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Massey

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[54] **CRYOGENIC LIQUID HANDLING SYSTEM**

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[58] **Field of Search**.....62/50.1, 514, 55, 62/DIG. 19, 45, 333; 138/32, 33, 34, 35, 103

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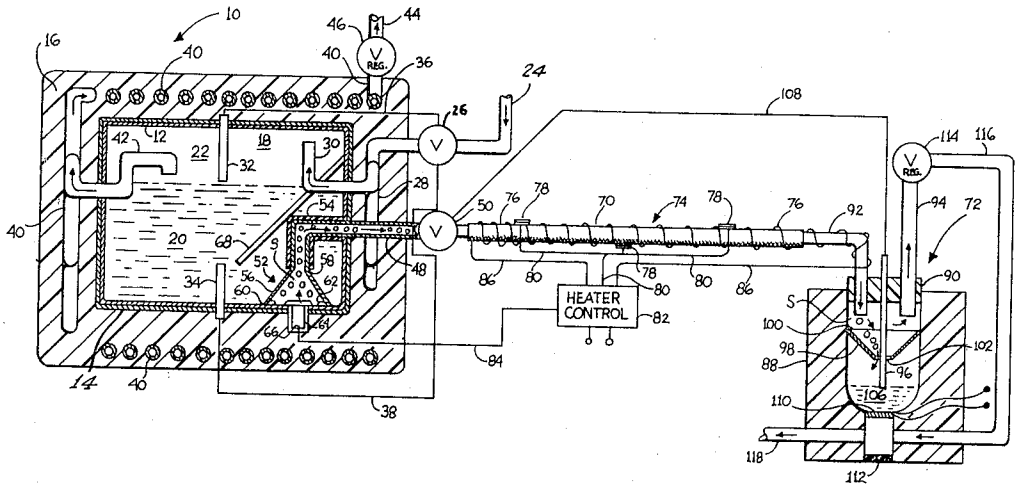
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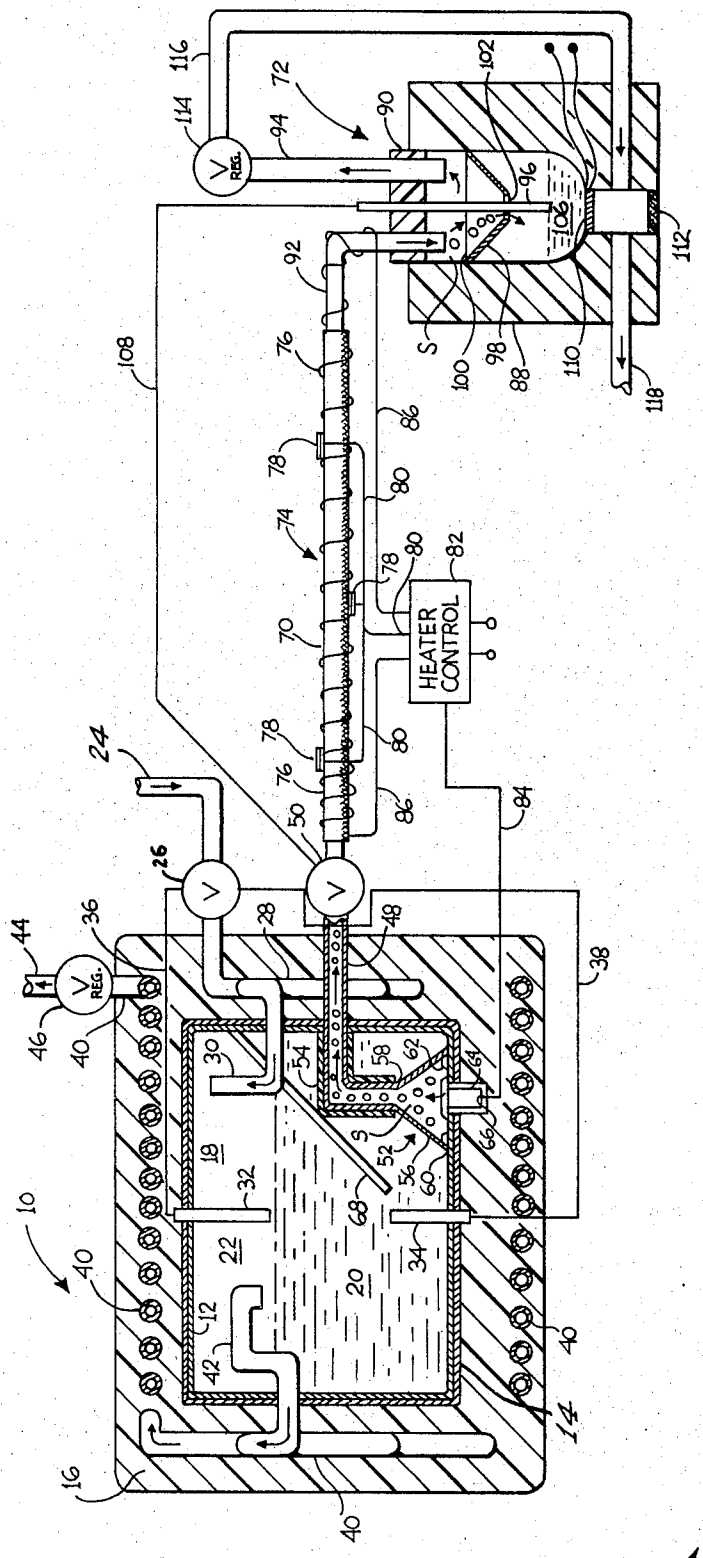
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[57] **ABSTRACT**

A cryogenic liquid handling system for infrared detection or the like having a cryogenic liquid supply container which is insulated in part by the flow of cryogenic vapor existing above the liquid level, a two phase flow generator in the container, a heated delivery line to maintain the two phase flow and a separator at the point of use, including a vapor feedback passage to prevent the formation of frost in the lens of the infrared detection system.

21 Claims, 1 Drawing Figure





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CRYOGENIC LIQUID HANDLING SYSTEM

BACKGROUND OF THE DISCLOSURE

The present invention relates to fluid handling systems and, more particularly, to an improved cryogenic fluid handling system. In my prior U.S. Pat. No. 3,418,822 a system is disclosed for transporting a stream of cryogenic liquified gas which is based on the Leidenfrost phenomena. According to the teachings of my prior patent, the cryogenic liquified gas is transported through a flexible or semi-rigid conduit without the usual deterioration thereof due to the low temperatures of the liquified gas. This is accomplished by converting a portion of the cryogenic liquid into a gaseous phase which surrounds the remaining liquid creating separate liquid spheroids which are propelled through the conduit by the gas. Near the point of use the gas is separated from the liquid spheriods whereby the liquid can be employed for its intended cooling purposes such as cryogenic surgery or infrared detection or the like.

The creation of the gas-liquid or two phase flow is accomplished by the application of heat in the conduit near the source of cryogenic liquid supply. Once the two phase flow is created it must be maintained. In my prior patent the maintenance of such flow is accomplished by the heat added to the conduit by the environment. Thus, my prior system must be designed with a precise knowledge of the environment for most efficient operation. Should environmental conditions change either in temperature or pressure, the efficiency of my prior system is significantly effected. For example, if the temperature increases more gas phase is produced resulting in less usable liquid. Should the environmental temperature decrease significantly, as it would in space applications, less heat is supplied by the environment to the conduit which, in turn, supplies less heat to the vapor phase thereby reducing the shielding effect for the liquid spheroids. These spheriods would thus come into contact with the relatively hot conduit walls and would vaporize. This action would repeat until most of the liquid has vaporized and little or no liquid would be left to perform a useful cooling function. Additionally, since the conduit walls looses heat to the spheroids and the vapor, the temperature thereof is reduced until its low temperature properties are reached, whereupon deterioration takes place. It is therefore necessary for efficient operation of the system that the heat added to the conduit must be just that necessary for the maintenance of the two phase flow in just the right proportions; where the environmental conditions change it is not possible with my prior system to achieve such a balance.

SUMMARY OF THE INVENTION

The foregoing disadvantages, as well as other, of prior systems are overcome according to the teachings of the present invention which provides an improved cryogenic fluid handling system that is simple, efficient, inexpensive, independent of environmental conditions, versatile and noise-free.

According to one aspect of the present invention a nonvacuum insulated cryogenic supply container incorporates a heat shield in the form of a heat exchanger having one end in communication with the vapor space in the container and the other end in communication with the environment whereby a portion of the heat

from the environment is absorbed before it reaches the cryogenic supply container.

According to a second aspect of the invention, the cryogenic container itself incorporates means to generate the Leidenfrost flow in the form of a heater cooperating with structure which guides the cryogenic liquid spheriods and the transporting gas vapor through the supply line.

Additionally, the present invention provides thermostatically controlled means for heating the supply conduit means substantially along the entire length thereof from the supply container to a point of use, whereby the Leidenfrost flow is maintained and the conduit is completely protected from freezing along the entire extent thereof, independent of the particular environmental conditions under which the cryogenic system is operating.

The present invention also incorporates means for separating the liquid spheroids from the transporting or propelling vapor, which means is located at the point of use. Thus, no portion of the conduit means is subject to direct contact with the cryogenic liquid and the resulting frost which would be caused by such contact.

The present invention further provides means to prevent the formation of frost at the structure to be cooled by the cryogenic fluid at the point of use.

Further objects, features and advantages of the present invention will become apparent as the description thereof proceeds.

BRIEF DESCRIPTION OF THE DRAWING

For a fuller understanding of the present invention, reference should be had to the following detailed description thereof taken in conjunction with the accompanying drawing wherein the only FIGURE is a schematic of the cryogenic handling system with parts thereof illustrated in section.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, the cryogenic supply apparatus is generally depicted by the numeral **10** and comprises a supply or storage container **12** fabricated of any suitable material, metallic or nonmetallic. Container **12** is surrounded by a layer **14** of a highly reflective material which functions as a radiation shield. Container **12** and layer **14** are suitably embedded in or surrounded by an insulating material **16** which may be urethane or any other suitable material.

Interiorly of container **12** is a chamber **18** in which is stored a cryogenic fluid **20** such as liquid nitrogen, hydrogen or the like. The vapor phase of the cryogenic liquid is located in volume **22** above the liquid level.

A supply conduit **24** delivers cryogenic fluid from a suitable source of supply (not illustrated) to chamber **18** through delivery valve **26**, a coiled heat shield or heat exchanger tubing **28** embedded in insulation **16**, and a delivery tube **30** communicating with the vapor space in chamber **18**. Conventional level sensing probes **32** and **34** are located in chamber **18** for developing high and low level signals via lines **36** and **38**, respectively, to control the actuation of valve **26** to maintain a substantially constant level of liquid in container **12**. Of course, valve **26** may be manually controlled, if desired.

Heat exchange means in the form of a coiled heat shield or tubing **40** embedded in insulation **16** has one end in communication with a vent conduit **42** located in the vapor space of chamber **18**; the tubing **40** has its other end in communication with the environment at **44** through a pressure control and relief valve **46** of conventional construction. Valve **46** functions to maintain a predetermined back pressure in the chamber **18**.

A cryogenic fluid outlet conduit **48** has one end in communication with a delivery valve **50** adjacent the exterior of apparatus **10**. The other end of conduit **48** communicates with a Leidenfrost flow generator depicted generally by the numeral **52**. Conduit **48** passes through coil **28** in heat exchange relation therewith. The portion of conduit **48** interiorly of chamber **18** is wrapped with a suitable insulating material **54**.

The Leidenfrost generator **52** comprises a conically flared or funnel shaped input **56** adjacent the bottom surface of container **12**; the narrow end section **58** of which is in communication with outlet conduit **54**, the wide end section **60** of which is in communication with the cryogenic liquid **20** via a plurality of slots or openings **62**. A suitable heater **64** is located adjacent end section **60** in a recess **66** in insulation **16**. Heater **64** may be of conventional construction such as one of the resistance heating type, for example.

A suitable baffle **68** is mounted to the wall of container **12** to prevent turbulence of the incoming cryogenic fluid from interfering with the generation of the liquid spheroid flow through generator **52**.

A delivery conduit **70** is in communication with the outlet of valve **50** for supplying cryogenic fluid to a point of use depicted generally as **72**. Conduit **70** may be flexible, semi-rigid or rigid and must be protected against deterioration by the freezing effects of the low temperature cryogenic flow. To this end, heating means **74** is provided in the form of a resistance heating wire or coil **76** which is spirally wrapped about the conduit **70** along substantially the entire extent thereof from apparatus **10** to point of use **72**. As illustrated schematically, the space between adjacent coils of wire **76** progressively increases from the valve **50** toward the point of use **72**. Thus, the quantity of heat supplied to conduit **70** by the heating wire progressively decreases. The amount of heat required and the exact spacing of the coils will be dictated by the operating conditions as would be known to those skilled in the art.

Although a heating wire coil has been disclosed, other forms of heating means can be employed. For example, axially extending resistance elements can be embedded about the peripheral surface of the conduit. These elements can be sized differently to achieve the different heat inputs along the length of the conduit.

One or more heat sensing means, which may comprise thermostats **78** or the like, are provided in heat exchange relationship with conduit **70**. Signals from thermostats **78** are transmitted by lines **80** to a heater control switch or the like **82** which actuates heater **64** via line **84** and heating wires **76** via lines **86**.

Point of use **72** may typically comprise an insulated cryogenic fluid container in the form of a dewar or flask **88** which is closed by a suitable cap or stopper **90**, through which pass an inlet tube **92**, a vent tube **94** and a level sensing probe **96**. Inlet tube **92** communicates with and may be considered a part of conduit **70**.

Mounted interiorly of container **88** is a spheroid-vapor separator in the form of a conical collector **98** having an upper wide mouthed section **100** tapering into a lower narrow mouthed section or opening **102**. The arrangement is such that the cryogenic liquid spheroids S drop through opening **102** whereas the lighter propelling gas vapor passes through vent tube **94**. The sphereoids passing through opening **102** collect and form a volume of cryogenic liquid **106**, the level of which is maintained by valve **50** in response to a signal from level sensor **96** via line **108**.

Located adjacent the cryogenic liquid **106** and in heat exchange relationship therewith is the material to be cooled, which may typically comprise a light sensitive detector **110** such as an infrared detector. A spaced observation window or lens **112** is provided for allowing the sensed light to fall upon detector **110**.

Vent tube **94** communicates with a conventional relief and regulator valve **114** which maintains a predetermined back pressure in dewar **88**. After passing through valve **114** the vent vapor is delivered via tube **116** to the space between detector **110** and lens **112** and thence to waste via line **118**.

OPERATION

In operation, cryogenic liquid is delivered to chamber **18** via tube **30** through coil **28** until probe **32** makes contact with the liquid, at which time valve **26** closes. Valve **26** is reopened to deliver more liquid when the level drops to the height of probe **34**. The cryogenic vapor in space **22** is exhausted through tube **42** and heat exchanger coils **40** through valve **46**. Since this vapor is still at a much lower temperature than the environment, the vapor will absorb heat from the environment before transmission to the container **12**. Thus, the coils **40** effectively function as a heat shield which, together with the insulation **16** and the reflective layer **14**, prevents substantial temperature increases in the container **12**.

The application heat from heater **64** adjacent funnel **56** causes the cryogenic liquid to form a two phase or Leidenfrost flow consisting of liquid spheroids S and a propelling cryogenic vapor which flow is guided and directed upwardly through funnel **56**, insulated section **54**, section **48** and valve **50** to delivery conduit **70**.

To maintain the two phase flow through conduit **70** a controlled amount of heat must be supplied thereto. This is accomplished by the heating coils **76**, which function under the influence of thermostats **78** and heater control **82** to supply just the right amount of heat to the conduit to maintain the proper balance between the liquid spheroid and vapor phase flowing therethrough. Since some heat may be supplied by the environment, the amount of heat supplied by coils **76** is variable with environmental conditions. It is however important to note that changing environmental conditions can be easily accommodated by simply varying the heat output of the coils as by changing the thermostat settings; thereby adding significantly to the versatility of the present system.

As the liquid spheroids are propelled downstream in conduit **70** they absorb heat from the surrounding transporting vapor, which in turn absorbs heat from the conduit walls due to the heat supplied from the coils **76**. To prevent the establishment of a too large vapor to

spheroid volume, it is necessary that less and less heat be supplied further and further downstream of valve **50**. Thus, the spacing between adjacent heating coils progressively increases from a minimum at valve **50** to a maximum at dewar **88**. The exact spacings will depend upon the temperatures that are to be maintained at the outer peripheral surface of conduit **70** which, in turn, are a function of particular system design and particular environmental conditions as would be known to those skilled in the art. It has been found that conduit outer wall temperatures in the range of 35°F to 100°F are suitable.

Upon entry into dewar **88** the two phase flow is separated; the heavier liquid spheroids falling by gravity through funnel **98** and puddling into a cryogenic liquid volume **106**, whereas the lighter vapor rises through vent tube **94**.

The volume of cryogenic liquid in dewar **88** is employed to cool material **110** which might typically comprise an infrared detector, which responds to rays impinging thereupon through window or lens **112**. For proper operation, it is imperative that the lens **112** be free of frost so that transparency thereof is maintained. To this end, the exhausted propelling vapor is passed through conduit **116** to the space between the detector **110** and the lens **112**. Since this gas vapor is substantially heated to environmental temperature before it reaches the space between detector **110** and lens **112**, the vapor functions to maintain this space at or near environmental temperatures. The existence of the same temperature on both sides of lens **112** will prevent the formation of frost.

Although a preferred embodiment of the present invention has been disclosed and described, changes will obviously occur to those skilled in the art. It is therefore intended that the scope of the present invention is to be limited only by the scope of the appended claims.

What is claimed is:

1. A cryogenic liquid handling system, comprising;
a. storage means for containing a cryogenic fluid,
b. conduit means for conveying said cryogenic fluid from said storage means to a point of use,
c. spheroid generator means for developing cryogenic liquid spheroids surrounded by a gas vapor for propelling said spheroid through said conduit means, and
d. means for maintaining the flow of said spheroids surrounded by said gas vapor along substantially the entire extent of conduit means from said storage means to said point of use, said means comprising first heater means for supplying heat to said conduit means along substantially the entire extent thereof from said storage means to said point of use.

2. The system according to claim **1**, wherein;
e. said spheroid generator means is located in said storage means.

3. The system according to claim **1**, further comprising;
e. insulating means surrounding said storage means, and
f. heat exchange means embedded in said insulating means for communicating the vapor space of said storage means to the environment whereby heat from said environment is absorbed by said heat exchange means to prevent its absorbtion by said storage means.

4. The system according to claim **1**, wherein;
e. said first heater means is attached to said conduit means in such a manner that the heat added thereto progressively decreases from a maximum at said storage means end to a minimum at said point of use end.

5. The system according to claim **4**, wherein;
f. said first heater means comprises a plurality of resistance heating elements in surrounding relation to said conduit means.

6. The system according to claim **5**, wherein;
g. said heating elements are helically wrapped about said conduit means.

7. The system according to claim **6**, further comprising;
h. heat sensing means responsive to the temperature of said conduit means, and
i. heater control means for actuating said first heater means in response to signals from said heat sensing means.

8. The system according to claim **1**, further comprising;
e. heat sensing means responsive to the temperature of said conduit means, and
f. heater control means for actuating said first heater means in response to signals from said heat sensing means.

9. The system according to claim **8**, wherein;
g. said first heater means is attached to said conduit means in such a manner that the heat added thereto progressively decreases from a maximum at said storage means end to a minimum at said point of use end.

10. The system according to claim **1**, wherein;
e. said spheroid generator means comprises a flared frusto-conical opening in communication with said conduit means and second heater means adjacent said opening.

11. The system according to claim **10**, further comprising;
f. heat sensing means responsive to the temperature of said conduit means, and
g. heat control means for actuating said first and second heater means in response to signals from said heat sensing means.

12. The system according to claim **11**, wherein;
h. said first heater means is so related to said conduit means that the heat added thereto progressively decreases from a maximum at said storage means end to a minimum at said point of use end.

13. The system according to claim **12**, wherein;
i. said first heater means comprises a plurality of resistance heating elements in surrounding relation to said conduit means.

14. The system according to claim **13**, wherein;
j. said heating elements are helically wrapped about said conduit means.

15. The system according to claim **1**, further comprising;
e. means for separating said liquid spheroids from said gas vapor at said point of use.

16. The system according to claim **15**, wherein;

f. said means for separating comprises a funnel shaped member having an opening at the lowermost portion thereof for collecting by gravity the heavier liquid spheroids and a vent tube above said funnel shaped member for allowing the lighter gas vapor to escape therethrough.

17. The system according to claim **1**, wherein;

e. said point of use comprises a cryogenic liquid container adapted to cool an infrared detector, and there is further provided;

f. means in said container for separating said cryogenic liquid spheroids from said gas vapor.

18. The system according to claim **17**, wherein;

g. said means for separating comprises a funnel shaped member having an opening at the lowermost portion thereof for collecting by gravity the heavier liquid spheroids and a vent tube above said funnel shaped member for allowing the lighter gas vapor to escape therethrough.

19. The system according to claim **18**, further comprising;

h. an infrared detector assembly in heat exchange relation with said cryogenic liquid container, said assembly comprising;

i. an infrared detector,

j. a lens spaced from said detector, and wherein;

k. said vent tube communicates with the space between said detector and said lens whereby the temperature in said space is brought to substantially that of the environment to prevent the formation of frost on said lens.

20. A cryogenic liquid handling system, comprising;

a. a cryogenic liquid container,

b. a light sensitive detector in heat exchange relationship with said container,

c. transparent means spaced from said detector for transmitting light thereto,

d. a vent tube communicating with said container and the space between said detector and said transparent means whereby the temperature in said space is brought to substantially that of the environment to prevent the formation of frost on said transparent means and

e. a funnel shaped separator in said container having and opening at the lowermost portion thereof for collecting by gravity cryogenic liquid flowing into said container.

21. A cryogenic liquid handling system, comprising;

a. a cryogenic liquid container,

b. conduit means communicating with said container for delivering liquid spheroids surrounded by a gaseous vapor to said container,

c. a funnel shaped separator in said container having an opening at the lowermost portion thereof for collecting by gravity said liquid spheroids, and

d. a vent tube communicating with said container for permitting said gaseous vapor to escape.

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