TRANSFER OF CRYOGENIC LIQUIDS

This invention relates to a system which permits the storage and transfer of cryogenic fluids without losses due to handling and venting and which is characterized by reversed-cascade filling procedure. This system for transfer of a cryogenic liquid from a supply container to a receiver is characterized in that only a single fluid connection is made between the container and receiver without venting the receiver so that the receiver-filling operation may be achieved without gas or liquid loss by evaporation or overflow as by the use of a submerged and continuously primed pump.
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BACKGROUND OF THE INVENTION

Aircraft are now being equipped with inerting systems for fire and explosion prevention and for fire extinguishment which comprise dewars containing an inert cryogenic liquid such as N₂ for release into fuel tank or other spaces which may contain combustible or explosive liquids or vapors. Accordingly, there is presented the problem of periodic refilling of the aircraft dewars.

In known inerting equipment, cryogenic liquid is transferred from a supply container to a vented receiver thus resulting in substantial loss of liquid by evaporation and overflow. Various practices sometimes provide complex transfer equipment such as an auxiliary tank and pump between the supply containers and the receiver, a vapor bleed-off mechanism, and several fluid interconnecting lines to effect transfer.

SUMMARY OF THE INVENTION

Contrary to the foregoing, the transfer of cryogenic liquids herein from a ground supply dewar to an aircraft dewar involves only the connection of a flexible supply hose from the supply dewar to the disconnect coupling of the aircraft dewar, the latter as aforesaid, being the inert gas supply source for the aircraft inerting system.

One object of the present invention is to provide for cryogenic liquid transfer from a supply dewar to an aircraft dewar without venting of the latter and without overflow, whereby there is no evaporation loss of the liquid nor is there any possibility, in the case of liquid N₂, of erosive or other damage to concrete pavement and the like due to overflow.

Another object of this invention is to provide for a transfer of cryogenic liquids, such as N₂, which entails the use of but a single fluid line connection between the supply dewar and the aircraft dewar, the supply dewar cart or trailer having the necessary control equipment to obtain desired automatic filling of the aircraft dewar with cryogenic liquid at predetermined saturated vapor pressure and to predetermined level.

Another object of this invention is to provide for the transfer of cryogenic liquids which utilizes a pump means between the supply dewar and the aircraft dewar, and an intervening heat exchanger which assures filling of the aircraft dewar to a predetermined saturation level for most effective use in inerting the fuel tank and other spaces of an aircraft.

Other objects and advantages of the present invention will become apparent as the following description proceeds.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic drawing of a preferred embodiment of the invention wherein an aircraft dewar is supplied with cryogenic liquid from a portable supply dewar; and

FIG. 2 is a similar schematic drawing illustrating a modification wherein a heat exchanger in an emergency application is substituted for the pump means of FIG. 1 to discharge liquid from the supply dewar.

DISCUSSION OF THE INVENTION

Referring to FIG. 1, the ground supply unit 1 may constitute a cart or trailer which carries thereon a supply container 2, i.e., a vacuum-insulated, double-wall dewar, a centrifugal pump 3, a heat exchanger 4, valves 5, 6, and 7, a thermal sensor unit 8, and an operating unit 9.

The outlet of the supply dewar 2 is connected to the inlet of pump 3 by conduit 10 and the outlet of said pump 3 is connected to the disconnect coupling 11 by conduit 12 via the check valve 13, the control valve 5, the mixing valve 7, and the thermal sensor unit 8. A bypass conduit 14 has therein the heat exchanger 4 and the control valve 6 whereby a portion of the pump discharge may be heated as hereinafter described in detail.

The airplane 15 has therein an aircraft dewar 16 having an outlet conduit 17 leading to the inerting system via a shutoff valve 18. A filling conduit 19 leads from the disconnect coupling 11 to a spray device 21 disposed within said dewar 16 and above the filling level switch 23 which has its electrical contact 24 plugged into a socket element 25 in the lead 26 of the operating unit 9. A relief valve 27 is set to relieve vapor pressure in aircraft dewar 16 exceeding a predetermined maximum. When the dewar 16 is to be filled a flexible hose 28, preferably of vacuum evacuated, double-wall construction, is connected to the disconnect coupling 11.

In normal operation the saturated vapor pressure in the aircraft dewar 16 operates at a predetermined level that is greater than the saturated vapor pressure in the supply dewar 2. In the event that the pressure in dewar 16 is higher than the predetermined level, this pressure must be reduced.

To fill the dewar 16, the flexible hose 28 is connected to the disconnect coupling 11 and the socket 25 is plugged into lead 24 of the level switch 23. The operating unit 9 is then actuated to the "fill" position to open control valve 5. If the pressure in the aircraft dewar 16 is higher than predetermined, control valve 29 is opened to allow the pressure to decrease. The operating unit 9 is provided with a pressure-actuated interlock 30 arranged to turn on the pump drive motor 31 when the pressure in the aircraft dewar 16 has reached the predetermined level, and when the pump 3 is driven it draws liquid from the supply dewar 2 and pumps it through the conduit 12, valves 5 and 7, thermal sensor unit 8, hose 28, and conduit 19 into the vapor space of the aircraft dewar 16. Initially, the conduit 12 and hose 28 between the supply dewar 2 and aircraft dewar 16 is somewhat warm and heat will be transferred to the liquid as it flows to the dewar 16. This causes the gas pressure in the space of the dewar 16 to start to increase at the time that the pump 3 is started. However, this flow action is followed by some liquid carried along with the gas and the two phase mixture enters the dewar 16 through the spray device 21 whereby the amount of gas initially introduced is rechilled by the cold walls of the dewar 16 and by the vapor therein.

The pressure increase at startup peaks out just below the relief pressure of the relief valve 27 at this point liquid droplets start to enter the dewar 16 to cause a pressure collapse of the vapor therein. The pressure decay continues and when it drops below the predetermined saturated level as pressure or temperature sensed by the thermal sensor unit 8, the latter is activated to position the control valves 5 and 6 so that some of the liquid delivered by the pump 3 is conducted through the heater exchanger 4, whereby the heated liquid passes through the control valve 6 to mix in the mixing valve 7 with the liquid passing through the other control valve 5. The filling rate is preferably such that the thermal heat gain in the liquid between the thermal sensor unit 8 and the dewar 16 is insignificant so that the sensor unit 8 constitutes a fairly accurate measurement of temperature of the liquid flowing into the dewar 16. Generally, the allowable range of saturation control of the liquid is wide enough so that additional controls are not required. However, should the range be relatively small such as, say, 5 p.s.i., the thermal sensor unit 8 may be installed in or adjacent the dewar 16 in which case, the signal to the control valves 5 and 6 constitutes a signal indicating the precise temperature in or adjacent the dewar 16.

When the level of the cryogenic liquid in the dewar reaches the level switch 23, the indicating light 32 is turned on, and the pump drive motor 31 is deenergized and the control valves 5 and 6 are closed, whereby no further liquid is supplied from the supply dewar 2 to the aircraft dewar 16. At that time, the operating unit 9 may be shifted from "fill" to "stop" and the electric plug-in and fluid disconnect couplings 25 and 11 may be separated, and as evident, the disconnect coupling 11 may be provided with self-sealing valve units to prevent escape of vapor or liquid.

As shown in FIG. 2, if the ground supply unit 1 is not provided with a pump 3, discharging pump on the line in the supply dewar 33 may be generated by opening solenoid valve 34 for flow of liquid through a pressure build up coil 35 into the top of the supply dewar 33 so that the increased vapor
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pressure on the liquid constitutes a pump means for forcing the liquid through the common discharge conduit 12. This method, of course, decreases the thermal efficiencies of the system when used in continuous operation.

As evident from the foregoing, there is but a single fluid line connection 28 between the ground supply cart 1 and the aircraft dewar 16 through which the latter is filled to a predetermined level as controlled by the level switch 23 and to predetermined saturation level as determined by the thermal sensor unit 8 whereby the saturated vapor pressure in the dewar 16 will be at a predetermined magnitude.

When the aircraft dewar 16 has thus been filled, the supply hose 28 and electrical lead 26 may be disconnected from the aircraft 15 and the aircraft is ready for takeoff. The pressurization of the fuel by N_2 and the supply of N_2 for other uses on the aircraft is not restricted or impaired by the servicing.

We, therefore, particularly point out and distinctly claim as our invention:

1. A system for transfer of a cryogenic liquid from a closed supply container into a closed receiver adapted to contain residual liquid therein at a temperature greater than that of the liquid in said container; conduit means between said container and receiver through which liquid from said supply container is introduced into said receiver; means establishing a pressure differential between said container and the vapor space of said receiver to effect flow of liquid from said container into said receiver without venting of the latter; and temperature control means in said conduit means operative to maintain the vapor pressure at a predetermined level in said receiver which is greater than the saturated vapor pressure of the liquid in said container.

2. The system of claim 1 wherein said means establishing a pressure differential comprises a pump in said conduit means to establish a pressure differential for flow of liquid from said container into said receiver.

3. The system of claim 1 wherein said means establishing a pressure differential comprises a pump and drive means therefor; wherein valve means between said supply container and the portion of said conduit means downstream of said pump opens communication between said supply container and receiver in response to vapor pressure in the latter exceeding a predetermined value thus to decrease such vapor pressure; and wherein a pressure actuated interlock energizes said drive means in response to decrease of such vapor pressure to predetermined value thus to drive said pump for flow of liquid from said container into said receiver.

4. The system of claim 1 wherein said temperature control means comprises a heat exchanger and a sensor unit therefor through which liquid may be conducted to increase the saturated vapor pressure in said receiver to predetermined level.

5. The system of claim 1 wherein said temperature control means comprises a thermal sensor unit; a heat exchanger; and valve means operative to divert a portion of the liquid flowing in said conduit means through said heat exchanger for heating thereof and for mixing of the heated liquid with the unheated portion of the liquid; said sensor unit actuating said valve means upon decrease of vapor pressure in said receiver below a predetermined value.

6. The system of claim 1 wherein said means establishing a pressure differential comprises a heat exchanger through which a portion of the liquid from said supply container is conducted and supplied therefrom to the vapor space of said supply container thus to effect flow of liquid from said supply container into said receiver.

7. The system of claim 1 wherein said conduit means terminates in spray means operative to break up liquid as it enters the vapor space of said receiver.

8. The system of claim 1 wherein relief valve means exposed to vapor pressure in said receiver relieves vapor pressure in said receiver when it exceeds a maximum pressure greater than said predetermined level.

9. The system of claim 2 wherein check valve means in said conduit means downstream of said pump prevents reverse flow of liquid in said conduit means from said receiver into said supply container.

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