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Becker

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[54] **METHOD OF AND SYSTEM FOR THE EMPTYING OF LIQUEFIED-GAS VESSELS, ESPECIALLY THE TANKS OF A TANK SHIP**

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[51] **Int. Cl.**.. **B67b 7/00**

[58] **Field of Search**...... 222/61, 64, 135, 136, 394, 222/396, 397, 399, 1; 62/55

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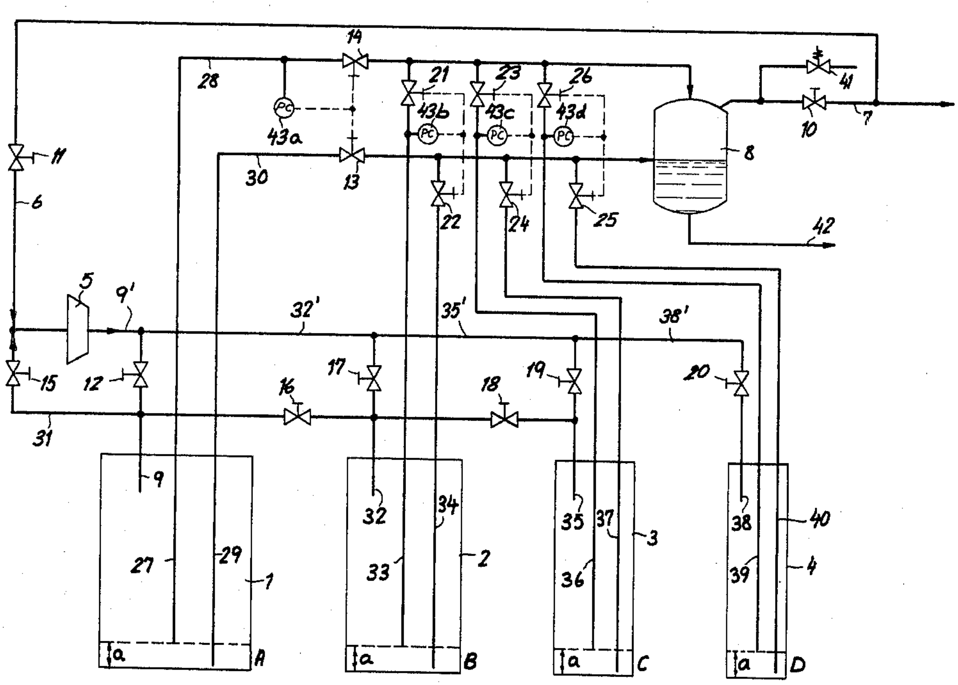
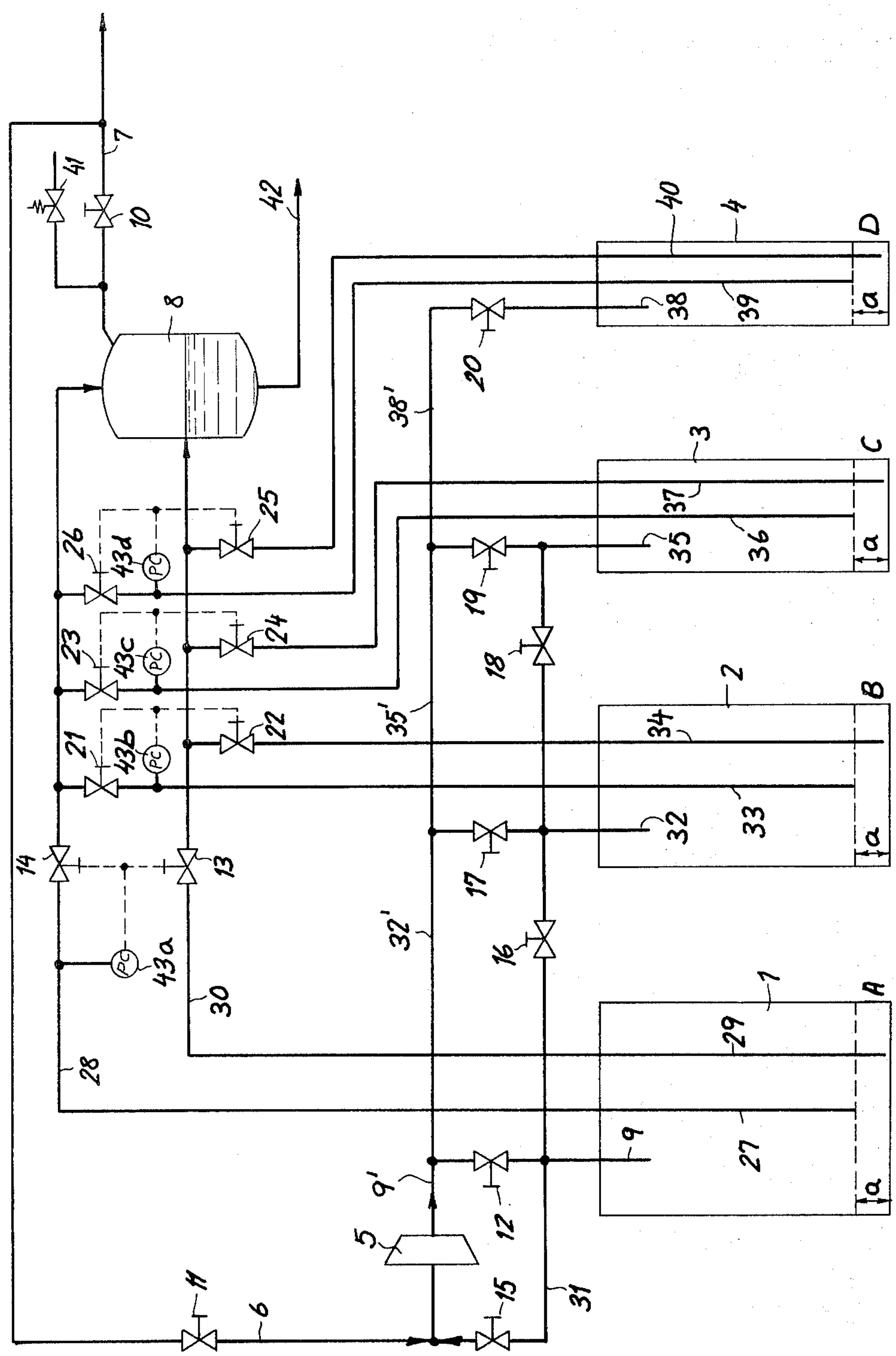
[57] **ABSTRACT**

A plurality of liquefied-gas storage or transport tanks, e.g., of a tank ship for carrying liquefied gas, are emptied under applied pressure by introducing a compressed gas into a first tank to drive at least a major portion of the liquefied gas therefrom, the vapor space of the first tank serving as the source of compressable gas to be fed into a subsequently discharged tank as a driving fluid. Consequently, only the last tank remains at a pressure equal to the displacement pressure at the conclusion of emptying of all of the tanks.

8 Claims, 1 Drawing Figure





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METHOD OF AND SYSTEM FOR THE EMPTYING OF LIQUEFIED-GAS VESSELS, ESPECIALLY THE TANKS OF A TANK SHIP

FIELD OF THE INVENTION

My present invention relates to a method of and apparatus for the emptying of a plurality of receptacles containing a liquid medium and at an elevated emptying pressure and, more particularly, to a system for discharging liquefied gas from an array of tanks or other receptacles containing same, e.g., in a tank ship or other transport vehicle.

BACKGROUND OF THE INVENTION

In recent years, the requirements for high-value fuels have led to the development of natural-gas fields at locations remote from the consumer, and to a large measure there has been increasing interest in the economic transport of the natural gas to the consumer from the source. One of the most effective transport systems currently in use is a tank ship or tanker in which the liquefied gas is introduced at the gas field at a liquefying installation, is stored in a number of tanks or receptacles at low temperature and is delivered to a port at which the liquefied gas is pumped from the ship and into storage tanks. It is a common practice, in such systems, to drive the liquefied gas through the conduits feeding the pumps at an elevated (superatmospheric) pressure supplied by introducing a compressed gas above the liqued in the tank. A pipe or conduit leading to the pump usually extends downwardly into the tank to a location close to the bottom thereof.

It is also known to transport other liquids in tank ships or multi-compartment tank vehicles of other types and to discharge such tanks under pressure applied above the liquid level from some external source. Also, stationary tanks at storage depots or the like can be discharged at least in part under pressure applied to the liquid surface by introducing compressed gas into the tank above the liquid level.

All of these systems have the disadvantage that the pressure-raising gas must be supplied in relatively large volumes as will be apparent hereinafter. For example, the pressure necessary to drive the liquid through the conduits leading to a displacement pump, is a function of the specific gravity of the liquid, the height to which the liquid must be elevated, the pump-intake pressure or suction capabilities, the conduit pressure drops and the like. Since the liquid-displacement pressure must be applied during the entire discharge of the tank, a volume of compressed gas is necessary which is equal to the volume of liquid displaced in each tank at the superatmospheric pressure which is applied. Such gas volumes are extremely large, especially when the emptying of large-capacity tank ships is considered.

Frequently the compressed gas must be a substance other than air and hence must be stored for eventual use in discharging the tanks. Such storage requires large-volume receptacles at high capital and maintenance cost. Furthermore, since the gas fed to the tanks has generally been retained or been vented in earlier systems, large losses of a valuable fluid have been encountered and must be taken into consideration in determining the economics of the system. For example, in a methane tanker which is to be emptied under applied pressure of two atmosphere gauge, 7.05 cubic meters

of gaseous methane (standard temperature and pressure, STP) are required for each cubic meter of the cargo space. Each cubic meter of the cargo-carrying space can deliver 586 cubic meters (STP) of methane so that the retained gas in each tank represents a loss of 1.35 percent of the usable cargo-carrying space. If the pressure-raising methane is vented, this valuable component is lost.

OBJECTS OF THE INVENTION

The principal object of the present invention is to provide a system for the discharging of a number of liquid-storage or liquid-transport tanks whereby the disadvantages of earlier systems, as described above, are obviated.

It is another object of the invention to provide a method of discharging tank ships and like systems of a plurality of liquefied-gas tanks or receptacles, in which the lost cargo-carrying space is reduced and the economics of the entire transport system improved.

It is still another object of the invention to provide a method of and apparatus for the emptying of tank ships and the like of liquefied gas in a plurality of tanks whereby losses are reduced without increasing the turnaround time fo the vessel.

SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, in a system for emptying a number of tanks of a storage installation or a transport vehicle or vessel or the like in which liquefied gas is carried, wherein, in a first phase of the emptying process, a part of the receptacle system is discharged by introducing a compressed gas under pressure. In a second phase, another portion of the receptacle system is entered by drawing gas from the first portion of the receptacle system which previously was charged, compressing this gas, and feeding it into the subsequent space to be discharged. The process is repeated, each time drawing the compressed gas from a preceding, previously emptied receptacle compartment, until all of the receptacles or tanks are discharged. Since the gas is drawn from one compartment through the compressor and discharged into the next compartment, the pressure within the previously discharged compartment is reduced and only the last compartment need remain at an elevated pressure.

According to the principal feature of the present invention, therefore, a receptacle has a first portion which is emptied in a first period by introducing above the liquefied gas therein a compressed pressurizing gas adapted to displace liquefied gas from this first portion of the receptacle and build up in the compartment previously containing the first portion of liquefied gas, a superatmospheric gas pressure. For For subsequent displacement of liquefied gas from other portions or compartments of the receptacle, the pressurizing gas is withdrawn from a previously emptied compartment or receptacle portion, is compressed, and is supplied to the top of the liquefied gas in the next compartment or receptacle portion to displace the liquefied gas therefrom and reduce the pressure in the previous compartment from which the pressurizing gas is withdrawn. The process is repeated, each time using the previously pressurized portion of the receptacle, or compartment, as the source of the pressurizing gas, until the only compartment or receptacle portion at a level of pressure equal to that used to displace liquefied gas from the system is the compartment or receptacle portion last emptied.

When reference is made herein to receptacle portions, it should be understood to mean individual tanks or containers of a particular installation, or a single container subdivided into respective tanks. The pressurizing or liquid-displacement gas may be of the same composition as the liquefied gas (e.g., methane) or can be an inert gas, e.g. nitrogen, incapable of reacting with the liquid component. The stored pressure referred to hereinafter will be the pressure remaining in each compartment after the displacement gas has been withdrawn, compressed and fed to another compartment, while the displacement pressure will be the pressure normally used to force liquid from the respective compartment. The stored pressure may, of course, be ambient or atmospheric pressure (1 atmosphere absolute) while the displacement pressure is higher, e.g., 2 atmospheres gauge.

The system described above has numerous advantages in that it allows each compartment to be discharged by a displacement gas at a superatmospheric discharge pressure, by ensuring substantially lower stored pressure at the comclusion of the emptying process for all of the compartments apart from the last. Only this last compartment remains at a superatmospheric discharge pressure. This reduces the gas volume overall in the cargo space of the vessel and permits more efficient utilization of the usable cargo space. In addition, the quantity of displacement gas used for the entire emptying process can be reduced by comparison with earlier systems since the displacement gas introduced into each compartment but the last is reused for another compartment.

According to another feature of the present invention, the liquefied gas is discharged from the portions of the receptacle or the tanks at a substantially constant volume rate of flow and I therefore provide that, where the emptying period is shorter the cross-section of the liquefied-gas outlet is greater and, where the emptying period is greater (larger volume of the compartment), the cross-section of the outlet conduit is smaller. Thus the volume rate of flow at each stage should be the same for all of the phases.

To minimize the quantity of displacement gas used, I arrange the tanks or compartments so that the first-phase volume can accommodate the displacement pressure, the total volume of gas required to maintain the stored pressure in each of the emptied tanks but the last plus the quantity of displacement gas required to provide the displacement pressure in the emptied last tank. Each subsequently emptied tank will thus be designed to hold, at the displacement pressure, a quantity of gas equal to that necessary to maintain the stored pressure in each subsequent tank (upon emptying) but the last, plus the quantity of gas required for the displacement pressure in the last tank when emptied. Thus the gas introduced into each subsequent compartment for displacement of the liquefied gas therein can exclusively be drawn from the preceding compartment.

The apparatus for carrying out the method of the present invention preferably comprises means for introducing above the liquefied gas in one compartment of a receptacle system a compressed displacement gas and forcing liquefied gas therewith from the first compartment, means for withdrawing the compressed displacement gas from the first compartment, compressing the gas withdrawn from the first compartment and introducing the compressed gas from the first compartment into another compartment to displace liquefied gas therewith from the next compartment, and means for automatically repeating these steps until all compartments are emptied and a displacement pressure of this gas is maintained in the last-emptied compartment while a low stored pressure is present in all of the other compartments.

According to another feature of this invention, each of the tanks or compartments is provided with a line (conduit) reaching downwardly into the tank substantially to the bottom thereof and through which, via automatically or manually controlled valves, the liquefied gas may be forced by the displacement gas upward and to the usual displacement pump. A compressor may be provided whose discharge side is connected to all of the compartments or tanks, via suitable valves, in parallel while the valves connect each of the compartments or tanks with the intake side of the compressor for all of the tanks apart from the last-emptied tank. The automatic control means may include an instrument line or duct, reaching into each tank or compartment but terminating above the bottom thereof for signaling the emptying of the tank to this point so that a small amount of liquefied gas remains at the bottom of each tank to maintain the latter at a low temperature.

DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which sole FIGURE is a flow diagram illustrating the invention.

SPECIFIC DESCRIPTION

In the drawing, the tanks or compartments emptied during the successive periods A, B, C and D are represented at **1**, **2**, **3**, and **4** and have successively reduced volumes for reasons which will become apparent hereinafter.

A compressor **5** is provided to generate the pressurized displacement gas and the intake side of the compressor **5** is provided with a line or conduit **6** having a valve **11** and connected to a line **7**. The latter is provided with a valve **10** and opens into the gas space of an expansion vessel **8** from which the liquid can be withdrawn at **42**. Lines **9'**, **32'**, **35'** and **38'** are connected to the discharge side of compressor **5** and communicate with the respective tanks **1**, **2**, **3** and **4** via valves **12**, **17**, **19** and **20** and line **9**, **32**, **35** and **38** opening into the tanks above the liquid level therein. Each of the tanks except the last is provided with means, e.g., the valves **15**, **16** and **18**, communicating with the intake side of compressor **5**.

The dip tubes or pipes **29**, **34**, **37** and **40**, through which the liquefied gas is discharged, are connected to line **30** via pressure controlled valves **13**, **22**, **24** and **25** and empty into the expansion vessel **8**. Pressure controllers **43***a*, **43***b*, **43***c* and **43***d* are connected to instrument lines or pipes **27**, **33** **36** and **39** which are provided with pressure controlled valves **14**, **27**, **23** and **26**, respectively. The gases from the instrument line are carried by duct **28** into the gas space of the vessel **8**.

In the drawing, a system for emptying a liquid-methane tank which in four phases or periods has been illustrated, the successive periods being represented at A, B, C and D indicated earlier. In practice, each emptying period will discharge a number of storage vessels which have been united in the diagram in the vessels **1** through **4**.

In operation, the first vessel or tank **1** (phase A) is emptied by admitting methane gas under the displacement pressure from the compressor **5** to the tank above the level of the liquefied gas therein. The gasified stored medium is drawn via lines **6** and **7** from the expansion chamber **8** (valves **10** and **11** being opened). The displacement gas is fed through lines **9** and **9'** into the tank. Valves **10** through **14** are open during this phase, while all of the other valves **15–26** are closed.

Under the head operated by the pressurized gas in vessel **1**, liquefied gas is forced upwardly through the instrument line **27** and the discharge line **29** through the duct **28** and **30** past valves **13** and **14** into the liquid portion of the expansion chamber **8**. The liquid may be withdrawn by a displacement pump connected to line **42**.

Line **28** is provided with the pressure controller **43***a* (as described previously) which produces a signal closing valves **13** and **14** since the liquid level in tank **1** sinks beneath the level *a* so that the pressure head of valve **14**, which has only a small passage, increases to trip the pressure controller. Liquefied gas to the depth *a* is maintained in each container during the return trip of the ship to maintain a low temperature in the liquefied gas storage tanks.

Upon emptying of the tank **1**, which is indicated by closure of the valve **13** and **14**, the valves **11** and **12** are closed by hand or automatically from the pressure controller **43***a*. At this point, the pressure within the tank **1** is equal to the displacement pressure.

In the next discharge period (phase B) valves **15, 17, 21** and **22** are opened (e.g., by the pressure controller **43***a*) so that the displacement gas is drawn via line **9**, and line **31** past valve **15** into the intake side of the compressor, the compressed displacement gas being pumped via lines **9'** and **32'**, past valve **17**, and through duct **32** into the tank **2** above the liquefied gas therein. The liquefied methane is forced upwardly through the lines **33** and **34** past valve **21** and **22** into the expansion chamber **8**. Here again, when the level *a* is reached, the pressure at line **33** increases to cause the pressure controller **43***b* to close valves **21** and **22.** Valve **17** is closed simultaneously by this pressure controller and valves **16, 19, 23** and **24** are open.

In this third phase (phase C) the compressor **5** draws the displacement gas from tank **2** via line **32**, valve **16**, line **31** and valve **15**, while discharging the compressed gas into the third tank **3** via lines **9', 32'** and **35'** past valve **19.** The gas within chamber **2** is initially at the displacement pressure and may be reduced in pressure to the stored pressure which may be above or below atmospheric pressure but is preferably equal to it. Asd the liquefied gas is displaced from tank **3** through lines **36** and **37**, past open valves **23** and **24** into the expansion chamber **8**, the level drops until it reaches the level *a* whereupon the pressure builds up behind valve **23** to trip the pressure controller **43***c*, close valves **23, 24** and **19** and open valves **18, 20, 25** and **26** for the last phase (phase D).

Gas is drawn by the compressor **5** via lines **31** and **35** past valves **15** through **18** from tank **3** and is forced into tank **4** via lines **9', 32', 35', 38'** and **38** past valve **20.** The liquefied methane is forced upwardly through lines **39** and **40** past valves **25** and **26** into the expansion chamber **8**, the valves **25** and **26** being closed by the pressure controller of **43***d* when the liquid level drops below the mouth of the duct **39.** The pressure within tank **4** is thus the displacement pressure. The successive pressure of compressor **5** is maintained by a pressure regulator at the stored pressure of the liquid methane, i.e., approximately 1 atm. abs. At the end of the discharge process, only tank **4** remains under the superatmospheric pressure while all other tanks are under the ordinary storage pressure of the methane. A safety valve **41** protects the expansion chamber **8** against unusually high pressures.

SPECIFIC EXAMPLE

The total storage capacity of the four containers **1** through **4** is about $10^5 m^3$. The storage pressure of the liquefied methane is 1 atm. abs., the storage temperature is 112°K and the displacement pressure is 2 atms. gauge. Initially the volume required for discharge of the system must be calculated so that all of the tanks can be emptied. In the last phase, 12.3 percent of the total volume must be replaced by gas, corresponding to $12{,}300 m^3$. After the emptying, of each compartment, the displacement gas will remain in each container at a pressure of 1 atm. abs. and at a temperature of 112°K. This corresponds to a total gas volume of $10^5 \times 273/112 = 2.44 \times 10^5 m^3$ (STP). To this must be added the additional quantity of gas required to bring tank **4** to the elevated pressure of about 2 atms. abs., this additional volume being calculated as follows: $12.3/100 \times 2.44 \times 10^5 m^3$ (STP). The total volume is thus $3.04 \times 10^5 m^3$ (STP). By comparison, the externally supplied gas volume using conventional methods of emptying the tanks would be $7.32 \times 10^5 m^3$ (STP).

In the individual liquid-discharge periods A–D, the following container volumes are provided.

First liquid-discharge period (phase A): $3.04 \times 10^5 \times 112/273 \times 1/3 = 4.15 \times 10^4 m^3$. Second liquid-discharge period (phase B): two thirds of the volume of the first phase since, from the first tank at a pressure of 3 atms. abs., only this fraction of the gas is required to provide a pressure of 2 atms. abs. for the second phase. In the second phase, $2.77 \times 10^4 m^3$ of liquid methane is displaced.

Third liquid-discharge period (phase C): two thirds of the volume of liquid methane displaced in the second period (phase B) stage is discharged at this stage.

Fourth liquid-discharge period (phase D): two thirds of the volume of liquefied methane displaced during the third period of $1.23 \times 10^4 m^3$ of liquid methane is displaced.

The sum of the liquid methane displaced in all four periods is this $10^5 m^3$. Thus, in order to maintain a uniform flow rate of liquid methane, each subsequently discharged vessel must be emptied faster than each preceding discharged vessel and this is accomplished by increasing the cross-section of the methane discharge conduit.

I claim:

1. A process for the discharging of a succession of liquefied gas storage compartments of steppedly smaller volumes in which the liquefied gas is under a storage pressure, comprising the steps of:

a. feeding a compressed liquid-displacement gas to a first of said succession of compartments to displace the liquefied gas therefrom:

b. withdrawing liquid-displacement gas from said first compartment, compressing the liquid-displacement gas thus withdrawn, and leaving said first compartment at said storage pressure;

c. feeding the compressed liquid-displacement gas of step (b) into a second of said sucession of compartments at a displacement pressure greater than said storage pressure to discharge liquefied gas from said second compartment; and

d. repeating steps (a) through (c) for all of said compartments in succession whereby only the last-emptied compartment remains at sad displacement pressure, while all of the compartments except said last compartment are at said storage pressure, the first compartment having a volume dimensioned to accommodate, at said discharge pressure, a quantity of liquid-displacement gas equal to the displaced volumes of all of said compartments when fully dispersed and at said storage pressure plus a quantity sufficient to raise the pressure in said last compartment to said discharge pressure.

2. The process defined in claim **1** wherein the liquid-displacement gas is introduced into each of said compartments at a rate and pressure controlled to displace the liquefied gas therefrom at a substantially constant volume-rate-of-flow for all of said compartments.

3. The process defined in claim **1,** further comprising the step of terminating the introduction of said liquid-displacement gas into each of said compartments upon the liquid level therein falling to a predetermined point above the bottom of the compartment.

4. The process defined in claim **3** wherein said liquefied gas is methane and said liquid-displacement gas is methane.

5. A liquefied-gas storage system comprising:

a. a succession of compartments containing liquefied gas at a storage pressure, said succession of compartments having steppedly smaller volumes from a first compartment to a last compartment of the succession;

b. means for feeding a liquid-displacement gas into said first compartment at a discharge pressure greater than said storage pressure and displacing liquified gas therefrom;

c. a compressor having an intake side connectable to said first compartment and a discharge side connectable to a second compartment of said succession for drawing said liquid-displacement gas from said first compartment and introducing it at a discharge pressure into said second compartment to displace liquefied gas therefrom;

d. means for connecting said intake side to each of the compartments in succession and for connecting said discharge side to each successive compartment next removed from the compartment to which the intake side is connected for displacing liquefied gas from all of said compartments;

e. a respective liquid-discharge conduit reaching downwardly into each of said compartments beneath the level of liquefied gas therein;

f. respective gas-feed conduits communicating with each compartment above the liquid level therein; and

g. instrument conduits extending into said compartments but terminating above the bottoms thereof, the last-mentionded means including:

a first set of valves selectively connecting said gas-feed conduits to said discharge side of said compressor,

a second set of valves for selectively connecting said gas-feed conduits to said intake side of said compressor,

a third set of valves for selectively connecting said liquid-discharge conduits to a common outlet,

a fourth set of valves connected to said instrument conduits, and

respective pressure controllers connected to each of said instrument conduits for automatic operating at least one of said sets of valves upon the fall of the liquid level in a respective compartment below the mouth of the respective instrument conduit.

6. The system defined in claim **5** wherein said outlet communicates with an expansion chamber, said instrument conduits opening into said expansion chamber beyond the valves of said fourth set.

7. The system defined in claim **6** wherein said liquid-discharge conduits are dimensioned in accordance with the emptying time of said compartments to maintain a substantially constant rate of flow of liquefied gas to said expansion chamber from said compartments until all are emptied.

8. The system defined in claim **7** wherein the means for introducing said liquid-displacement gas into said first comparment includes a duct connecting said expansion chamber with said intake side.

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