

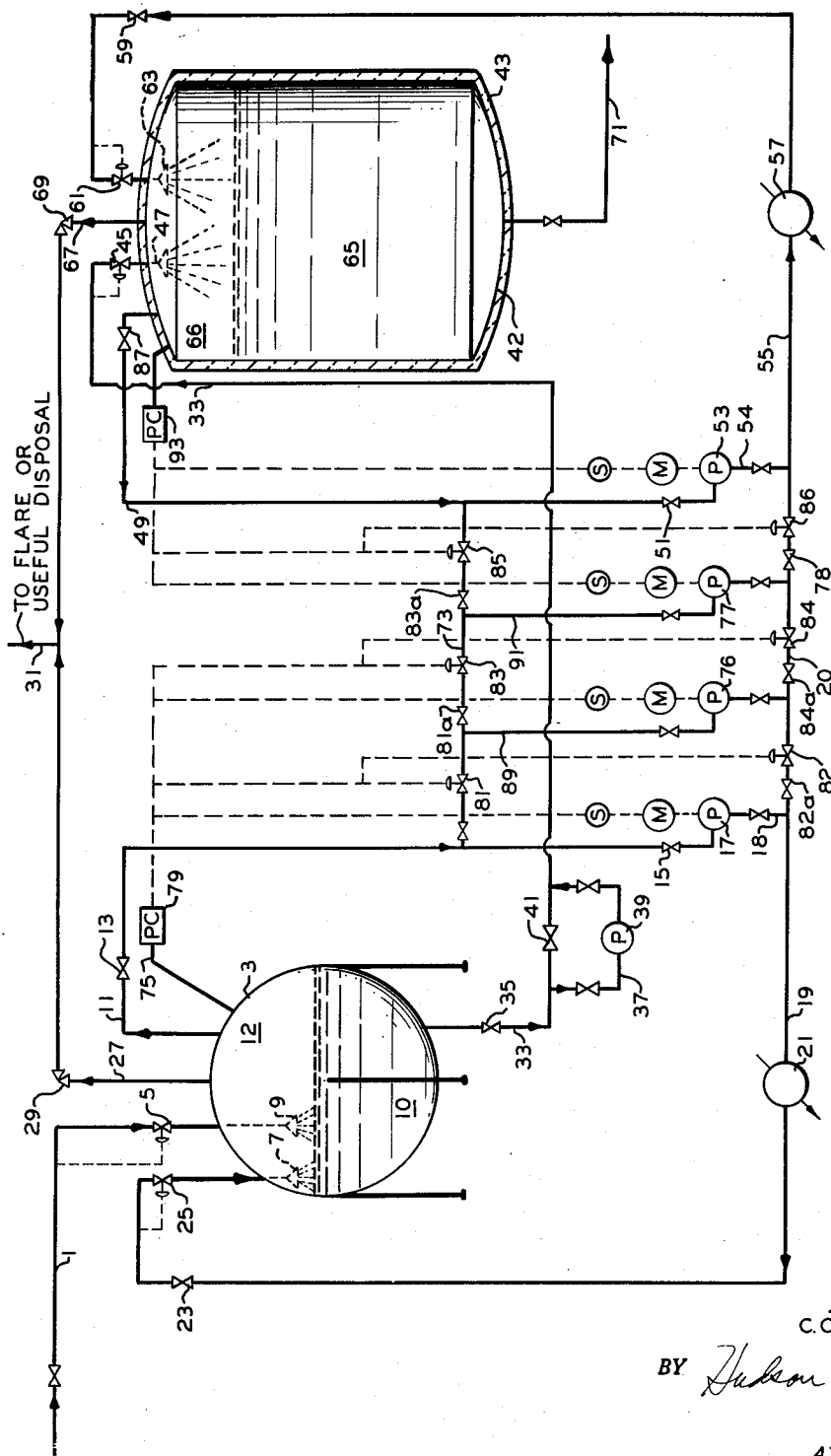
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C. C. ANDERSON

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RECEIPT AND STORAGE OF LIQUEFIED GASES

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INVENTOR.
C. C. ANDERSON

BY *Hudson & Young*

ATTORNEYS

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RECEIPT AND STORAGE OF LIQUEFIED GASES

Carlton C. Anderson, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

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This invention relates to storage of liquefied petroleum gas, natural gasoline, anhydrous ammonia and such other products normally requiring pressure storage at atmospheric temperature conditions. In one aspect this invention has particular application in the storage of liquefied petroleum gas and anhydrous ammonia.

In the following specification the apparatus and its operation will be described relative to the storage and handling of liquefied propane as an example of this invention.

The storage of LP-gas (liquefied petroleum gas) and anhydrous ammonia at low temperatures and pressures shows definite promise of real economy as compared to storage in conventional high pressure storage vessels. However, one problem in low temperature storage is the cost of refrigeration for cooling at a high rate the stream of material entering the storage system down to the low temperature of the storage system.

This invention proposes a system and its method of operation whereby the product stream, such as liquefied propane, is first received from the transportation facility at a high rate of transfer into a tank which is adapted to contain the propane under pressure. This tank, which may or may not be cooled by separate refrigeration, is sufficiently large to accommodate the volume of a rail shipment, a transport truck shipment, or a pipe line slug. The term "slug" or "pipe line slug" as used herein is intended to mean the volume of a single product transferred in a pipe line at one pumping. The product is then transferred from the high pressure receiving tank into a low pressure storage tank at a relatively slow rate, that is, a rate sufficiently slow that refrigeration can be applied thereto at an economical rate. It is realized that the same amount of work is performed on cooling the product from the temperature of the product as received to the storage temperature when the cooling is carried out in a single step as when the cooling is carried out in more than one step. However, this invention involves the carrying out of the cooling and concomitant pressure reduction in more than one step. By carrying out this operation in stages, the total investment in equipment and the operating costs are substantially reduced.

An object of this invention is to provide a method for storing easily liquefiable, normally gaseous fluids in the liquid state. Another object of this invention is to provide an economical method for storing such material at substantially atmospheric pressure. Yet another object of this invention is to provide storage wherein the cost of storage and accessory equipment is less than conventional high pressure equipment for storing the same volume of material. Still other objects and advantages of this invention will be realized upon reading the following description which, taken with the attached drawing, respectively describes and illustrates a preferred embodiment.

The drawing illustrates, in diagrammatic form, an arrangement of apparatus parts for carrying out the process of my invention.

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In the drawing reference numeral 1 identifies a pipe through which the liquefied gas for storage is received from a transportation facility, not shown. Reference numeral 3 identifies a relatively small high pressure tank which is of sufficient size to contain a pipe-line pumping, or the volume of liquid received in one shipment. Pipe 1 is sufficiently large to transfer the shipment of liquid for storage at the pipe-line receiving rate, or at a rapid transport truck or tank car unloading rate. Reference numeral 5 identifies an expansion valve which is adjusted at the proper opening in order to permit an appreciable pressure reduction on passage of the liquid through the valve. For example, when liquid propane is received at, for example, 180 to 200 p.s.i.g. (pounds per square inch gauge), valve 5 permits a pressure reduction to, for example, from 160 to 175 p.s.i.g. On experiencing this pressure reduction, the liquefied gas flash vaporizes on passing through the valve 5 and a spray nozzle 9, with the result that an appreciable proportion of the propane remains as a cooled liquid while the remainder vaporizes. Cooling or refrigeration is then required only at such times as tank temperature exceeds 81° to 87° F., the temperatures at which propane has vapor pressures of 160 and 175 p.s.i.g., respectively. When the propane in tank 3 exceeds a predetermined pressure, for example 175 p.s.i.g., this pressure is transmitted through a pipe 75 to a pressure controller 79 which actuates a switch in communication with a motor for starting a pump 17. Pump 17 is preferably referred to as being a compressor. Thus upon acquiring the mentioned predetermined maximum pressure in tank 3, controller 79 starts compressor 17 and this compressor withdraws vapor from tank 3 through a pipe 11, with manually operable valves 13 and 15 being open, and discharges the vapor at a pressure somewhat above 200 p.s.i.g. through a pipe 18 into a conduit 19. Conduit 19 leads the compressed gas to a condenser 21 which is operated at such a temperature as to condense the compressed propane. Condensate flows on through conduit 19 and through an open valve 23, an expansion valve 25, and through a spray nozzle 7 into tank 3. This condensate, similar to the liquid entering tank 3 from pipe 1, is partially vaporized, resulting in production of cold liquid and vapor. Vapor from spray nozzle 7 is also withdrawn from tank 3 through pipe 11 and flows the same circuit as just described for the vapor from spray nozzle 9. Since the rate of transfer of liquid through pipe 1 is relatively great, it is desirable under certain conditions to provide a second and relatively large compressor 76 which assists in compressing the relatively large volume of vapor from tank 3 while receiving liquid for storage. However, under other circumstances, compressors 17 and 76 have similar capacities so they are interchangeable. If receiving temperature from a pipe line or tank car is seldom above about 81° to 87° F., refrigeration is then not required in the receiving tank. Pressure controller 79 communicates with a motor valve 81 thereby opening the valve in response to a predetermined high pressure in tank 3. A motor valve 82 in a manifold pipe 20 is also opened by the actuation of the pressure controller 79 at the same time valve 81 is opened. Also, at the same time, the controller actuates a switch which starts the motor to drive compressor 76 for compressing vapor in excess over that compressed by compressor 17. Thus, when large volumes of vapor are evolved in tank 3, pressure controller 79 is provided for starting compressors 17 and 76. At such a time that the volume of liquid entering tank 3 from pipe 1 is not so large, and pumps 17 and 76 withdraw the vapor from tank 3 at a faster rate than the rate at which it is formed, the pressure within the tank decreases below the aforementioned maximum pressure and controller 79 actuates the switch and motor to stop com-

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pressor 76 and to close motor valves 81 and 82. In this manner pressure maintenance may be accomplished by the operation of compressor 17 alone. In this manner pressure maintenance in tank 3 is accomplished at a lesser cost than when both pumps are used. When liquid is present in tank 3, upon opening valves 35 and 41 in pipe 33, liquid at the pressure in tank 3 passes through this pipe and through an expansion valve 45 and through a spray nozzle 47 into a storage tank 42. This tank is a low pressure storage tank, that is, one designed to operate at a maximum pressure of, for example, 1 p.s.i.g. As the liquid in pipe 33 passes through expansion valve 45 and spray nozzle 47 into the zone of reduced pressure, further flash vaporizing and cooling takes place. On the final transfer of liquid propane into tank 42, the temperature of the liquid in tank 42 approaches its normal boiling temperature which is about -44.5° F. However, it is preferable to carry at least a little pressure above atmospheric in tank 42 so as not ever to be below atmospheric.

By operating tank 42 in such a manner that the liquid propane stored therein is maintained at a temperature at or very slightly above its normal boiling point, the tank is not constructed for pressure storage. In other words, tank 42 is a relatively inexpensive tank as compared to one constructed for storage of propane at atmospheric temperature. As liquid propane enters tank 42 through expansion valve 45 and spray nozzle 47, a portion of this propane vaporizes and the vapors so produced follow a compression and condensation cycle similar to that explained relative to tank 3. This cycle involves withdrawal of vapor through a pipe 49 with manually operable valves 51 and 87 being open for passage of vapor to the inlet of a compressor 53. When the propane in tank 42 reaches, for example, the aforementioned 1 p.s.i.g. pressure, a pressure controller 93 actuates a switch which starts a motor for driving compressor 53 for compression of the vapor from pipe 49. Compressor 53 discharges compressed propane through a pipe 54 into a pipe 55 for condensation in a condenser 57. Condensate therefrom passes through an open valve 59 and through an expansion valve 61 and a spray nozzle 63 into tank 42. Particularly when this system is being started up and all equipment is warm, or during the time propane for storage is entering the tank, the volume of vapors formed through the spray nozzles is very large. Thus, in tank 42, under this condition, this large volume of vapor is compressed in two compressors, that is, a compressor 77 in conjunction with compressor 53. Pressure controller 93 actuates in response to the aforementioned 1 p.s.i.g. and starts pumps 53 and 77 and opens motor valves 85 and 86 for pressure maintenance in tank 42. A valve 78 is opened manually to allow compressed propane from compressor 77 to enter manifold 20 at a pressure of about 260 p.s.i.g. along with compressed propane from compressor 53. The combined propane is condensed in condenser 57 and the condensate is flash vaporized in expansion valve 61 and spray nozzle 63. When the tank 42 and its accessories are cooled to the desired propane storage temperature, the volume of vapor formed through the sprays entering tank 42 is greatly reduced and the auxiliary compressor 77 will then not be needed. In this case the pressure controller 93 actuates to open the switch for stopping pump 77 and for closing valves 85 and 86. In this case, then, only the single compressor 53 is used.

One important point of my operation is the sizing of tank 3 for accommodating a shipment of liquefied propane at a rapid unloading rate and then transferring the propane from tank 3 through pipe 33 into tank 42 at a sufficiently slow rate that compressor 53, which is a relatively small compressor, can maintain a pressure at or below the aforementioned 1 p.s.i.g.

Similarly, when tank 3 is receiving a shipment of propane from pipe 1, excessively large volumes of vapor

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are formed and the two compressors 17 and 76 are required for pressure maintenance in this tank. Furthermore, under the condition that the liquid propane in pipe 1 is abnormally warm, or if propane flow through pipe 1 is greater than normal, pressure controller 79 starts compressor 76, and in extreme cases the controller opens valves 83 and 84 and compressor 77 is started manually. In this case manually operable valves 81a and 84a are opened and manually operable valves 83a and 78 are closed. However, if the propane is received from, for example, a pipe line which transports liquid propane at a temperature considerably below summer atmospheric temperature, it may be that a single compressor, such as compressor 17, is sufficiently large for pressure maintenance during filling of tank 3.

Under either of these aforementioned temperature conditions, after the tank cars and/or trucks are unloaded or the complete pipe line slug has been received in tank 3, pump 17 alone can maintain proper pressure in tank 3. After the shipment has been received in tank 3, transfer of the liquid propane from tank 3 through pipe 33 is started. However, it is usually preferable to start transfer of liquid into tank 42 as soon as sufficient liquid is present in tank 3 that a pump, as pump 39, is certain not to go on gas.

It is realized that such a storage tank as tank 42 must be properly insulated, as by insulation 43. As desired, tank 3 is or is not insulated. In other words, it is not critical or essential that tank 3 be insulated. Whether tank 3 is or is not insulated may be determined for each individual installation, taking into consideration cost of insulating and maintenance versus increased operating costs without insulation. However, according to ambient temperature, temperature of propane received, etc. it may be desirable to operate the receiving tank at temperatures and pressures substantially below those mentioned hereinbefore. In such a case insulation would probably be required. In some cases an operating pressure in the receiving tank of 100 p.s.i.g. (55° F.) might prove advantageous.

When storing butane, liquid ammonia, natural gasoline, or other high pressure liquids, corresponding temperatures and pressures will need be selected for the receiving tank, with or without insulation, as will be understood by those skilled in the art.

Under some conditions, the pressure of the propane in tank 3 is sufficient for transfer of the propane through pipe 33 into tank 42 without need of a transfer pump. However, under some conditions, it may be desired to provide a transfer pump. In this case a valve 41 is provided in pipe 33 and on either side of this valve a bypass pipe 37, containing a pump 39, is provided as illustrated. Suitable valves are provided in pipe 37 on opposite sides of pump 39.

Tank 3 is provided with a vent pipe 27 which contains a relief valve 29 for pressure relief in case of emergency. Similarly, tank 42 is provided with a vent pipe 67 which contains a relief valve 69. Vent pipes 27 and 67, as illustrated, connect with a pipe 31 which may lead to a flare for burning vented gas or it may lead to a useful disposal, such as a tank, for accumulation of the vented gas for subsequent use. In case compressors 17, 76, 77 and 53 are driven by gas engines, these engines may be powered in part by the vented gas. The remaining fuel for operation of these engines can, if desired, be obtained from the propane being stored.

In tank 3 reference numeral 10 identifies liquid propane while reference numeral 12 identifies the vaporous propane. Similarly, in tank 42 reference numeral 65 identifies the liquid and reference numeral 66 identifies the vapor. Reference numeral 73 identifies a manifold pipe which contains the aforementioned valves 81, 83 and 85. Motor valves 83 and 84 are provided in their respective manifolds in case three compressors are ever needed for withdrawal of vapor from tank 3. This mani-

folding makes for economy in the need for provision of only a minimum number of compressors.

A pipe 71 is provided for withdrawal of stored propane from tank 42 for passage to transportation or to such use as desired. Numerous manually operable valves, some of which have been identified by reference numerals and some of which have not, are in general provided as safety features or as valves for closing off certain portions of the equipment for maintenance purposes.

The receiving tank 3 can be spheres, spheroids, cigar shaped, or any other shape suitable for the purpose at hand.

The following example illustrates an advantage of the low pressure storage of this invention in comparison to conventional high pressure storage, when storing equal volumes of liquefied propane.

250,000 bbl. storage¹

Prior Art H. P. (250 p.s.i.g.) Storage	One 250,000 Bbl. Dome-Roof Tank and a 25,000 Bbl. Receiving Sphere
Standard 30,000 gal. tanks; 395 tanks required. Each tank=37 tons steel	One dome-roof tank, ² 1 p.s.i.g. working pressure, 925 tons steel. One 25,000 bbl. receiving tank, 423 tons steel. Total steel=1,348 tons.
Total steel (395 tanks)=14,615 tons.	

¹ Weight of piping, etc., not included.

² Dome-roof tank made of rings of progressively lighter plate up the tank.

It is thus seen that there is a marked saving in steel tonnage, i.e., 14,615—1,348=13,267 tons of steel saved in tanks alone. Much less piping also is required in my system than required for operation of 395 spaced pressure tanks. Valves and other equipment requirements are also less.

An additional safety feature is involved in the system of this invention. In case of the unlikely occurrence of an extended failure of compressors, etc., the flare is provided for vapor disposal. In case the low pressure storage tank is full of liquid, a shutdown of 24 hours or more would be required for the tank working pressure to be exceeded and the relief valves to open for venting. The time required for a part full tank to exceed working pressure varies with the level of the liquid in the tank and the thickness of the insulation. The least desirable condition is at such a time as the tank is nearly empty. In this case the amount of vapor lost to the flare is correspondingly less.

Liquid anhydrous ammonia boils at about -28° F. at atmospheric pressure. Such ammonia is then stored in a dome-roof, low working pressure tank as herein disclosed, at a temperature of about -25° F. (at 1 p.s.i.g. pressure). Liquid butane and natural gas gasoline of vapor above atmospheric pressure are stored as herein disclosed.

While I have illustrated a system for receiving 250,000 barrel volumes of liquefied propane with a one-tank storage capacity of 250,000 bbls.; it is realized that installations of other sizes, larger as well as smaller, can be employed using the storage system as herein disclosed.

The condensers 21 and 57 are, as desired, water cooled if sufficient cooling water is available, or they are air cooled. Preferably one or more blower fans provide air circulation in case the condensers are air cooled.

By providing four compressor units, as herein disclosed, operating costs are less than when a single unit is used for the receiving tank and a single unit for the storage tank. With four units operating cost is less by operating only as much capacity as required.

For the storage of 94,000 barrels of propane is the following:

10,000 bbl. min. slug size, 15,000 b.p.d. (438 g.p.m.) receiving rate

Use 3—3,300 bbl., 13' x 125' receiving tanks:

Design pressure, 175 p.s.i.g.

Working pressure, 160 p.s.i.g. at 80° F.

1—80,000 bbl., 120' x 40' dome-roof storage tank

Working pressure, 1 p.s.i.g. at -53° F.

3" insulation

Transfer rate, 50 g.p.m.

Days to fill storage, 47

Estimated investment cost, \$6.00 per barrel storage

Estimated operating cost, \$0.15 per barrel of throughput per year

Comparable conventional:

High pressure storage, \$19.00 per barrel

Operating costs, negligible

In these examples it is readily observed that the capital investment is markedly less when the process of my invention is used.

The vent pipes 27 and 67 are provided mainly for the unlikely occurrence of an extended failure of all compressor equipment. In such a case, the vented material is passed through these vent lines and their corresponding relief valves to a flare or other disposal as mentioned.

For most installations the low pressure tank, such as tank 42, should be insulated; and with a full tank of liquid propane, as mentioned hereinbefore, a shutdown of 24 hours or more would be required for the tank working pressure to be exceeded. That is, in case the liquid were

maintained in the tank at its normal boiling point of -44.5° F., 24 hours or more would be required for the temperature of the contents thereof to reach such a value that the vapor pressure would be 1 p.s.i.g. The number of hours required for the warming up of the contents of

the tank when only partly filled are less than required for a full tank. The most serious consideration from this point of view would be when a tank is nearly empty; then a relatively short time might be required for the vapor to be vented through the relief valves. However,

in this case, if compressor repair were not quickly made, only a relatively small amount of propane would be lost.

The system as herein disclosed probably has its greatest application in the storage of large volumes of liquid propane for natural gas utility peak-shaving. By the

term "peak-shaving" is meant in case a utility has an ample volume of, for example, natural gas available for normal use but does not have a sufficient volume of natural gas for peak seasonal use, then the large stored volume of propane satisfies the peak requirement. In such a case,

propane is withdrawn from the storage tank, is vaporized and is admixed with sufficient air to bring down its B.t.u. content to that required for mixing with the available natural gas to meet contract requirements.

Thus, according to this invention, compressors 17 and

76 are sized to handle vapors produced by transfer of LPG at conventional unloading rates into the receiving tank, and then the LPG is transferred from the receiving tank 3 to the storage tank 42 at a slow rate so that small capacity, and thus less costly, compressors 77 and 53 can be used for pressure maintenance in the storage tank during the transfer and for pressure maintenance during storage, i.e., without transfer of liquid from tank 3. This latter pressure maintenance merely offsets increase of pressure due to temperature radiation from the atmosphere through the insulation into the contents of the tank.

The switches herein disclosed in conjunction with the motors for driving the several compressors and the several motor valves may be pressure actuated apparatus. The controllers can be, if desired, pneumatic, electric output signal controllers. Furthermore, the controllers can be pneumatic output signal controllers, in which case the switches which open and close the power circuits to the motors driving the compressors are pneumatically operated switches. It is within the scope of this invention to use electrically actuated valves and switches. In either

case the proper pressure controllers 79 and 93 are selected for pressure or for electrical actuation of equipment.

While certain embodiments of the invention have been described for illustrative purposes, the invention obviously is not limited thereto.

While two compressors are disclosed as being used in conjunction with the unloading tank and two compressors with the storage tank, it will be realized that more than two compressors, such as three or four compressors, or any desired number, can be used with the unloading tank, and also with the storage tank. Obviously, when more than two compressors are used with either the unloading tank or with the storage tank, piping and controls will be supplied accordingly. While it is disclosed hereinabove that compressors 17, 76 and 77 can be used for compressing vapors from the unloading tank 3, with compressor 53, only, being employed on vapors from the storage tank 42, it is realized that compressors 53, 77 and 76 under some conditions can be used on vapors from the storage tank 42 by opening valves 83a, 81a, 78 and 84a, with, of course, valves 81 and 82 being closed. In this latter case valves 83 and 84 obviously are disconnected from controller 79, and they can be opened manually, or they can be attached to controller 93 for operation therewith.

I claim:

1. A method for the liquid phase storage of an easily liquefiable, normally gaseous fluid comprising reducing the pressure of said material from a superatmospheric pressure to a lower superatmospheric pressure and at the lower pressure passing the material into a receiving zone in a first spray flash vaporizing operation wherein liquid and vapor result, withdrawing flash vapor from said receiving zone, compressing the withdrawn vapor, condensing the compressed vapor thereby producing a first condensate, reducing the pressure of said first condensate to said lower superatmospheric pressure and at the reduced pressure passing the condensate into said receiving zone in a spray flash vaporizing operation wherein liquid and vapor result, withdrawing liquid from said receiving zone, reducing the pressure of this withdrawn liquid from said lower superatmospheric pressure to a still lower superatmospheric pressure and at this latter pressure passing the liquid into a storage zone in a second spray flash vaporizing operation wherein liquid and vapor result, withdrawing flash vapor from said storage zone, compressing the latter withdrawn vapor, condensing the latter compressed vapor thereby producing a second condensate, reducing the pressure of said second condensate to said still lower superatmospheric pressure and at the still lower superatmospheric pressure passing the second condensate into said storage zone in a spray flash vaporizing operation wherein liquid and vapor result, and storing the liquid in said storage zone.

2. A method for storing liquefied petroleum gas comprising reducing the pressure of said liquefied gas from a superatmospheric pressure to a lower superatmospheric pressure and at the lower pressure passing the liquefied gas into a receiving zone in a first spray flash vaporizing operation wherein liquid and vapor result, withdrawing flash vapor from the receiving zone, compressing the withdrawn vapor, condensing the compressed vapor thereby producing a first condensate, reducing the pres-

sure of said condensate to said lower superatmospheric pressure and at the reduced pressure passing the condensate into said receiving zone in a spray flash vaporizing operation wherein liquid and vapor result, withdrawing liquid from said receiving zone, reducing the pressure of this withdrawn liquid from said lower superatmospheric pressure to a still lower superatmospheric pressure and at this latter pressure passing the liquid into a storage zone in a second spray flash vaporizing operation wherein liquid and vapor result, withdrawing flash vapor from said storage zone, compressing the latter withdrawn vapor, condensing the latter compressed vapor thereby producing a second condensate, reducing the pressure of said second condensate to said second superatmospheric pressure and at this latter pressure passing the second condensate into said storage zone in a spray flash vaporizing operation wherein liquid and vapor result, and storing the liquid in said storage zone.

3. The method of claim 2 wherein said liquefied petroleum gas is propane.

4. The method of claim 2 wherein said liquefied petroleum gas is butane.

5. The method of claim 1 wherein said material is a natural gasoline.

6. The method of claim 1 wherein said material is propane.

7. The method of claim 1 wherein said material is butane.

8. The method of claim 1 wherein said material is anhydrous ammonia.

9. A method for storing liquefied petroleum gas comprising receiving said liquefied gas at a superatmospheric pressure, passing the liquefied gas into a receiving zone wherein liquid and vapor result, withdrawing flash vapor from the receiving zone, compressing the withdrawn vapor, condensing the compressed vapor thereby producing a first condensate, reducing the pressure of said condensate and passing the condensate of reduced pressure into said receiving zone wherein liquid and vapor result, withdrawing liquid from said receiving zone, reducing the pressure of this withdrawn liquid to a second superatmospheric pressure, said second superatmospheric pressure being only slightly above atmospheric pressure, and at this latter pressure passing the liquid into a storage zone in a spray flash vaporizing operation wherein liquid and vapor result, withdrawing flash vapor from said storage zone, compressing the latter withdrawn vapor, condensing the latter compressed vapor thereby producing a second condensate, reducing the pressure of said second condensate to said second superatmospheric pressure and at this latter pressure passing the second condensate into said storage zone in a spray flash vaporizing operation wherein liquid and vapor result, and storing the liquid in said storage zone.

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