as 74 and 77, extend in the opposite direction. They are connected to circumferential collecting pipes sloping downward to lower points 78 and 79 and a pair of pipes going on downward to join in pipe 34 sloping downward to the right to cut off valve 36 and drain valve 54 in the lower right-hand portion of FIGURE 1. This enables any condensed liquid to be withdrawn and not block the passage of normally compressed vapor. Similarly, the space inside foundation 49 can be drained through downwardly-sloping pipe 57. There should not normally be any liquid to drain from valves 53, 54 and 56, but they are for any emergency.

While a specific example has been shown in the drawings and described in the specification for purposes of illustration, it should be obvious that the invention is not limited thereto, but covers the various modifications suggested or obvious from the above discussion for the storage of any volatile liquid having a substantial vapor pressure in freezing weather. For example, while a water-cooled condenser is shown at 39, obviously air-cooled condensers or any type of condenser known to the prior art may be substituted within the present invention.

Having described my invention, I claim:

1. The process of storing a volatile liquid at low gauge pressure and at a temperature below 32° F. in a closed tank resting on the ground, comprising withdrawing vapor from said tank, compressing and thereby heating said vapor, passing said compressed and heated vapor in indirect heat exchange with the ground under said tank, cooling and condensing said compressed vapor into liquid under a higher gauge pressure than said tank, and flashing said liquid into said tank to at least partially vaporize at said low gauge pressure and refrigerate said volatile liquid in said tank.

2. Apparatus for storing a volatile liquid at a first low gauge pressure and at a temperature below 32° F., comprising a foundation, a tank resting on said foundation, heat insulation on the walls and roof of said tank, an indirect heat exchange pipe in said foundation, means to draw vapor from said tank, means to compress and thereby heat said vapor, means to pass said compressed and heated vapor through said heat exchange pipe, means to then cool said compressed vapor and condense the same to liquid under a second gauge pressure higher than said first pressure, and means to pass said liquid into said tank at a third pressure between said first and second pressure.

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3. Apparatus for storing a volatile liquid comprising in combination on the ground surface:

- a water-sealing blanket of asphalt cement;
- a layer of sand on said cement supported by the ground;
- an indirect heat exchange pipe resting on said sand;
- a layer of broken lumps of rock resting on said sand and on said heat exchange pipe;
- a closed metal tank having a side, a top and a bottom resting on said rock;
- a layer of heat insulation on the side and top of said metal tank;
- a covering of metal on the side and top of said heat insulation; and
- a layer of asphalt cement sealing the space around said foundation extending from said asphalt cement layer on the ground to the metal cover on the heat insulation on the wall of said tank.

4. Apparatus for storing a volatile liquid comprising in combination on the ground surface:

- a layer of sand supported by the ground;
- an indirect heat exchange pipe resting on said sand;
- a layer of broken lumps of rock resting on said sand;
- a closed metal tank having a side, a top and a bottom resting on said rock;
- a layer of heat insulation on the side and top of said metal tank;
- a covering of metal on the side and top of said heat insulation; and
- a layer of asphalt cement sealing the space around said foundation extending from the ground to the metal cover on the heat insulation on the wall of said tank.

5. Apparatus for storing a volatile liquid comprising in combination on the ground surface:

- a layer of sand supported by the ground;
- an indirect heat exchange pipe resting on said sand;
- a layer of broken lumps of rock resting on said sand;
- a closed metal tank having a side, a top and a bottom resting on said rock;
- a layer of heat insulation on the side and top of said metal tank; and
- a layer of asphalt cement sealing the space around said foundation extending from the ground to the heat insulation on the wall of said tank.

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ROBERT A. O'LEARY, *Primary Examiner.*

LLOYD L. KING, *Examiner.*