United States Patent [19]

Perkins et al.

[11] **3,845,635**

[45] **Nov. 5, 1974**

[54] **PHASE-SEPARATING SPRAY HEADER**

[75] Inventors: **Warren Edwin Perkins,** Wyckoff, N.J.; **Michael Anthony Marchese,** Elmsford, N.Y.

[73] Assignee: **Union Carbide Corporation,** New York, N.Y.

[22] Filed: **Oct. 24, 1972**

[21] Appl. No.: **299,734**

[52] **U.S. Cl.** **62/51,** 55/189, 239/550

[51] **Int. Cl.** **F17c 7/02**

[58] **Field of Search** ... 62/514, 63, 45, 50, 374–376, 62/380; 239/549, 550; 55/189

[56] **References Cited**

UNITED STATES PATENTS

2,496,816	2/1950	Schlumbohm	62/514 X
3,109,296	5/1963	Williamson et al.	62/514 X
3,427,820	2/1969	Hart	62/380 X

Primary Examiner—Meyer Perlin
Assistant Examiner—Ronald C. Capossela
Attorney, Agent, or Firm—Bernard Lieberman

[57] **ABSTRACT**

Apparatus for selectively dispensing liquid phase cryogen from a two phase cryogenic fluid, and process therefor, comprising:

1. at least one liquid spray nozzle for directing a spray of liquid cryogen upon the products to be refrigerated,
2. at least one vapor venting nozzle for directing substantially all of the vapor phase cryogen into the surrounding atmosphere, and
3. manifold means connected to a source of cryogenic fluid for conveying said cryogenic fluid to the liquid and vapor nozzles.

The respective inlet ports of the liquid spray nozzle and the vapor venting nozzle are located in the lower and upper sections, respectively, of the manifold means. The equivalent cross-sectional area of the discharge orifice of the vapor venting nozzle is from about 1/3–2/3 of the corresponding area of the discharge orifice of the liquid spray nozzle.

4 Claims, 4 Drawing Figures

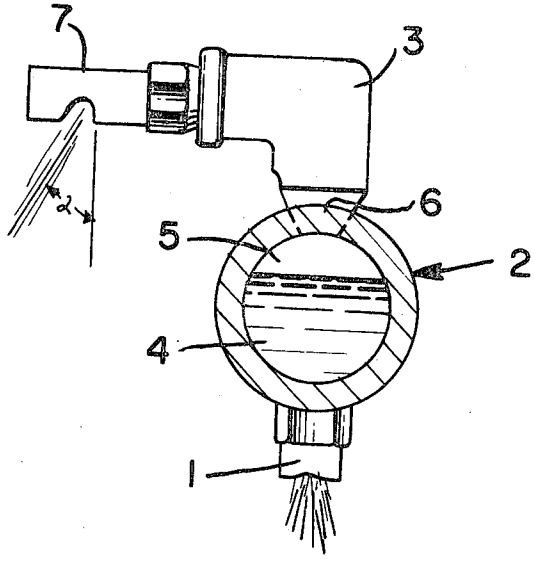


FIG. 1

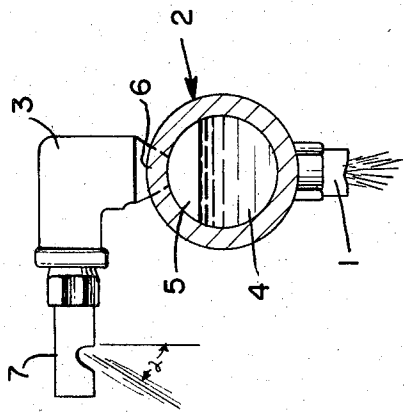


FIG. 2

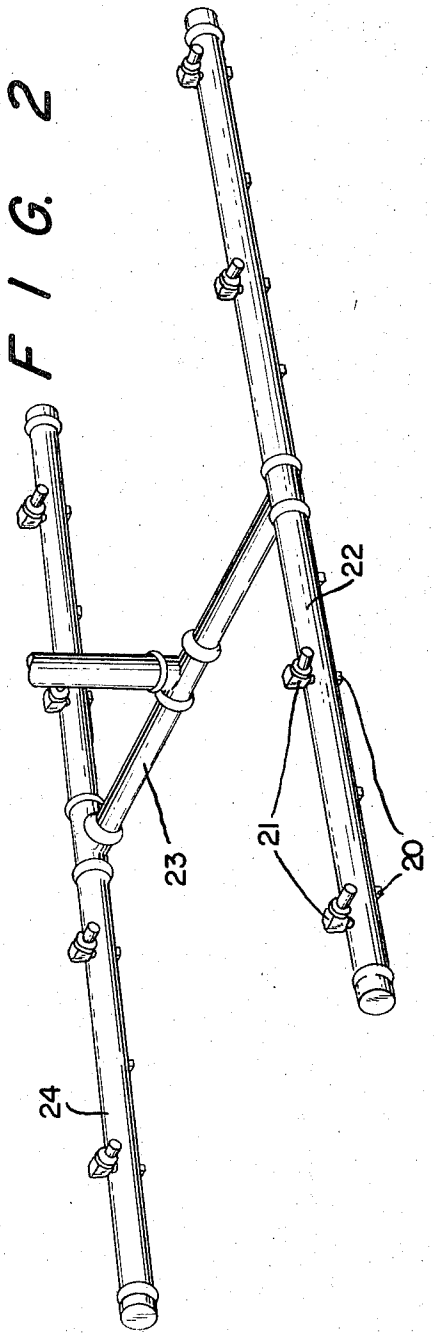


FIG. 3

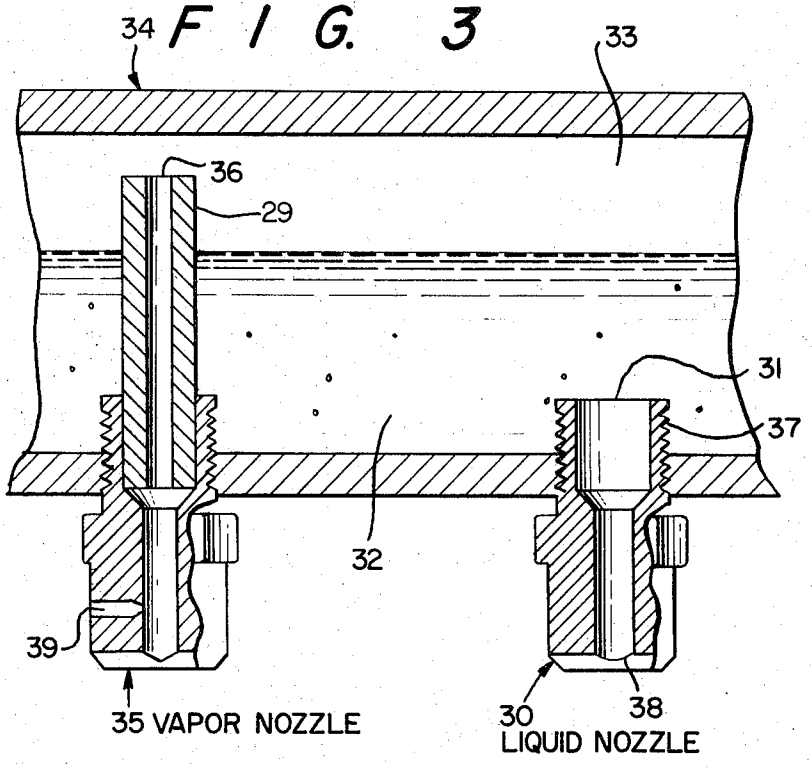
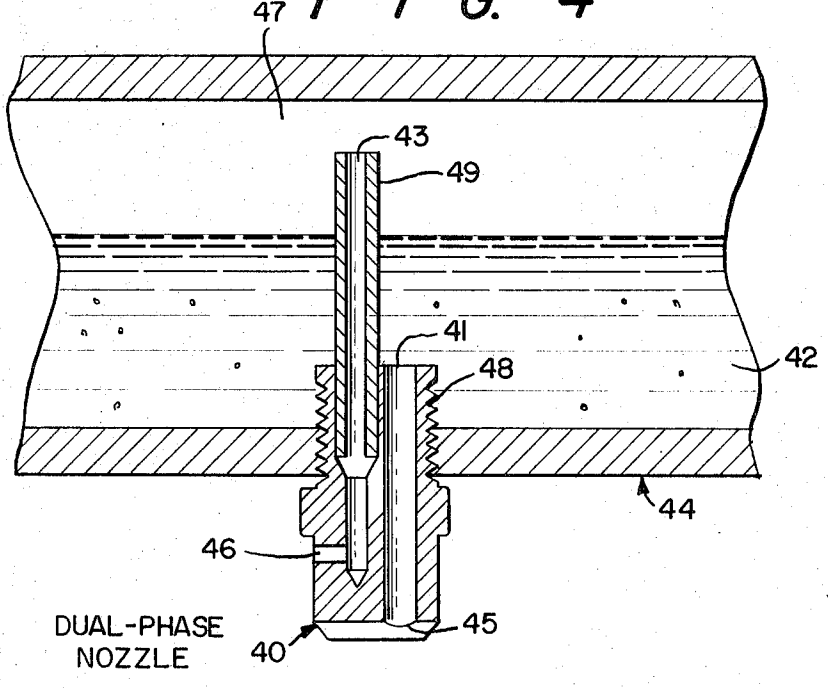

34
33
36
29
31
37
32
39
35 VAPOR NOZZLE
30
38
LIQUID NOZZLE

FIG. 4


47
43
49
41
48
42
44
46
45
DUAL-PHASE
NOZZLE
40

PHASE-SEPARATING SPRAY HEADER

BACKGROUND

This invention relates to a method and apparatus for spraying liquid phase cryogenic fluid onto products to be refrigerated.

In conventional direct contact cryogenic refrigeration systems, the cryogen is generally stored under pressure in an insulated tank from which it is transferred, upon demand, through a dispensing system to a terminal, commonly called a spray header, which discharges the cryogen over a preselected area to be refrigerated. In food freezing applications, for example, a continuous line of food products, such as meat patties, are passed through the preselected area wherein they are directly contacted with the cryogenic refrigerant. As heat gradually leaks into the storage tank, the cryogenic liquid tends to become saturated at the pressure of the storage tank and starts to boil. Further vaporization occurs when the cryogen is depressurized in the distribution lines. Specifically, the cryogenic liquid refrigerant undergoes a pressure drop along its flow path through the delivery system, resulting ultimately in a two-phase (vapor-liquid) cryogenic fluid in the spray header.

The presence of both liquid and vapor in the spray header is highly undesirable, because it causes uneven refrigeration of the products to be frozen. This is attributable primarily to the fact that for a refrigerant, such as liquid nitrogen or liquid air, the vapor phase contains only about half as much usable refrigeration as does the liquid phase; the enthalpy of the vapor being substantially higher because it includes the latent heat of vaporization. Consequently, the uniform refrigeration of products on a production-line basis becomes particularly difficult, since a given nozzle discharges gas and liquid alternately and in an unpredictable manner. In addition, it is desirable to dispense only liquid phase cryogen directly onto the product being refrigerated in order to take advantage of its substantially higher heat transfer coefficient. That is, a smaller heat exchange area is required when refrigerating with liquid phase cryogen because the surface heat transfer coefficient of boiling liquid in contact with the product being refrigerated is five to 15 times higher than the corresponding coefficient between the vapor phase cryogen and the product surface. Moreover, for a given differential pressure, a substantially greater mass flow of liquid, than of vapor, will be dispensed through a given orifice in the spray header. Therefore, an orifice dispensing predominantly vapor delivers not only less mass flow for a given differential pressure, but also a reduced refrigeration capacity per unit of mass than does an orifice which dispenses primarily liquid. Thus, the overall result of discharging vapor instead of liquid from a nozzle is to lower its refrigerating capacity by more than an order of magnitude.

Heretofore, conventional spray headers have been designed with orifices (or nozzles) generally mounted in the header with their inlets at substantially the same level. If the refrigerant to be dispensed is a two-phase fluid, it is extremely important that the spray header be level because even a slight incline will result in gross differences in refrigeration being dispensed from nozzles on the high and low sides due to vapor and liquid separation which occurs within the header. That is, the higher nozzles may dispense only vapor, leaving "stripes" of non-uniform, top-refrigerated products. Consequently, care must be taken to insure that all of the nozzle inlets be maintained at the same relative height in the spray header. However, even if the nozzle inlets are properly aligned, the presence of a two-phase fluid in the header is still troublesome because of the uneven venting of the vapor phase. That is to say, the fluid being vented from any nozzle at any given instant of time is an unpredictable combination of vapor and liquid, and hence, produces a correspondingly unpredictable level of refrigeration.

Phase separators, well known in the art, have been placed upstream of the spray header in an attempt to remove all the vapor from the refrigerant and feed only a single phase, liquid cryogen, to the spray header. This, however, has numerous disadvantages, and has proven to be generally unsuccessful in commercial operations. Primarily, this is because the phase separator is located upstream of the principal areas of depressurization, namely, the flow control valve and the spray header. Therefore, as the fluid proceeds through additional piping and the flow control valve, two phase flow once again appears. Thus, the use of a separator upstream of the spray header reduces the problem in that it reduces the percentage of vapor in the fluid, but does not solve the problem, since even small amounts of vapor in the header create serious refrigeration problems. Furthermore, the use of an external phase separator is impractical, from a mechanical standpoint, in that the separator represents additional apparatus which must be installed and insulated, and two insulated lines, for transporting the separated liquid and vapor, must be run from the separator into the processing area adjacent to the spray header. This complicates the overall refrigeration system and represents an additional source of thermal inefficiency.

OBJECTS

Accordingly, it is an object of the present invention to provide an apparatus and process for selectively dispensing cryogenic liquid from a two-phase cryogenic fluid over a preselected area to be refrigerated.

It is another object of this invention to provide a refrigerating apparatus and process capable of operating efficiently with fluid refrigerants of variable quality, i.e., refrigerants which, when depressurized, contain variable percentages of vapor.

It is still another object of this invention to provide a freezing apparatus and process capable of operating efficiently over a relatively wide range of refrigerant mass flow rates.

SUMMARY

These and other objects, which will become apparent from the detailed disclosure and claims to follow, are achieved by the present invention, one aspect of which comprises: apparatus for selectively dispensing liquid-phase cryogen from a two-phase cryogenic fluid onto products to be refrigerated passing beneath said apparatus, comprising in combination:

1. at least one liquid spray nozzle having an inlet port and a discharge rate-controlling orifice for directing a spray of liquid cryogen upon the products to be refrigerated,

2. manifold means for conveying said two-phase cryogenic fluid to said spray nozzle, said manifold means

being connected to a source of cryogenic fluid and having an upper and a lower section, said inlet port of said liquid spray nozzle being located in the lower section of said manifold means, and

3. at least one vapor venting nozzle for directing substantially all of the vapor phase cryogen into the surrounding atmosphere, said vapor venting nozzle having an inlet port located in the upper section of said manifold means and a discharge rate controlling orifice communicating with the surrounding atmosphere, the equivalent cross-sectional area of the discharge orifice of said vapor venting nozzle being from about 1/3 – 2/3 of the equivalent cross-sectional area of the discharge orifice of said liquid spray nozzle.

The second aspect of the present invention is a process for selectively dispensing liquid cryogen from a two-phase cryogenic fluid onto products to be refrigerated comprising the steps of:

1. providing manifold means having an upper and lower section, and connected to at least one liquid spray nozzle having an inlet port located in said lower section and at least one vapor venting nozzle having an inlet port located in said upper section,

2. introducing said two-phase cryogenic fluid into said manifold means,

3. discharging substantially all the liquid phase cryogen through said spray nozzle onto the products to be refrigerated, and

4. discharging substantially all the vapor phase cryogen through said vapor venting nozzle into the surrounding atmosphere, said vapor venting nozzle having a discharge rate controlling orifice with an equivalent cross-sectional area of from about 1/3 – 2/3 of the equivalent cross-sectional area of the discharge rate controlling orifice of the liquid spray nozzle.

One of the essential discoveries of the present invention is that by providing a vapor venting nozzle in the spray header, the spray header becomes, unexpectedly, much less sensitive to attitude, i.e., being level. Specifically, the presence of a vapor nozzle in the upper section of the manifold permits the vapor phase cryogen to be vented independent of the liquid spray nozzle. This is significant, because unlike prior art spray headers, the apparatus of the invention can be operated at an unexpectedly large incline relative to the horizontal, without discharging vapor from the relatively higher inclined liquid dispensing nozzle or dispensing liquid from the relatively lower inclined vapor venting nozzles. In other words, the presence of a vapor venting nozzle within the spray header serves to insure that all liquid nozzle inlet ports will operate substantially submerged, thereby greatly reducing the sensitivity of the header to precise leveling.

To insure stable operation, it is important that the vapor and liquid dispensing nozzles have their inlet ports located in the upper and lower sections, respectively, of the manifold means so as to insure that the inlet ports of vapor and liquid nozzles are not at the same level, and hence not in contact with the same phase in the spray header; the vapor phase being predominantly in the upper section of the manifold and the liquid phase being predominantly in the lower section of the manifold. Specifically, the "upper" section has as its lower boundary the elevation along the manifold below which substantially vapor phase cryogen will not be discharged from the vapor venting nozzle. Correspondingly, the "lower" section has as its upper boundary the elevation along the manifold above which substantially liquid phase cryogen will not be discharged from the liquid spray nozzle. Preferably, the vertical separation, as viewed axially along the manifold, between the vapor nozzle inlet port and the inlet port of the liquid spray nozzle is at least 1/4 inch. However, the minimum required separation between the respective inlet ports of the liquid and vapor nozzles, for purposes of the invention, is a function of several variables. Included among these are the flow rate of the refrigerant, the discharge pressure of the liquid spray nozzle, the length and cross-sectional area of the manifold, and the incline of the header with respect to the horizontal. For any given set of conditions, the locations of the "upper" and "lower" sections, as herein defined, are best determined experimentally.

A further important feature of the present invention is that it accomplishes phase separation at the point where it will be most effective, namely, at the point of final depressurization in the spray header. Moreover, phase separation is accomplished efficiently, simply, dependably and inexpensively. By way of contrast, the use of a conventional phase separator is costly, undependable and ineffective inasmuch as it does not eliminate the essential operational problems concomitant with dispensing a two-phase cryogenic fluid, namely, uneven refrigeration when refrigerating products on a continuous production-line basis because of the intermittent discharge of vapor from the liquid spray nozzle, and the extreme sensitivity of the spray header to orientation.

The term "equivalent" cross-sectional area, as used herein, has specific reference to non-circular orifices for which the cross-sectional area should be calculated using the equivalent diameter.

The equivalent cross-sectional orifice area of the liquid dispensing nozzle is normally selected in terms of the peak refrigeration demand rate. That is, the orifice area should be such as to dispense the required peak mass flow of liquid refrigerant when the pressure across the liquid spray nozzle is from about 15–40 psig. The vapor venting nozzle should be sized to create sufficient back pressure so as to provide the driving force for liquid expulsion from the liquid nozzle. Accordingly, the equivalent cross-sectional area of the vapor nozzle discharge orifice should generally be about 1/3–2/3 of the corresponding area of the liquid nozzle with the preferred ratio being about 1/2.

A further aspect of the invention which enhances uniform refrigeration is that regardless of the liquid saturation pressure in the tank, the spray header tends to operate at nearly the same pressure for a given refrigeration flow rate. In conventional spray headers, the operating pressure in the header necessary for maintaining a given refrigeration rate is dependent upon the quality of the liquid refrigerant. That is to say, whenever vapor and liquid are being dispensed through a common nozzle, the operating pressure of the nozzle will, of necessity, be sensitive to liquid quality. This is undesirable because the quality of the refrigerant is continually changing with time, and hence the pressure in the header must fluctuate accordingly resulting in variable atomization and, therefore, an erratic refrigeration process. By way of contrast, the present invention permits the header to operate at substantially the same pressure, for a given refrigeration demand rate, during the entire operating cycle which includes start-up when

the refrigerant is "warmer," i.e., has a higher saturation pressure and temperature, and during steady-state operation when the supply line has become thoroughly cooled and liquid saturation pressure and temperature are lower.

Although, only one liquid nozzle and one vapor nozzle need be provided in the spray header, for most practical operations, a plurality of liquid and vapor nozzles, uniformly distributed along the length of the manifold, is preferred. It should be noted, however, that regardless of the number of nozzles actually employed, the ratio of the cumulative cross-sectional areas of the respective liquid and vapor nozzle orifices, is to be selected in the manner previously discussed.

DRAWINGS

FIG. 1 is a schematic drawing showing, in cross-section, a spray header with oppositely mounted liquid and vapor dispensing nozzles, one embodiment of the apparatus of the invention.

FIG. 2 is an isometric view of a spray header containing a plurality of liquid and vapor dispensing nozzles.

FIG. 3 is a schematic drawing showing, in cross-section, liquid and vapor dispensing nozzles mounted along the bottom of the manifold, another embodiment of the apparatus of the invention.

FIG. 4 is a schematic drawing similar to FIG. 3, illustrating a unitary structure comprising a unitary liquid and vapor dispensing nozzle structure.

DETAILED DESCRIPTION

Referring to FIG. 1, liquid spray nozzle 1 and vapor venting nozzle 3 are shown mounted in the lower and upper sections, respectively, of manifold 2. The cryogenic refrigerant is shown separated in manifold 2 into liquid phase 4 and vapor phase 5. The vapor phase cryogen 5 is vented from manifold 2 by entering inlet port 6 of vapor nozzle 3 and is discharged to the surrounding atmosphere through discharge port 7. Discharge port 7 is preferably disposed at an angle α relative to the vertical, so as to direct the discharged vapor into the mass of refrigerant vapor which is continually being recirculated over the area to be refrigerated, or in the event any liquid from liquid phase cryogen 4 should enter inlet port 6, it will be vaporized before it comes into contact with the products to be refrigerated, thereby dispensing the liquid with the same effect as if it were vapor. The importance of properly orienting the discharge port 7 is to insure that any discharged liquid cryogen will travel an extra distance through the relatively warmer ambient vapors before it strikes the products to be refrigerated, thereby causing it to be vaporized. In so doing, the effluent becomes a part of the recirculated vapor and the uniform refrigeration of the products is enhanced.

Reference to FIG. 2 shows a preferred embodiment of the apparatus of the invention, namely, a plurality of liquid and vapor dispensing nozzles 20 and 21, respectively, uniformly spaced along manifold means 22. Connector pipe 23, communicating with a source of cryogenic fluid (not shown), feeds the two-phase cryogen into manifolds 22 and 24. In FIG. 2 the vapor venting nozzles 21 are shown positioned along the upper section of manifold 22 such that their inlet ports (not visible in this view) will be in substantial vertical alignment with the inlet port of a corresponding liquid spray nozzle 20 mounted along the lower section of manifold 22. Numerous alternate arrangements may also be effectively used. Thus, for example, the vapor venting nozzles 21 may optionally be positioned along the upper section of manifold 22 midway between two corresponding liquid spray nozzles 20 mounted along the lower section.

FIG. 3 illustrates an embodiment of the invention wherein both the liquid and vapor nozzles are mounted at the bottom of the manifold. Liquid spray nozzle 30 is mounted into manifold 34 via thread 37 and has its inlet port 31 located in the lower section of manifold 34. Inlet port 31 communicates with discharge orifice 38. Vapor nozzle 35, similarly mounted at the bottom of the manifold 34, has an extension tube 29 extending into the upper section 33 of manifold 34 so that the inlet port 36 will be located in the aforesaid upper section 33. Inlet port 36 communicates with vapor discharge orifice 39.

Reference to FIG. 4 shows an embodiment of the invention wherein a unitary structure comprises both the liquid and vapor nozzles. Dual-phase nozzle 40 is mounted at the bottom of manifold 44 via thread 48 and has two inlet ports 41 and 43 communicating with two corresponding discharge orifices 45 and 46, respectively. Inlet port 41 is located in the lower section 42 of manifold 44, and inlet port 43, at the top of extension tube 49, is located in the upper section 47 of manifold 44. Liquid phase cryogen is discharged through orifice 45 and vapor phase cryogen is discharged through orifice 46. For purposes of the drawings, vapor nozzle 35 and dual-phase nozzle 40, illustrated in FIGS. 3 and 4, are shown rotated 90° on their respective nozzle axes from the preferred orientation of the vapor phase discharge orifice.

What is claimed is:

1. Apparatus for selectively dispensing liquidphase cryogen from a two-phase cryogenic fluid onto products to be refrigerated passing beneath said apparatus, comprising in combination:
   1. at least one liquid spray nozzle having an inlet port and a discharge rate-controlling orifice for directing a spray of liquid cryogen upon the products to be refrigerated,
   2. manifold means for conveying said two-phase cryogenic fluid to said spray nozzle, said manifold means being connected to a source of cryogenic fluid and having an upper and a lower section, said inlet port of said liquid spray nozzle being located in the lower section of said manifold means, and
   3. at least one vapor venting nozzle for continuously directing substantially all of the vapor phase cryogen into the surrounding atmosphere, said vapor venting nozzle having an inlet port located in the upper section of said manifold means, and a discharge rate controlling orifice communicating with the surrounding atmosphere, the equivalent cross-sectional area of the discharge orifice of said vapor venting nozzle being from about 1/3 – 2/3 of the equivalent cross-sectional area of the discharge orifice of said liquid spray nozzle.

2. The spray header of claim 1 wherein the vertical separation, as viewed axially along the manifold, between said vapor nozzle inlet port and said liquid nozzle inlet port is at least 1/4 inch.

3. The spray header of claim 1 wherein the equivalent cross-sectional area of the discharge orifice of the vapor venting nozzle is about one-half of the corresponding area of the discharge orifice of the liquid spray nozzle.

4. The spray header of claim 1 wherein the liquid nozzle and the vapor nozzle are mounted at the bottom and top, respectively, of the manifold.

* * * * *