

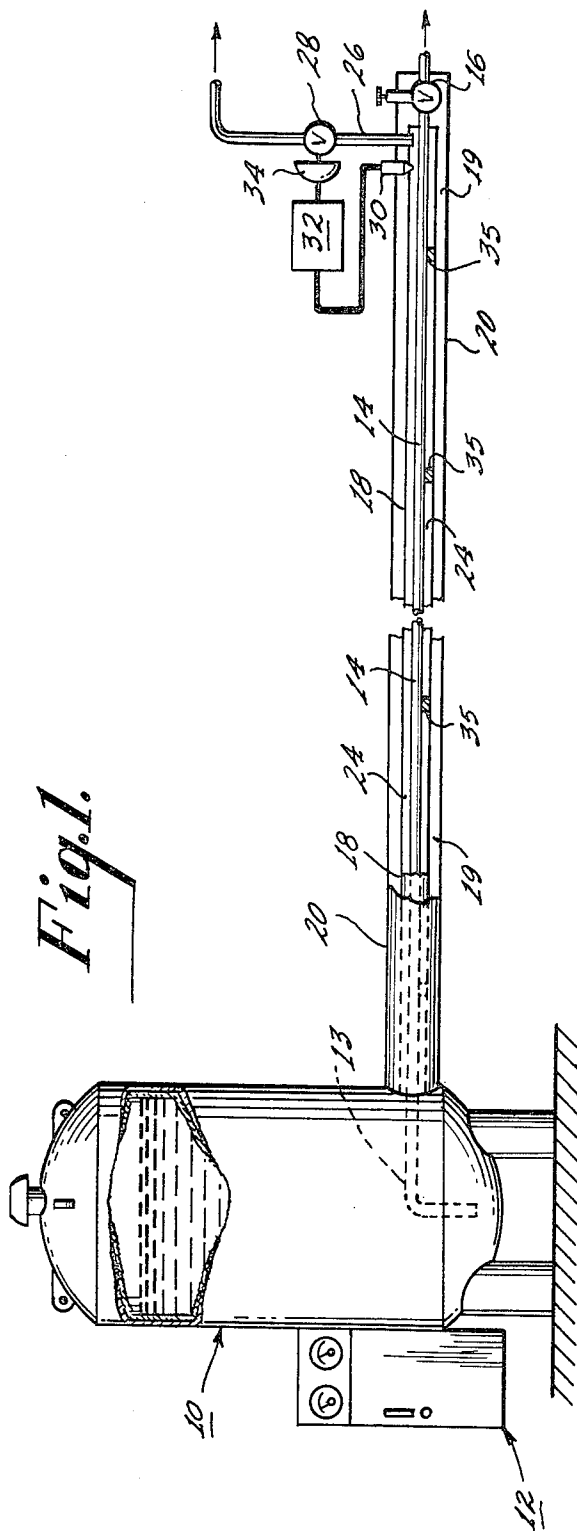
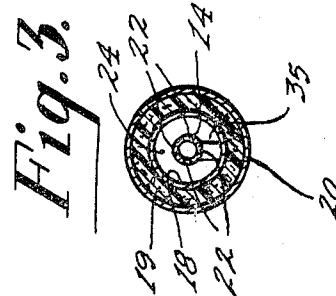
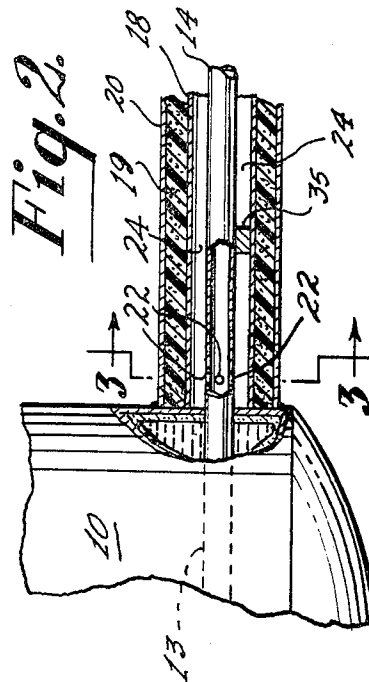
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CRYOGENIC FLUID CONVEYING SYSTEM

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ABSTRACT OF THE DISCLOSURE

A cryogenic liquid transfer line is disclosed for conveying cryogenic fluids over substantial distances in pure liquid phase. The transfer line includes an inner line surrounded by an outer line with ports providing open communication between the two lines. The liquid is admitted to both lines such that heat leak is adsorbed by vaporization of the liquid in the outer line while that in the inner line remains in the pure liquid phase. A temperature responsive control system is provided for venting the vaporized liquid from the outer line.

The present invention relates to an improved cryogenic liquid transfer system and, more particularly, to a cryogenic transfer line whereby cryogenic liquids such as, for example, liquid nitrogen, oxygen, helium, and hydrogen as well as other liquids having normal liquefaction points below -100° F. may be transferred or conveyed over substantial distances and delivered at a remote point of use in substantially 100 percent liquid phase without the need for intermediate gas-liquid separators.

In the prior art, many efforts have been made to design cryogenic transfer lines having minimum heat leak values such that undesirable vaporization losses of liquid in the line are minimized. To this end, various insulation techniques are well known, including the use of low conductivity insulation materials, either alone or in conjunction with vacuum jacketing with or without radiation shields. In addition, the use of cold gaseous envelopes has been resorted to in certain instances to reduce heat leak while a cryogenic liquid is actually flowing through the conduit as, for example, from a liquid storage tank outside the walls of a plant to a remote point of use within the plant.

While these prior art techniques have been reasonably effective in minimizing vaporization losses during periods of fluid flow through the line, they have not been successful in keeping loss of liquid by vaporization in transit at levels less than 0.5 to 1.0 percent by weight of the liquid. While this figure may appear to be quite low in terms of weight loss, it must be appreciated that the volumetric ratio between the liquid and gaseous phase is in the order of 600 to 1. Thus, a vaporization loss in the line of only one percent by weight results in the production of a two-phase fluid being delivered at the point of use which, on a volume basis, is composed of 99 parts liquid and 600 parts gas. For this reason, it has previously been necessary to employ liquid-gas separators in the transfer system immediately upstream of the point at which it is necessary to supply pure liquid such as, for example, in applications involving the use of cryogenic liquids for rapidly freezing and/or embrittling various articles.

In addition to the expense and maintenance requirements accompanying the use of such separators, transfer lines of the prior art types have in no way solved the problem of liquid losses due to vaporization of the liquid upon the initial and subsequent periods of cooldown to the transfer line. That is, after intermittent periods of nonuse, the transfer system becomes quite warm approaching ambient temperature. Then, when it is desired to operate the system and deliver cryogenic liquid to the point of use,

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there is a relatively long period during which the ultra-cold liquid is completely vaporized in reducing the temperature of the line of the normal vaporization temperature of the liquid. Thus, it is only after this period of cooldown, that the line begins to deliver fluid in the liquid phase. It will, therefore, be appreciated that many installations requiring intermittent periods of liquid consumption at the point of use the above mentioned delay does not satisfy the need for having the cryogenic liquid in substantially pure liquid phase constantly available at that point.

It is, therefore, a principal object of the present invention to provide a cryogenic liquid transfer line wherein substantially pure cryogenic liquid may be made available at a point of use remote from the point of storage regardless of the intermittent nature of the demand for the liquid.

It is a further object of the present invention to provide a cryogenic liquid transfer system which is compatible with the auxiliary requirements often accompanying a cryogenic liquid installation such that the operating cost of the system would be economically advantageous.

The above objects as well as other relating more particularly to the details of construction and operation will become more fully apparent from the following description when taken with the accompanying drawings in which:

FIGURE 1 is a schematic diagram, partly in section, illustrating one preferred embodiment of the transfer system;

FIGURE 2 is an enlarged view, partly in cross-section, showing the details of construction at the left end of the transfer line; and

FIGURE 3 is a sectional view of the transfer line taken along the plane indicated by view lines 3—3 of FIGURE 2.

Referring now to the drawing and particularly to FIGURE 1, the transfer system includes a bulk storage tank 10 containing a cryogenic liquid as defined hereinabove. The tank 10 is of conventional construction and includes a tank pressurizing and control system generally indicated by numeral 12. Disposed below the liquid level in the tank there is a dispensing dip tube 13 through which the liquid is forced by the controlled pressure existing in the ullage space at the top of the tank. Tube 13 extends through the insulated wall of the tank and is integral with or connected to the elongated, centrally disposed liquid transfer line 14, through which the liquid is conducted from the storage tank to the remote point of use; a control valve 16 being provided at the extreme end of the line.

As further shown in FIGURE 1 and, more clearly, in FIGURES 2 and 3, liquid transfer line 14 is surrounded by a second conduit 18 spaced therefrom. Conduit 18 is covered or surrounded by an insulating element 19 hereinafter referred to as an insulating jacket.

In the preferred practice of the invention, the insulating jacket 19 is formed by providing a shell 20 spaced from and surrounding conduit 18, the space between the shell and conduit 18 being filled with inexpensive polyurethane expanded foam which, for purposes of example, may be in the order of three to four inches (3—4") in radial thickness. While the use of this particular type of insulation has been found to give excellent results particularly in terms of low capital investment, it will be readily apparent that other, more sophisticated, types of insulation may be employed. For example, the space between shell 20 and conduit 18 may be evacuated and filled or partially filled with other types of insulation including those with multiple layer radiation shields comprised of aluminum foil or other reflective materials. However, as will be more fully described hereinafter, it should be understood that

the use of the more sophisticated forms of insulation may be objectionable from the standpoint of higher initial cost but would not be detrimental to the overall operation of the system.

Referring now to FIGURES 2 and 3, liquid transfer line 14 is provided with a plurality of radially extending ports 22 through which the cryogenic liquid in line 14 may flow radially outwardly into the annular space 24 provided between line 14 and conduit 18. Thus, the same cryogenic liquid which is conveyed through the transfer line 14, is also conveyed externally thereto and in the same direction (to the right as viewed in FIGURE 1) through surrounding space 24 to the righthand end or terminal point of conduit 18 wherein space 24 is connected to a gas discharge line 26 having a control valve 28 positioned therein. Although it will be apparent that valve 28 may be of the manually operated type, it is preferably of the automatically operated type. For automatic operation, as illustrated, a pneumatic or electrical actuator 34 is associated with valve 28, operating in response to a signal received from a conventional controller 32, having a temperature-sensing probe 30 disposed in the space 24 adjacent the terminal point of conduit 18.

The operation of the transfer system will now be described assuming, for purposes of example, that tank 10 contains liquid nitrogen having a normal liquefaction or boiling point of -320° F. As previously mentioned, the pressurizing and control system 12 maintains the liquid nitrogen in the tank under a predetermined superatmospheric pressure such as, for example, 20 p.s.i.g. Thus, the pressurized cryogenic liquid is caused to flow upwardly through the dip tube 13 into line 14 and thence through line 14 towards the discharge outlet at valve 16. A portion of the cryogenic liquid in line 14 passes through radial ports 22 into the annular space 24 flowing through said space to the righthand end of conduit 18, wherein the gas resulting from the vaporization of the liquid is removed from conduit 18 through gas vent line 26 so long as valve 28 is open. Assuming, therefore, that controller 32 is set at a temperature in the order of minus 270° F., valve 28 will remain open and permit continuous removal of vapors in conduit 18 resulting from heat leak through insulating jacket 19 so long as the resultant fluid in the vicinity of sensor 30 remains at a temperature above the preset temperature of minus 270° F. during the initial cooldown of the line. As soon as the temperature in conduit 18 at the locus of sensor 30 is reduced to below the preset temperature, controller 32 operates to close valve 28. The temperature in conduit 18 will thus be maintained at or below the preset temperature regardless of whether discharge valve 16 is open or closed. As a result, the liquid in transfer line 14 is continuously maintained at a temperature substantially equal to the liquefaction point of the liquid whereby cryogenic liquid in substantially pure liquid phase is continuously available at valve 16. All radial heat leak into the fluid transfer system is absorbed by the cryogenic fluid in surrounding space 24 which heat is utilized first to satisfy the latent heat of vaporization of the liquid admitted to conduit 18, then in heating such vapors to the preset venting temperature, leaving no significant heat available to effect vaporization of the cryogenic liquid in line 14.

From the foregoing description of the operation it will be apparent that gas is continuously generated in space 24 such that it is available for secondary use after passage out of the line through line 26. This continuous availability of the fluid in gaseous form is a distinct advantage over the previous systems wherein intermittent cooldown periods caused generation of large amounts of gas at frequent or infrequent intervals. Therefore, in the present invention, the more or less continuous availability of the gas permits its utilization in secondary operations such as blanketing or inert packaging or other applications wherein the properties of an inert gas such as nitrogen, argon or helium are highly useful. By way of one specific example,

the pure liquid nitrogen available at valve 16 may be utilized in the ultrafast freezing of food products while the inert nitrogen gas available from line 26 may be used concurrently to package the frozen product in an inert atmosphere. Alternatively, however, the gas available from line 26 may be recompressed and charged into transport cylinders or tubes for subsequent use at a totally remote point of application, this being possible with or without the use of a conventional gas purification system, depending upon the purity requirements of the particular application as well as the composition of tubes 14 and 18, which constitute the sole sources of impurity contamination. Thus, this described aspect of the invention provides the further advantage of continuously maintaining the liquid transfer line at the cryogenic temperature or normal liquefaction point while utilizing a second portion of the same liquid in absorbing the heat leak by vaporization, the resulting vapors being thus made available on a more or less continuous basis for a secondary use which may or may not be related to the use of the liquid in the pure liquid phase.

In order to further illustrate the capability of a transfer system utilizing the above-described principles and without limiting the invention to such specific values, the following operating data are presented in the case of one particular application. In this application a copper tube having a three-eighths ($\frac{3}{8}$ ") inch I.D. was utilized as line 14 and extended approximately eighty (80') feet in length externally of the storage tank. This tube was surrounded by a second copper tube having a three-quarter ($\frac{3}{4}$ ") inch I.D. which, in turn, was surrounded with rigid polyurethane expanded foam having a radial thickness of three (3") inches. Initially, the concentric tubes and the insulation were at an ambient temperature in the order of 70° F. when valves 16 and 28 were opened, thereby permitting the flow of liquid nitrogen through line 14 as well as through space 24. The initial cooldown period required approximately five minutes until lines 14 and 26 were noted to discharge nitrogen in substantially liquid phase, the temperature sensed by sensor 30 being in the order of -320° F. Thereafter, the controller 32 was set to open valve 28 at a sensed temperature in the order of -250° F. and valve 16 was intermittently opened and closed for periods of twenty (20) seconds, over a test period of several hours. In each instance, the opening of the valve produced nitrogen at the outlet of valve 16 in substantially liquid phase while approximately twenty (20) pounds of nitrogen were vaporized per hour and removed from the system through line 26.

Other tests were run with liquid nitrogen, at various preset temperatures sensed at the vent line 26 over the range of -140 to -270° F. The liquid transfer line operated with good results at measured temperatures in conduit 18 (at vent line 26) of -200° F. and below; only fair results were obtained at temperatures of -160 to -180° F. at -140° F. there was considerable erratic discharge of nitrogen vapor with the liquid from transfer line 14. At the -200° F. temperature and below immediate flow of substantially pure liquid is obtained at the discharge of line 14 each time valve 16 is opened during short alternate on-off cycles of 15 and 20 seconds, as well as following longer intervals of delay between tests of from five minutes to several hours.

The precise temperature at which the valve 28 should be set to open under control of regulator 32 and temperature sensor 30 will depend upon the degree to which the first small amount of gas can be tolerated in the liquid product when the liquid discharge valve 16 is initially opened. For operations such as deflashing of molded rubber articles by LIN embrittlement, relatively short intermittent cycles in the order of 10 to 30 seconds are required, consistent with those employed in the described tests. For supply of LIN to food-freezing processes, on the other hand, longer continuous on stream periods are in order. If the vaporized cryogenic fluid vented from

line 26 is to be put to use as such, there is less concern for the rate at which vaporization takes place in conduit 18, it being understood that the amount of cryogenic liquid vaporized and vented is increased as the preset temperature to be maintained in conduit 18 is lowered. For liquid nitrogen, preset venting temperatures in the range of about minus 160 to minus 300° F. can be used with the preferred range being at minus 200 to 270° F. In general for most, if not all, cryogenic gases, discharged at the outlet of the liquid transfer line at pressures of about 1 to 2 atmospheres, and with ordinary insulation such as polyurethane foam surrounding conduit 18, the venting temperature for regulator 32 can be set at a value in the range about 50 to 100° F. above the atmospheric boiling point of the cryogenic fluid to be dispensed.

The described arrangement of the invention can be utilized to advantage for transferring highly volatile liquids, and particularly cryogenic liquids, from a storage vessel or other source of supply to a point of use or delivery which point is at an ambient temperature which exceeds the boiling point of the liquid being dispensed, and with further enhanced benefits in those systems wherein the demand for the dispensed liquid is alternately interrupted at regular or irregular intervals.

In installations wherein the transfer line is of considerable length, suitable supporting blocks may be employed to maintain the spacing between transfer line 14 and fluid conduit 18, as shown for example at 35. The blocks or spacers are preferably made of materials stable at cryogenic temperatures.

Obviously, many modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

What is claimed:

1. A cryogenic transfer system for conveying cryogenic liquid from a supply source to a remote location in substantially pure liquid phase comprising: a liquid transfer line extending from said supply source to said remote location, valve means in said liquid transfer line at said remote location for controlling the discharge of liquid therefrom, a conduit spaced from and surrounding said liquid transfer line throughout substantially the full length thereof, said liquid transfer line and said surrounding conduit forming an elongated annular space therebetween, open passage means immediately adjacent said supply source, said open passage means placing the interior of said liquid transfer line in open communication with said annular space for passing liquid from said liquid transfer line into said annular space surrounding said liquid transfer line, vent means having one end in communication with said annular space adjacent said remote location, the other end of said vent means discharging to a region having a pressure at least equal to atmospheric pressure, temperature sensing means in the end portion of said conduit adjacent said remote location, and means for open-

ing said vent means in response to said temperature sensing means for venting vaporized liquid from said annular space.

2. In combination, a storage tank containing a cryogenic liquid, means for maintaining the liquid under superatmospheric pressure in said tank, an elongated transfer line having one end in open communication with the liquid in said tank, the other end of said elongated transfer line extending a substantial distance away from said tank and terminating at a point of use remote from said tank, a valve in the remote end of said transfer line for controlling the discharge of pure liquid from said transfer line at said remote point of use; a conduit spaced from and surrounding said liquid transfer line throughout substantially the full length thereof, said liquid transfer line and said surrounding conduit forming an elongated annular space therebetween, open passage means placing the end of said annular space adjacent said tank in fluid communication with the liquid in said tank whereby some of said liquid under superatmospheric pressure flows into said annular space, insulation means surrounding said conduit for reducing heat leak into said annular space whereby only a minor portion of the liquid passed into said annular space is vaporized, a positive pressure vapor discharge line having one end in fluid communication with said annular space at a location adjacent said remote point of use, the other end of said vapor discharge line being open to a region having a pressure at least equal to atmospheric pressure, temperature sensing means for sensing the temperature in said annular space at the location of said vapor discharge line, valve means in said vapor discharge line for controlling the flow of vapor there-through, and means responsive to said temperature sensing means for opening said valve and discharging vapor at positive pressure only when the sensed temperature is above a predetermined value, said predetermined temperature being no lower than the liquefaction temperature of the liquid in said transfer line, whereby the liquid in said annular space maintains the liquid in said transfer line in pure liquid phase.

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