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CRYOGENIC FLUID TRANSFER SYSTEM

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Fig. 1.

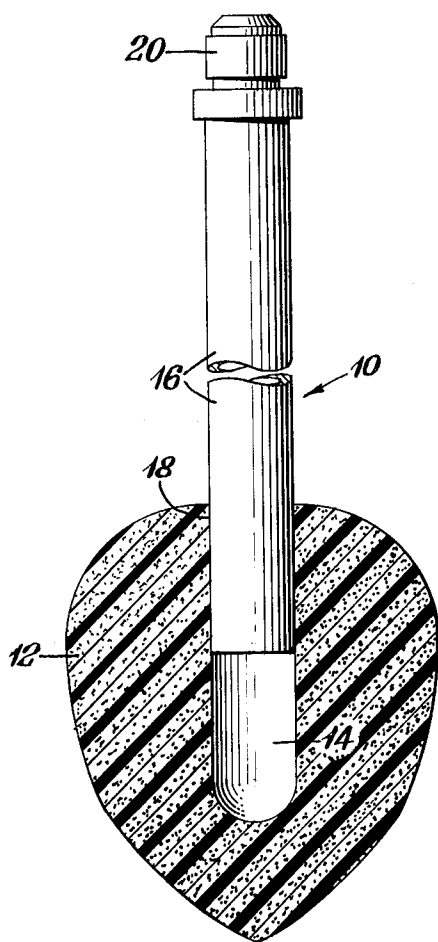
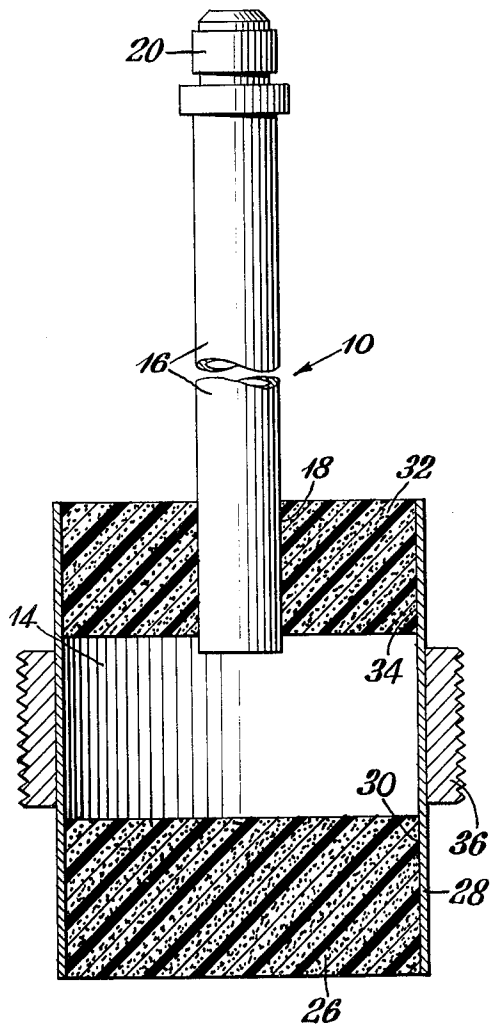


Fig. 2.



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CRYOGENIC FLUID TRANSFER SYSTEM

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6 Claims. (Cl. 62—55)

This invention relates to cryogenic liquid transfer systems and particularly to such systems which are used to transfer pressurized cryogenic liquids into low pressure surroundings.

A primary object of the present invention is to provide a system for transferring pressurized cryogenic liquids into low pressure surroundings by minimizing evaporation caused by droplet diversion and splashing. Another object is to provide a system for rapid cryogenic liquid transfer into low pressure surroundings. Still another object is to provide a system for transferring pressurized cryogenic liquids into low pressure surroundings with a minimum hazard for personnel operating the system. These and other objects and advantages of the present invention are described hereinafter in conjunction with the accompanying drawings of which:

FIGURES 1 and 2 are elevational views in cross-section, illustrating features of the present invention.

When a pressurized cryogenic liquid is discharged from a transfer conduit into low pressure surroundings, such as an open container at atmospheric pressure, heat leakage through the walls of the transfer conduit into the liquid and decrease of pressure through the transfer conduit cause the liquid in the transfer conduit to partially vaporize. The resulting two-phase fluid, containing minute droplets of liquid, is discharged into the low pressure surroundings at high velocity with the result of large liquid losses due to vaporization, droplet diversion and splashing. This manner of cryogenic liquid discharge is undesirable because it contributes to a loss of valuable product liquid, creates a safety hazard to operating personnel, and necessitates severely restricting the rate of liquid discharge to minimize the previously-described deleterious effects.

The problems created by an uncontrolled discharge of cryogenic liquids, for example, liquid methane, oxygen, nitrogen, argon, neon, hydrogen and helium, and other easily vaporizable liquids, are particularly acute because any decrease in the rate of liquid discharge increases the period during which ambient temperature heat can evaporate the discharged liquid. The present invention provides a pressurized cryogenic liquid transfer system that substantially completely eliminates excessive product liquid loss by reducing the discharged liquid pressure and velocity without decreasing the rate of liquid discharge.

The present invention comprises a cryogenic fluid transfer system including transfer means having a transfer conduit for transferring pressurized cryogenic fluid, means connected to the transfer means for separating cryogenic fluid into a minor vapor portion and a major liquid portion, means for venting the minor vapor portion from the major liquid portion, and means for gradually reducing the velocity of the major liquid portion and for discharging the major liquid portion from the cryogenic liquid transfer system. The present invention also comprises a method for transferring a cryogenic liquid comprising the steps of conducting a cryogenic fluid into a phase separator zone, separating the cryogenic fluid into a minor vapor portion and a major liquid portion in the phase separator zone, venting the minor vapor from the phase separator zone, and gradually reducing the velocity of the major liquid portion and discharging the major liquid portion from the phase separator zone in a centralized stream.

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An important feature of the present invention is that the reduction of the liquid pressure and velocity and the phase separation of the cryogenic fluid do not reduce the rate of liquid discharge from the system. This is preferably accomplished by providing a phase separator connected to a transfer conduit which comprises a body having a hollow interior into which the cryogenic fluid is transferred, an upper section, and a lower section constructed of porous material. Phase separation of the cryogenic fluid into a minor vapor portion and a major liquid portion must occur at least partially within the hollow interior of the phase separator. The minor vapor portion is vented through suitable means provided in the upper section of the phase separator and the major liquid portion is discharged from the system through the porous lower section of the phase separator.

The porous lower section of the phase separator must be sufficiently porous so that the major liquid portion is discharged as rapidly as the cryogenic fluid is conducted into the phase separator. The porous lower section must also provide sufficient flow resistance so that the pressure and velocity of the cryogenic major liquid portion of the fluid in the phase separator interior will be satisfactorily reduced. However, if this porous lower section creates too substantial a flow resistance to the major liquid portion to cause a decrease in the pressurized volatile liquid flow rate into the phase separator, because of increased back pressure, the capacity of the transfer conduit and the phase separator have been mismatched. For example, a phase separator having a capacity designed for a pressurized volatile liquid flow rate through a 1/2-inch diameter transfer conduit may not have sufficient capacity to handle the flow rate through a 1-inch diameter transfer conduit.

The means for venting the minor vapor portion of the cryogenic fluid through the upper section of the phase separator must provide sufficient flow resistance so that the major liquid portion will not preferentially discharge through it rather than through the porous lower section of the phase separator. If such means are constructed of the same porous material as the lower section of the phase separator, the necessary increased flow resistance can be achieved by making such means thicker than the porous lower section of the phase separator.

The mode of operation of the phase separator of the present invention is not fully understood but it is thought that the following description explains its principle. Transfer of a cryogenic liquid through warm surroundings is always a two-phase phenomenon because of the low-temperature boiling characteristics of such liquids, pressure drop along the transfer means, and the impossibility of completely insulating the transfer means from ambient heat leakage. As a portion of the liquid evaporates during transfer, the velocity of the two-phase fluid increases; sometimes approaching sonic velocity. Generally, most of the pressure drop occurs within the transfer means, for example, across a flow control valve and/or as a result of fluid flow resistance. Consequently, without the use of the phase separator of the present invention, the liquid portion of the two-phase fluid is discharged as a mass of minute droplets having substantial momentum. The mass of droplets provides a large surface area resulting in high evaporation losses, the momentum of the mass forces the droplets to disperse (called droplet dispersion), and the droplets splash and splatter on contact with a storage container surface, thereby increasing evaporation losses. The porous material of the phase separator, which has a matrix-like construction, absorbs the momentum of the liquid portion of the two-phase fluid on discharge from the transfer means. Also, the matrix-like construction entraps any rising

liquid droplets and returns them by the combined effects of gravity and liquid surface tension to the lower, liquid-containing section of the porous material. The liquid portion is then discharged in a centralized stream of low velocity.

The preferred embodiment of the present invention is shown in FIGURE 1. A phase separator 10 is constructed of an open cell foam plastic material 12, such as polyurethane foam, with a hollow interior 14. A tube 16 is inserted into the foam plastic material 12 and attached by suitable means such as an adhesive material 18. The end of tube 16 communicates with hollow interior 14 in a manner such that a substantial portion of the surface of hollow interior 14 is formed by the porous material 12 to permit the necessary phase separation to take place within hollow interior 14. An adapter fitting 20 is attached to the outer end of tube 16 so that the phase separator 10 may easily be connected to and disconnected from transfer means including a transfer conduit (not shown in FIGURE 1).

The foam plastic 12 is preferably constructed so as to have a curved or pointed lower section as shown and oriented substantially vertically when operated to promote the formation of a vertical, small diameter major liquid portion stream as the liquid is discharged from the phase separator. If the transfer conduit is not oriented vertically, tube 16 can be suitably constructed to suspend the foam plastic 12 in the vertical direction.

The required wall thickness of the foam plastic 12 is related to the internal cryogenic liquid pressure and viscosity, and the porosity of the porous material. For example, a foam plastic having a wall thickness of at least $\frac{1}{2}$ inch and a porosity of about 20 to 30 open cell pores per inch has been found to provide adequate major liquid portion velocity reduction in a transfer system for pressurized cryogenic liquids. As shown in FIGURE 1, the foam plastic wall thickness below hollow interior 14 is less than the thickness adjacent to or above hollow interior 14 to create a preferential flow of liquid out through the lower section of the phase separator 10.

A preferred urethane foam plastic material has a skeletal structure in which about 95% of the cells are in communication with adjacent cells and has a void volume greater than 95%. This material has a low heat capacity which minimizes product liquid loss due to cool-down of the phase separator, and also permits quick warmup which prevents frost formation on the phase separator.

Tests have shown that use of a phase separator 10 constructed of the preferred foam plastic 12, having 20-30 open cell pores per inch and a diameter of $3\frac{3}{8}$ inches and a length of $2\frac{7}{8}$ inches, attached to a $\frac{3}{8}$ inch outside diameter tube 16, permits the withdrawal of two liters of liquid nitrogen in 15 seconds from a container pressurized at 18 p.s.i.g. Without using the phase separator the withdrawal of two liters of liquid nitrogen from the same container pressurized at 18 p.s.i.g. required 85 seconds. Tests have also shown that, at a driving pressure of 5 p.s.i.g., the evaporation of liquid nitrogen discharged from this phase separator was 15% less than when no phase separator was used, and 24% less at a driving pressure of 30 p.s.i.g.

Another embodiment of phase separator 10 is shown in FIGURE 2. The porous lower section 26 of the phase separator 10 is preferably constructed of a foam plastic material and attached to the lower part of a shell 28 by suitable means such as an adhesive 30. The means for venting a minor vapor portion of the pressurized volatile liquid through the upper section of phase separation 10 is also preferably constructed of a foam plastic material 32 which is attached to the upper part of shell 28 by suitable means such as an adhesive 34. In this embodiment, cryogenic fluid is conducted through tube 16 into hollow interior 14 defined by the side walls of shell 28 and the foam plastic materials 26 and 32. A minor vapor

portion is separated from a major liquid portion and vented through foam plastic 32 and the major liquid portion is discharged through the foam plastic 26 at a reduced pressure and velocity.

In place of the foam plastic material 12 of FIGURE 1 and materials 26 and 32 of the FIGURE 2 embodiment, other suitable porous materials such as metal shavings, metal wool, glass fibers, porous metal sheets, metal screens, metal foams, and the like may be substituted. If foam plastic material is used, it may be desirable to enclose the foam plastic with a wire screen or a perforated metal plate to protect the foam plastic during use inasmuch as the low temperature of cryogenic liquids would tend to embrittle the foam plastic during and shortly after use.

The FIGURE 2 embodiment of the phase separator 10 is provided with a flanged or threaded ring 36 for attachment to a container or the like. This permits using the phase separator as a permanent element of a container structure which could be converted to a container filling hose by adaptor 20. The embodiment shown in FIGURES 1 and 2 could be constructed similarly by encasing foam plastic 12 with a perforated metal sheet and attaching a threaded ring 36 to the outside of the perforated plate. Also, rather than connecting the phase separator to the end of a transfer conduit, the phase separator could be mounted within a section of a transfer conduit with suitable provision for vapor removal from the transfer conduit.

In an embodiment such as that shown in FIGURE 2, substantially all of the phase separation of the cryogenic fluid into a minor vapor portion and a major liquid portion must take place within hollow interior 14. In the FIGURES 1 and 2 embodiment, however, phase separation can take place within the porous structure of the foam plastic 12 with the vapor portion being conducted through the porous structure and vented from the upper section of the phase separator 10. The FIGURE 2 embodiment is thus usually limited to use with cryogenic liquids at relatively low driving pressures because of the relatively small amount of vapor venting area available. For a particular size phase separator 10, the use of a porous material, such as foam plastic 12 in FIGURES 1 and 2, provides the most efficient phase separation over a wider range of volatile liquid driving pressures.

It is to be understood that although preferred embodiments of the invention have been described above, there are numerous other arrangements that may be devised by those skilled in the art which are within the scope of this invention. For example, if non-rigid porous material is used to form the body of phase separator 10 of FIGS. 1 and 2, such material should be either bonded together or contained within a porous enclosure to maintain the desired structural configuration. When glass fiber is used as the porous material, it is preferred that a wire screen enclosure be used to contain the glass fiber. If desired, such a wire screen enclosure could be shaped to the pointed or curved configuration shown in FIG. 1 to promote the formation of a centralized major liquid portion stream.

What is claimed is:

1. A method for transferring a cryogenic liquid comprising the steps of conducting a cryogenic fluid into a phase separator zone; separating the cryogenic fluid into a minor vapor portion and a major liquid portion in said phase separator zone; venting said minor vapor portion from said phase separator zone; and reducing the velocity of said major liquid portion by passage through a porous material, said porous material being contiguous with said phase separator zone; and discharging said major liquid portion from said porous material at such reduced velocity.

2. A cryogenic liquid transfer system comprising conduit means for transferring a cryogenic fluid; means connected to said conduit means and having a hollow in-

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terior for separating the cryogenic fluid into a minor vapor portion and a major liquid portion, a substantial portion of the surface of said hollow interior being formed by porous material; means for venting said minor vapor portion from said major liquid portion; and porous means for reducing the velocity of said major liquid portion, and for discharging said major liquid portion from said cryogenic liquid transfer system, said conduit means communicating with said hollow interior in a manner such that the surface of said hollow interior formed by porous material is unobstructed by said conduit means.

3. In a cryogenic liquid transfer system, apparatus which comprises a body having (a) a hollow interior for at least partially separating a cryogenic fluid into a minor vapor portion and a major liquid portion, a substantial portion of the surface of said hollow interior being formed by porous material (b) an upper section provided with means for venting said minor vapor portion from said major liquid portion, and (c) a lower section constructed of porous material for reducing the velocity of said major liquid portion and for discharging said major liquid portion from said apparatus; and means for conducting a pressurized cryogenic fluid into said hollow interior, said means communicating with said hollow interior in a manner such that the surface of said hollow interior formed by porous material is unobstructed by said means.

4. In a cryogenic liquid transfer system, apparatus which comprises a body constructed of porous material having (a) a hollow interior for at least partially separating a cryogenic fluid into a minor vapor portion and a major liquid portion, a substantial portion of the surface of said hollow interior being formed by porous material (b) an upper section for venting said minor vapor portion from said major liquid portion, (c) a lower sec-

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tion for reducing the velocity of said major liquid portion and for discharging said major liquid portion from said apparatus, said porous material having a wall thickness suitable for creating a preferential flow of said major liquid portion through said lower section; and means for conducting a pressurized cryogenic fluid into said hollow interior, said means communicating with said hollow interior in a manner such that the surface of said hollow interior formed by porous material is unobstructed by said means.

5. Apparatus according to claim 3 wherein said body comprises a shell enclosed at an upper end by said upper section and at a lower end by said lower section with the interior of said body defined by the shell and the upper and lower sections comprising said hollow interior; and wherein the upper and lower sections are constructed of open cell foam plastic and joined to said shell by an adhesive.

6. Apparatus according to claim 4 wherein said body is constructed of open cell foam plastic; and wherein the lower section of said body is curved to promote the formation of a small diameter major liquid portion stream.

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