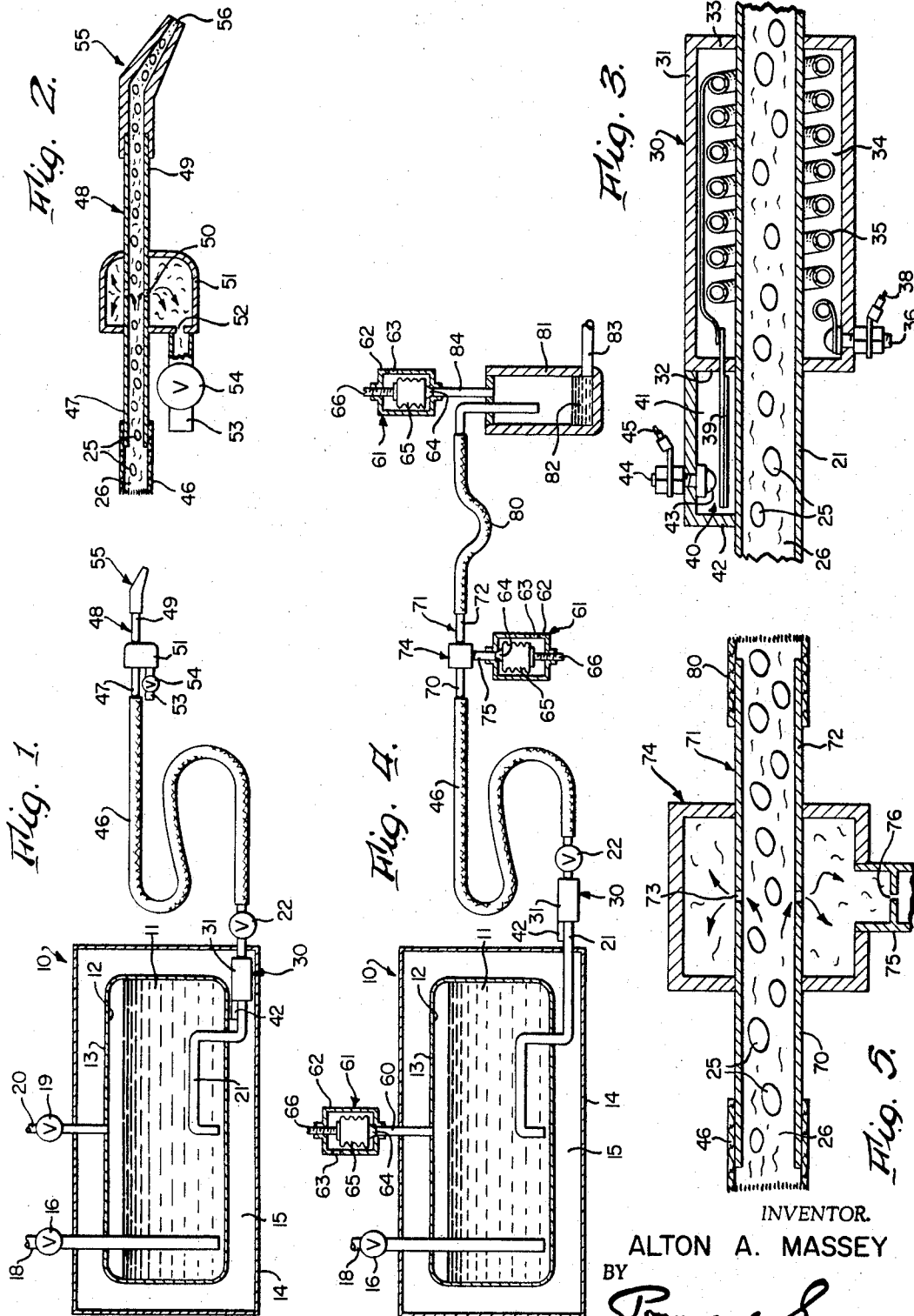


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 APPARATUS FOR TRANSPORTING A STREAM
 OF CRYOGENIC LIQUIFIED GAS
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APPARATUS FOR TRANSPORTING A STREAM OF CRYOGENIC LIQUIFIED GAS

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ABSTRACT OF THE DISCLOSURE

In cryosurgery, infrared detectors, and chilling parts being machined, the receiver for a low controlled volume of cryogenic liquid desirably is highly maneuverable and comfortable to handle. Conventional supply equipment requires hoses the flexibility of which deteriorates and which become relatively rigid as cryogenic temperatures are reached. The present apparatus takes advantage of the Leidenfrost phenomena which is a phase transition phenomena of liquified gases involving resolution of the liquid into liquid spheroids and a transport gas flowing simultaneously. The liquified gas from a source is heated in the proximity of Leidenfrost flow development and both the spheroids and transport gas then conducted by a flexible hose to a hollow body having an outlet in line with its inlet bleed openings in its side so that the spheroids are projected through the outlet to the receiver, while a part of the transport gas escapes through the side bleed openings. The temperature of the flexible hose remains close to ambient so that hose flexibility and handleability with bare hands is not impaired. With a pressure source, system operating pressure can be maintained by a discharge metering device from the receiver, and system driving pressure can be maintained constant by regulation of the source pressure and the effect of this discharge metering device. Bleeding of transport gas from the hollow body is regulated in accordance with downstream requirements.

In the accompanying drawings, FIG. 1 is a diagrammatic representation of the invention as applied to a cryogenic surgical tool, or tool for cooling parts being machined. FIG. 2 is an enlarged longitudinal section through the surgical tool which acts as a receiver for the spheroids projected through the gas bleed hollow body forming a handle for the tool. FIG. 3 is an enlarged longitudinal section through the line heater forming one of the components. FIG. 4 is a view similar to FIG. 1 showing a modified form of the invention. FIG. 5 is an enlarged longitudinal section through the gas bleed hollow body of the form of the invention shown in FIG. 4.

FIGS. 1-3

Referring to the form shown in FIGS. 1-3, the numeral 10 represents a dewar bottle forming the pressurized source for a body 11 of cryogenic liquified gas contained in the chamber 12 provided by an inner container 13. The inner container is surrounded by an outer shell 14 with a vacuum space 15 therebetween, this space containing the usual insulation (not shown). The chamber 12 can be refilled with the cryogenic liquified gas 11 through a fill valve 16 in a fill line 18 and a regulated pressure can be maintained in the chamber 12 by means of a pressure relief valve 19 in a relief line 20.

The cryogenic liquified gas 11 is discharged through an outlet line 21 from the bottom of the chamber 12 and extending through the walls of the inner container 13 and outer shell 14, this line being provided with an on-off valve 22.

A principal feature of the invention resides in the application of heat to the exterior of the discharge line 21

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to produce a succession of liquid spheroids 25 surrounded by gas 26 which forms a transport gas for these spheroids, this liquid to gas phase transition being known as the Leidenfrost phenomena. Such heating is effected by a heater indicated generally at 30 and shown as arranged within the vacuum space 15 around the discharge pipe 21. As later illustrated, this heater could be outside of the dewar 10, or it could be immersed in the body 11 of liquid, it being important that the heater be located close to the pressurized source 10 of liquified gas 11.

The heater 30 is shown as comprising a tubular shell 31 of dielectric material surrounding the outlet pipe 21 and having end heads 32 and 33 in contact therewith to form an enclosed annular heating chamber 34. In this heating chamber 34 is arranged an electrical resistance heating coil 35 of any suitable form having one end connected through a terminal 36 to one side 38 of the power line. The other end of this resistance heating coil 35 connects with a bimetallic contact 39 of an electric thermostatic switch 40, this bimetallic contact extending through the end head 32 into a chamber 41 provided by a box 42 of dielectric material forming an extension of the body 31 of the heater 30. This bimetallic element 39 engages with a stationary contact 43 forming part of a terminal 44 connected with the other side 45 of the power line.

The thermostatic switch 40 is responsive to the temperature of the gas 26 passing through the outlet line 21, the resolution of the liquid 11 into such gas and the spheroids 25 taking place immediately in advance of the heater 30. The thermostatic switch 40, of course, serves to break up the liquified gas 11 from the dewar 10 into spheroids 25 in accordance with the Leidenfrost phenomena with a minimum production of the gas 26 which serves as a transport gas for transporting the spheroids into the inlet end of a flexible hose 46.

Such flexible hose 46 is manually flexible and its flexibility as well as its handleability is never lost, the outside temperature of this flexible hose 46 being maintained within 20° F. of the ambient temperature in spite of its service in transporting a cryogenic liquified gas. The flexible hose 46 is preferably selected so that its flexibility is maintained from 50° F. above ambient to 50° F. below zero.

The flexible hose 46 discharges into the inlet end 47 of a hollow body 48, this hollow body preferably being in the form of a straight tube so that its outlet end 49 is in straight line relationship with its inlet end 47 and so that the liquid spheroids 25 are projected through the hollow body 48 like bullets. However, a part of the transport gas 26 is bled off through a plurality of bleed openings 50 in the sides of the hollow body 48. This gas from the bleed openings 50 is received in a manifold 51 having a discharge opening which can be in the form of a restricted orifice 52 and which discharges into an outlet line 53 also having a pressure relief valve 54 controlling the discharge of gas from the manifold 51. This gas can be vented or can be usefully employed in any suitable manner (not shown).

In the form of the invention shown in FIGS. 1-3, the remaining carrier gas 26 and spheroids 25 pass from the outlet end 49 of the tube 48 into the inlet end of a receiver 55 which is shown as being in the form of a tool for performing cryosurgery or cryobiology, the tool for this purpose being in the form of a bent tube having its inlet end fixed directly to the outlet end 49 of the hollow body or tube 48 and having a restricted outlet orifice 56 which sets up a back pressure against the gas 26.

Operation—FIGS. 1-3

With the heating coil 35 energized, and the valve 22 open, the pressurized liquified gas 11 from the chamber 12 passes via the discharge pipe 21 through the heating

zone of the heater 30. In accordance with the Leidenfrost phenomena, before entering the heating zone provided by the heater 30 the liquified gas 11 breaks up into liquid spheroids 25 surrounded by transport gas 26 as the first part of transition from liquid phase to gas phase. So heating the liquid passing through the outlet pipe 21 is essential to produce this phenomena, but minimum heating is desirable so as to retain as much as possible of the liquified gas in its liquid phase as spheroids 25. The transport gas 26 and liquid spheroids 25 pass through the flexible hose 46 and due to the fact that the heat exchange between the inner surface of the flexible hose 46 is with the transport gas 26, this flexible hose is not cooled to such low temperature as to render it rigid or incapable of being handled with bare hands. Due to the fact that the exterior of the flexible hose is heated from ambient sources, the temperature of the exterior of this hose does not drop more than 20° below ambient temperature.

The transport gas 26 and liquid spheroids 25 enter the tube or hollow body 48 in which a part of the carrier gas 26 is bled off through the bleed openings 50 in the sides of this tube into the manifold 51, the discharge from which is under control of a pressure relief valve 54.

In the form of the invention shown in FIGS. 1-3, the remaining transport gas 26 and liquid spheroids 25 pass from the outlet end 49 of the hollow body 48 into the receiver 55 in the form of a cryosurgical tool. The liquid spheroids 25 and remaining transport gas are projected out from the restricted nozzle end 56 of the tool by the doctor against the tissue or growth to be frozen. The size of the discharge orifice 56 from the tool, together with the source pressure, determines the operating pressure and the valve 54 is adjusted to provide the required rate of discharge from the nozzle end 56 of the cryosurgical tool 55. This tool 55 could also be used to project the droplets or spheroids 25 against a workpiece (not shown) being machined and the flexible hose 46 used to permit this tool 55 to follow the tool (not shown) doing the machining.

FIGS. 3-5

Referring to the form shown in FIGS. 3-5, the numeral 10 again represents a dewar bottle forming the pressurized source for a body 11 of cryogenic liquified gas contained in the chamber 12 provided by an inner container 13. The inner container is surrounded by an outer shell 14 with a vacuum space 15 therebetween, this space containing the usual insulation (not shown). The chamber 12 can be refilled with the cryogenic liquified gas 11 through a fill valve 16 in a fill line 18. In the form of the invention shown in FIGS. 3-5, however, the source pressure is shown as being varied in response to ambient pressures, as would be desirable in supplying cryogenic liquid to the receiver of an infrared detector (not shown) in an airplane, so as to insure a constant delivery of the liquid to provide a datum temperature for the detector, with a minimum amount of cryogenic liquid, regardless of changes in altitude (and hence the ambient pressure) of the airplane. For this purpose, the pressure relief line 60 is under control of a first conventional aneroid valve 61 shown as comprising a discharge valve seat at the outlet end of the line 60 facing the interior of a casing 62 maintained at ambient through a vent 63. The valve seat is engaged by a valve head 64 at the end of an evacuated bellows 65, the position and effect of which is adjustable by means of a screw mounting 66. As the ambient pressure decreases its effect in tending to open the valve head decreases.

The cryogenic liquified gas 11 is discharged through an outlet line 21 from the bottom of the chamber 12 and extending through the walls of the inner container 13 and outer shell 14, this line being provided with an on-off valve 22.

As with the form of FIGS. 1-3, a principal feature of the invention resides in the application of heat to the ex-

terior of the discharge line 21 to produce a succession of liquid spheroids 25 surrounded by gas 26 which forms a transport gas for these spheroids, this liquid to gas phase transition being known as the Leidenfrost phenomena. Such heating is effected by the heater and shown as arranged exteriorly of the dewar 10 around the discharge pipe 21. The heater 30 is of the same construction as the heater in FIGS. 1-3 and hence its description will not be repeated.

The liquid spheroids 25 and transport gas 26 discharge into the inlet end of a flexible hose 46 which discharges into the inlet end 70 of a hollow body 71, this hollow body preferably being in the form of a straight tube so that its outlet end 72 is in straight line relationship with its inlet end 70 and the liquid spheroids 25 are projected through the hollow body 71 like bullets. However, a part of the transport gas 26 is bled off through a plurality of bleed openings 73 in the sides of the hollow body 71. This gas from the bleed openings 73 is received in a manifold 74 having a discharge line 75 containing a restricted orifice 76. The required output of the apparatus is controlled by a valve 61 which is shown as being a second aneroid valve identical with the first aneroid valve 61 serving to maintain source pressure. Accordingly a description of the construction of this second aneroid valve will not be repeated, and the same reference numerals have been used for identical parts. The gas from this second aneroid valve 61 can be vented or can be usefully employed in any suitable manner (not shown).

The spheroids 25 and remaining transport gas 26 from the hollow body or tube 71 discharge into a flexible tube 80 which can be identical to the flexible tube 46. This flexible tube 80 discharges into a receiver 81 shown as being in the form of a closed hollow body in which the liquid 82 derived from the spheroids 25 collect and are withdrawn at 83 for use, say, to supply a low datum temperature of infrared detection.

To adjust the operating pressure to changes in ambient pressure when used in an airplane, the gas pressure in the receiver 81 can be controlled by a third aneroid relief valve 61 in a pressure relief line 84, this valve being of the same construction as the first and second aneroid valves 61 and the same reference numerals therefore having been applied to this third aneroid valve.

It will be seen that the apparatus of FIGS. 4-5 operates in the same manner as that of FIGS. 1-3 except that the droplets or spheroids 25 collect in the closed hollow body 81 instead of being projected from a nozzle, and that the operating pressure is determined by the first and third aneroid valves 61 for the Dewar 10 and receiver 81, respectively, and the required supply to the receiver 81 is determined by the aneroid valve 61 for the bleed manifold 74, the use of these aneroid valves compensating for changes in ambient pressure as in airplanes, for example, changes in altitude.

I claim:

1. Apparatus for transporting a stream of cryogenic liquified gas from a source to a receiver which comprises a heater, means conducting the liquified gas from said source in heat exchange relation to said heater to develop a plurality of liquid spheroids separated by a transport gas, means conducting said liquid spheroids and transport gas from said heater toward said receiver including a hollow body having an outlet in line with its inlet and at least one bleed opening in its side intermediate such aligned inlet and outlet whereby said liquid spheroids are projected from said inlet out through said outlet passing said bleed opening and a part of said transport gas is discharged from said hollow body through said bleed opening, and means conducting said liquid spheroids from said outlet to said receiver.

2. Apparatus for transporting liquified gas as set forth in claim 1 wherein said heater is arranged in closely spaced relation to said source.

3. Apparatus as set forth in claim 2 wherein said means

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conducting said liquified spheroids and transport gas from said heater toward said receiver comprises a flexible hose which would be rendered rigid at the cryogenic temperature of said liquified gas.

4. Apparatus as set forth in claim 1 wherein said heater comprises a heat source, and means responsive to the temperature of the transport gas regulating the input from said heat source.

5. Apparatus as set forth in claim 1 additionally including means regulating the pressure in said receiver.

6. Apparatus as set forth in claim 5 additionally including means regulating the pressure of the carrier gas discharged through said bleed opening.

7. Apparatus as set forth in claim 1 wherein said receiver is in the form of a nozzle having a restricted outlet to provide a back pressure against the flow of spheroids and transport gas out from said nozzle.

8. Apparatus as set forth in claim 1 additionally in-

cluding a first aneroid valve responsive to ambient pressure maintaining said source under pressure, a second aneroid valve responsive to ambient pressure regulating the bleed of gas through said bleed opening, and a third aneroid valve responsive to ambient pressure regulating the pressure in said receiver.

References Cited

UNITED STATES PATENTS

2,981,278	4/1961	Bergson	62—52	X
3,126,711	3/1964	Miller	62—55	X
3,289,424	12/1966	Shepherd	62—55	

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