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TRANSFER OF VOLATILE LIQUIDS

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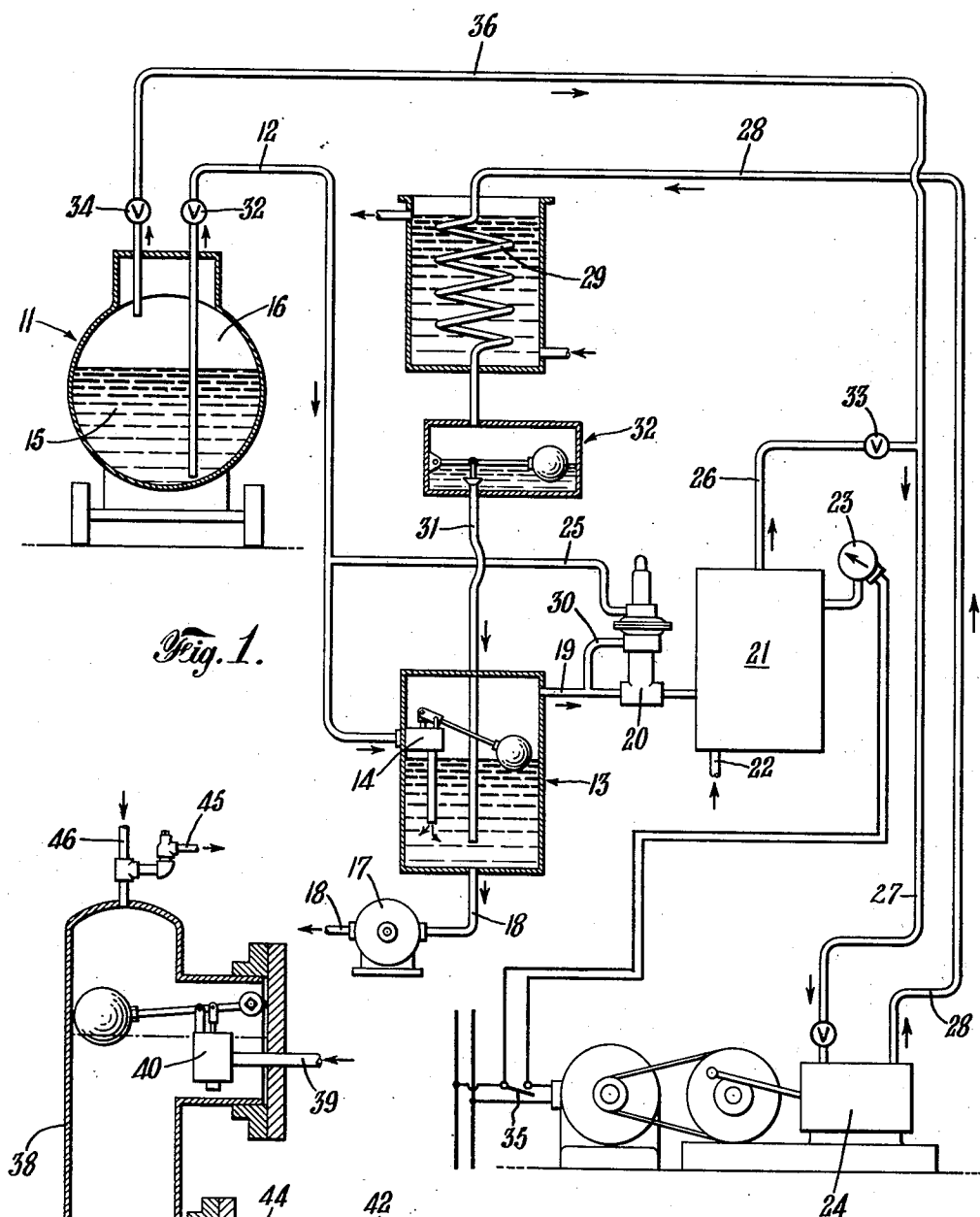


Fig. 1.

Fig. 2.

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TRANSFER OF VOLATILE LIQUIDS

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This invention relates to the transfer of volatile liquids, and more particularly to a method of and apparatus for transferring a highly volatile liquid from a first container to a second container. The invention is especially concerned with the transfer of liquefied gases, such as liquefied propane, butane, and similar gases, from a tank car or similar container to the cylinders on a charging rack of a liquefied-gas charging plant.

Liquefied gases generally have been unloaded from tank cars by pumping the liquid directly from the tank car to the charging rack with either reciprocating or rotary pumps. Railroad tank cars used for transporting liquefied gases are not permitted to be fitted with bottom discharge valves, thus requiring that the liquid be elevated to a point considerably above the normal liquid level within the tank car during discharge to the pipe line, which at times may be at a higher temperature than the liquid within the car. Consequently, some of the discharged liquid flashes to vapor, and the pump may become vapor bound and will not operate efficiently. Another drawback of such a transfer system is the necessity for pumping blow-back gas from cylinders, charging leads, and other vapor collecting parts of the system back into the tank car, with the result that the gradual increase in the quantity of vapor at a high pressure within the tank car increases the time and cost of pumping off and re-liquefying the residual vapor after the liquid has been completely removed from the tank car.

Although attempts have been made to utilize the vapor pressure within the tank car to force the liquid first into an intermediate liquid receiver, these attempts have not been wholly successful because the vapor pressure in the liquid receiver rapidly builds up to equal the vapor pressure in the tank car, with the result that no more liquid may then be transferred. Transfer of liquid by the vapor pressure in the tank car is additionally complicated by the gradual reduction of the vapor pressure in the tank car as liquid is removed. In other systems, moreover, both of the direct-pumping type and of the vapor-pressure type, no completely satisfactory and efficient provision is made for reliquefying and transferring to the charging rack the vapors inevitably evolved during the transfer of the liquid.

The principal object of the present invention is to provide a novel, efficient, and economical method of and apparatus for transferring a highly volatile liquid from a first container to a second container, which will overcome the above-mentioned difficulties. Another important object is

the provision of such a method and apparatus for transferring a highly volatile liquid from a first container to a second container, at least partially by the vapor pressure of the liquid in the first container. Another object is the provision of a system for the transfer of a highly volatile liquid, partially by the vapor pressure in the first container and partially by pumping, wherein the pump is protected against vapor binding. Still another object of the invention is the provision of such a system wherein blow-back vapor may be salvaged without being discharged back into the first container. Still another object is the provision for a vapor reliquefaction cycle which will be automatically controlled in accordance with conditions in the liquid transfer system.

The above and other objects, and the novel features of the invention, will become apparent from the following description, having reference to the annexed drawing, wherein:

Fig. 1 is a diagrammatical representation of a preferred form of volatile liquid transfer system embodying the principles of the invention; and

Fig. 2 is a vertical sectional view of a modified form of a part of the system of Fig. 1.

In accordance with the invention, there is provided a method of transferring or emptying a batch of a highly volatile liquid from a closed first container to a second container, comprising the steps of forcing liquid from the first container into an intermediate liquid receiver solely by the pressure of the vapor evaporated from the liquid in the first container, maintaining the vapor pressure in the liquid receiver at a value lower by a substantially constant amount than the vapor pressure in the first container by controlling the release of vapor from the liquid receiver in accordance with the vapor pressure in the first container, and pumping the liquid from the liquid receiver into the second container.

The vapor released from the liquid receiver, as well as any vapor blown back from the cylinders, the charging leads, or any vapor traps in the system, is reliquefied by compressing and condensing it, and then is returned in liquid form to the liquid receiver. After the liquid has all been discharged from the first container, the residual vapor is sucked out and reliquefied, and the reliquefied residual vapor then is delivered in liquid form to the liquid receiver for pumping to the second container.

Also in accordance with the invention, there is provided apparatus for transferring a highly

volatile liquid from a first container to a second container, comprising a liquid receiver, a conduit for conducting liquid from the first container to the liquid receiver, a conduit for conducting liquid from the liquid receiver to the second container, and a pump for pumping liquid through the last-named conduit. The apparatus also includes an outlet for releasing vapor from the liquid receiver, and a differential pressure-actuated valve or regulator controlling the outlet, the valve including pressure-responsive valve-actuating mechanism in communication with the liquid receiver and also adapted and arranged to communicate with the first container, for maintaining the vapor pressure in the liquid receiver at a lower value than in the first container. A vapor receiver is connected to the outlet of the liquid receiver and to any other sources of vapor, and means is connected to the vapor receiver for reliquefying the accumulated vapor, the liquefied vapor being returned thereafter to the liquid receiver. The operation of the reliquefying means is controlled automatically by pressure-responsive means associated with the vapor receiver. Another conduit, which is provided for exhausting the residual vapor from the first container after all the liquid has been removed, is connected directly to the reliquefying means, the liquefied vapors thereafter being conducted to the liquid receiver as described above.

The invention will be described more particularly hereinafter, by way of example only, as applied to the unloading of a liquefied gas, such as propane or butane, from a first container, such as a tank car, into a smaller second container, such as a cylinder. The invention, however, may be applied to the transfer of other highly volatile liquids in a similar manner.

As shown in the drawing, a tank car 11 partially full of liquefied gas, such as propane, may be drawn up at the siding of a cylinder charging plant. A conduit 12 extending down through the top of the tank car 11 has its intake end within and near the bottom of the tank car below the level of the liquid 15. The conduit 12 leads to an intermediate liquid receiver 13 for emptying the liquid into the liquid receiver through a float-controlled valve 14, which prevents the liquid level in the receiver 13 from rising too high. The pressure of the vapor in the space 18 above the liquid 15 in the tank car 11 forces the liquid through the conduit 12 into the liquid receiver 13, from which the rotary pump 17 pumps the liquid from the bottom of the liquid receiver 13 through a conduit 18 to a charging rack (not shown) where it may be charged into cylinders. By this arrangement, a positive supply of liquid with a gravity head can be maintained at the inlet of the liquid pump 17, and the pump may be positioned close to the liquid receiver 13, thereby preventing vapor binding. Although the liquid receiver 13 is shown at a lower position than the tank car 11, liquid may be transferred satisfactorily when the liquid receiver is at the same or a higher position than the tank car.

The evaporation of liquid in the liquid receiver 13 autogenously cools the body of liquid in the receiver to some extent, thus reducing the tendency to flash into vapor during the passage of the liquid through the conduit 18 and the pump 17.

Continuous transfer of liquid from the tank car 11 to the receiver 13 requires that the vapor pressure in the receiver 13, above the level of

the liquid therein, must be maintained at a value lower than in the tank car. This is accomplished by bleeding off vapor from the liquid receiver 13 through an outlet conduit 19, having a differential pressure regulator 20 therein, and into a vapor blow-down receiver 21, where it mingles with any gas blown back through the conduit 22 from cylinders or charging leads and other vapor collecting parts of the system. The differential pressure regulator 20, which may be of any well-known type, is operatively connected both to the liquid conduit 12 and the vapor outlet conduit 19 through the pressure connections 25 and 30, respectively. In this way, the differential pressure regulator 20 is adapted to be in communication both with the interior of the closed tank car 11, and with the interior of the liquid receiver 13, so as to maintain a constant pressure differential between the tank car and the liquid receiver.

One form of differential pressure regulator which may be used comprises a valve connected to a pressure-responsive diaphragm, upon the opposite sides of which act the pressures in the tank car 11 and the liquid receiver 13 through the connections 25 and 30, respectively. The two opposed pressures thus may act against the diaphragm of the regulator 20, and the pressure differential is maintained by mechanically biasing the diaphragm toward the open position of the valve, as by an adjustable spring. The pressure differential, therefore, will be maintained at the value of the force exerted by the biasing spring throughout the liquid unloading process, even though the vapor pressure in the tank car 11 decreases gradually as the liquid is withdrawn. With such an arrangement, a gradually decreasing vapor pressure is maintained in the receiver 13 constantly lower than the decreasing pressure in the tank car 11. Rate-of-flow controller No. 142 of the McAlear Manufacturing Company is an example of such a regulator. It is evident, of course, that other types of differential pressure regulators may be used.

When the gas in the vapor blow-down receiver 21 builds up to a predetermined pressure, a pressure-responsive mercury switch 23 is actuated to close the electrical circuit through an electrically-operated compressor 24. The compressor 24 then sucks the gas from the vapor receiver 21 through the conduits 26 and 27, compresses it, and discharges the compressed gas through a conduit 28 to a condenser 29, wherein it is reliquefied. The liquid from the condenser 29 then passes to a liquid-return regulating trap 32 for permitting the passage of liquid into the receiver 13 while substantially preventing the passage of vapor. The trap 32 has a float-operated valve through which, when a predetermined liquid level is reached, the liquid passes to a conduit 31 having its lower end in the receiver 13 below the normal liquid level. As the liquid from the conduit 31 enters the receiver 13, cooling due to vaporization takes place within the main body of liquid. The condenser 29 may be water cooled, atmospherically cooled, or may be cooled in any other suitable manner. When the pressure in the vapor blow-down receiver 21 falls to a predetermined low value, the pressure-responsive mercury switch 23 is actuated to open contact, and the compressor 24 ceases operation while the pressure in the vapor receiver again builds up.

After the liquid has all been discharged from the tank car 11, there remains a large quantity of vapor in the tank car which must be salvaged.

First the valves 32 and 33 in the conduit 12 and the conduit 28, respectively, are closed. Then the valve 34, in a conduit 36 which has its intake end within the first container or tank car 11, is opened and the compressor 24 is started by closing the jump switch 35. The vapor is then sucked from the tank car 11 through the conduits 36 and 27, compressed in the compressor 24, discharged through the conduit 28 to the condenser 29 where it is liquefied, and is then delivered to the liquid receiver 13 through the liquid-regulating trap 32 and the conduit 31. In this way, a highly efficient recovery of the liquid and gas from the tank car 11 is effectuated.

After the tank car has been emptied, the conduits 12 and 36 either may be withdrawn completely from the tank car, or suitable detachable couplings may be provided in the conduits by which they may be disconnected. In the latter case, of course, a portion of each conduit is permanently associated with the unloading apparatus and may be coupled at will to the corresponding portion permanently associated with the tank car.

Although in the drawing the liquid pump 17 has been shown outside of the container or liquid receiver 13, it sometimes may be desirable to provide a liquid pump actually within the container and immersed in the liquid therein, to provide continuous cooling of the pump and to insure against vapor binding. An example of such an arrangement is shown somewhat schematically in Fig. 2, wherein a liquid receiver 38 receives liquid from the tank car through a conduit 39 controlled by a float-operated valve 40. A rotary pump 41 near the bottom of the receiver 38 is operated by a motor 42 outside the receiver, and is constructed to suck liquid in through an intake 43 and discharge it to the discharge conduit 44. Vapor may pass to a vapor receiver through a conduit 45 at the top of the receiver 38, and liquid may be returned from a condenser through the conduit 46.

From the foregoing description, it is evident that there have been provided a novel and advantageous method of and apparatus for transferring highly volatile liquid from a first container to a second container with high efficiency and a minimum of expense.

What is claimed is:

1. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; an outlet for releasing vapor from said liquid receiver; and means controlling the vapor pressure in said liquid receiver, said means including a differential pressure-responsive device in communication with said liquid receiver and adapted to communicate with such first container for regulating the release of vapor through said outlet to maintain the vapor pressure in said liquid receiver at a lower value than in such first container.

2. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; and a differential pres-

sure-actuated valve controlling said outlet, said valve including pressure, responsive valve actuating mechanism in communication with said liquid receiver and adapted to communicate with such first container for maintaining the vapor pressure in said liquid receiver at a lower value than in such first container.

3. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; means associated with said liquid receiver for controlling the level of the liquid therein; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; and a differential pressure actuated valve controlling said outlet, said valve including pressure-responsive valve actuating mechanism in communication with said liquid receiver and adapted to communicate with such first container for maintaining the vapor pressure in said liquid receiver at a lower value than in such first container.

4. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; a differential pressure actuated valve controlling said outlet, said valve including pressure-responsive valve actuating mechanism in communication with said liquid receiver and adapted to communicate with such first container for maintaining the vapor pressure in said liquid receiver at a lower value than in such first container; and means connected to said outlet for relieving the vapor released from said liquid receiver.

5. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; a differential pressure actuated valve controlling said outlet, said valve including pressure-responsive valve actuating mechanism in communication with said liquid receiver and adapted to communicate with such first container for maintaining the vapor pressure in said liquid receiver at a lower value than in such first container; means connected to said outlet for relieving the vapor released from said liquid receiver; and a conduit connecting said last-named means to said liquid receiver for returning liquid thereto.

6. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; a differential pressure actuated valve controlling said outlet, said valve including pressure-responsive valve actuating mechanism in communication with said liquid receiver and adapted to communicate with such

first container for maintaining the vapor pressure in said liquid receiver at a lower value than in such first container; means connected to said outlet for reliquefying the vapor released from said liquid receiver; a conduit connecting said last-named means to said liquid receiver for returning liquid thereto; and liquid-return regulating means controlling said last-named conduit for permitting the passage of liquid into said liquid receiver while substantially preventing the passage of vapor.

7. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; a differential pressure actuated valve controlling said outlet, said valve including pressure-responsive valve actuating mechanism in communication with said liquid receiver and adapted to communicate with such first container for maintaining the vapor pressure in said liquid receiver at a lower value than in such first container; a vapor receiver connected to said outlet; means connected to said vapor receiver for reliquefying the vapor released from said liquid receiver; and pressure-responsive means associated with said vapor receiver for controlling the operation of said reliquefying means.

8. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; a differential pressure actuated valve controlling said outlet, said valve including pressure-responsive valve-actuating mechanism in communication with said liquid receiver and adapted to communicate with such first container for maintaining the vapor pressure in said liquid receiver at a lower value than in such first container; a vapor receiver connected to said outlet; means connected to said vapor receiver for reliquefying the vapor released from said liquid receiver; pressure-responsive means associated with said vapor receiver for controlling the operation of said reliquefying means; a conduit connecting said reliquefying means to said liquid receiver for returning liquid thereto; and liquid-return regulating means controlling said last-named conduit for permitting the passage of liquid into said liquid receiver while substantially preventing the passage of vapor.

9. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; a differential pressure actuated valve controlling said outlet, said valve including pressure-responsive valve actuating mechanism in communication with said liquid receiver and adapted to communicate with such first container for maintaining the vapor pressure in said liquid receiver at a lower value

than in such first container; means connected to said outlet for reliquefying the vapor released from said liquid receiver; a conduit for connecting said reliquefying means to such first container for exhausting vapor therefrom and reliquefying the same; and a valve controlling said last-named conduit.

10. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump for pumping liquid through said last-named conduit; an outlet for releasing vapor from said liquid receiver; a differential pressure actuated valve controlling said outlet, said valve including pressure-responsive valve actuating mechanism in communication with said liquid receiver and adapted to communicate with such first container for maintaining the vapor pressure in said liquid receiver at a lower value than in such first container; means connected to said outlet for reliquefying the vapor released from said liquid receiver; a conduit for connecting said reliquefying means to such first container for exhausting vapor therefrom and reliquefying the same; a valve controlling said last-named conduit; and a conduit connecting said reliquefying means to said liquid receiver for conducting liquid thereto.

11. Apparatus for transferring a highly volatile liquid from a first container to a second container, comprising a liquid receiver; a conduit for conducting liquid from such first container to said liquid receiver; a conduit for conducting liquid from said liquid receiver to such second container; a pump within said liquid receiver for pumping liquid through said last-named conduit, said pump being arranged to be immersed in such liquid; an outlet for releasing vapor from said liquid receiver; and differential pressure actuated means controlling the vapor pressure in said liquid receiver, said means including pressure responsive mechanism in communication with said liquid receiver and adapted to communicate with such first container for regulating the release of vapor through said outlet to maintain the vapor pressure in said liquid receiver at a lower value than in such first container.

12. Method of emptying a batch of highly volatile liquid from a closed first container to a second container, comprising the steps of forcing liquid from the first container into an intermediate liquid receiver solely by the pressure of the vapor evaporated from the liquid in the first container, such pressure gradually decreasing; maintaining a gradually decreasing vapor pressure in the liquid receiver constantly lower than in the first container by the controlled release of vapor from the liquid receiver; and discharging liquid from the liquid receiver into the second container.

13. Method of transferring a highly volatile liquid from a closed first container to a second container, comprising the steps of forcing liquid from the first container into an intermediate liquid receiver by the pressure of the vapor in the first container; maintaining the vapor pressure in the liquid receiver at a value lower than in the first container by controlling the release of vapor from the liquid receiver in accordance with the vapor pressure in the first container; pumping liquid from the liquid receiver into the second container; and reliquefying and returning to the liquid receiver the vapor released therefrom.

14. Method of transferring a highly volatile liquid from a closed first container to a second container, comprising the steps of forcing liquid from the first container into an intermediate liquid receiver by the pressure of the vapor in the first container; maintaining the vapor pressure in the liquid receiver at a value lower than in the first container by controlling the release of vapor from the liquid receiver into a vapor receiver in accordance with the vapor pressure in the first container; pumping liquid from the liquid receiver into the second container; reliquefying and returning to the liquid receiver the vapor in the vapor receiver; and controlling the reliquefying of the vapor in accordance with the vapor pressure in the vapor receiver.

15. Method of transferring a highly volatile

liquid from a closed first container to a second container, comprising the steps of forcing liquid from the first container into an intermediate liquid receiver by the pressure of the vapor in the first container; maintaining the vapor pressure in the liquid receiver at a value lower than in the first container by controlling the release of vapor from the liquid receiver in accordance with the vapor pressure in the first container; pumping liquid from the liquid receiver into the second container; reliquefying and returning to the liquid receiver the vapor released therefrom; after completion of liquid discharge from the first container, withdrawing and liquefying the residual vapor therefrom; and delivering the liquefied residual vapor to the liquid receiver.

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