United States Patent [19]

Davis

[11] **3,858,404**

[45] **Jan. 7, 1975**

[54] **PHASE SEPARATOR FOR CRYOGENIC FLUID**

[75] Inventor: **Robert Bruce Davis,** Nyack, N.Y.

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

[22] Filed: **June 25, 1973**

[21] Appl. No.: **373,382**

[52] **U.S. Cl.** **62/51,** 62/54, 62/55

[51] **Int. Cl.** **F17b 7/02**

[58] **Field of Search** 62/45, 55, 54, 50, 51

[56] **References Cited**

UNITED STATES PATENTS

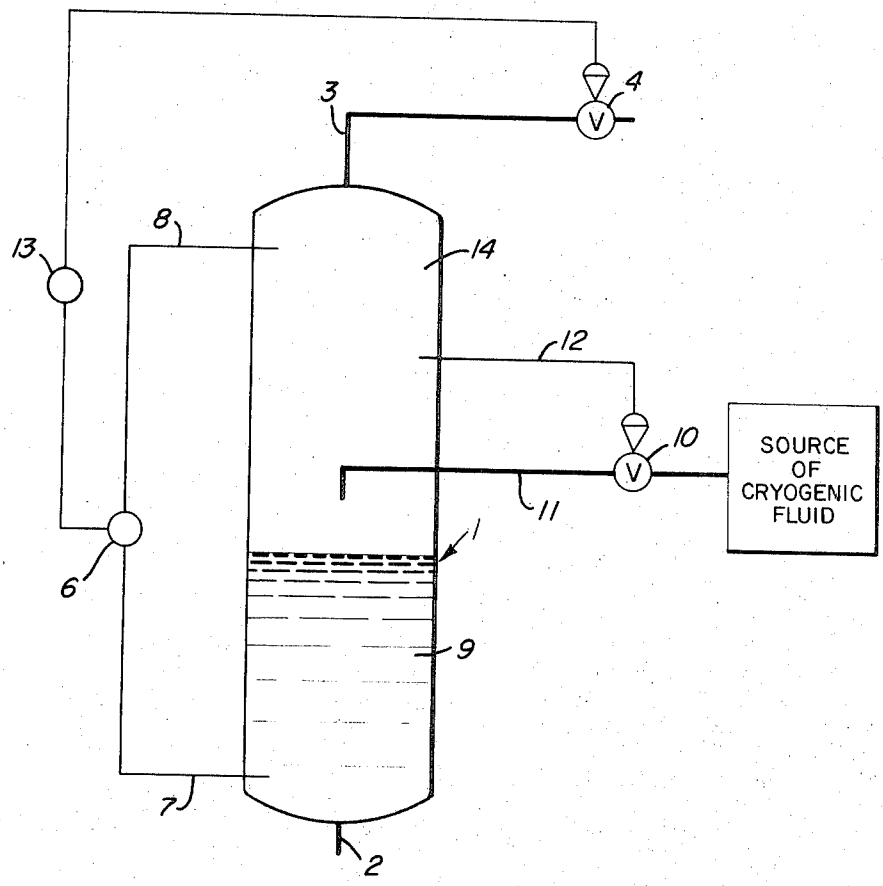
2,756,765	7/1956	Agule et al.	62/55 X
2,964,916	12/1960	Keeping	62/55 X
3,097,496	7/1963	Petts et al.	62/55 X
3,262,280	7/1966	Chaney	62/55 X
3,555,483	1/1971	Tener	62/55 X

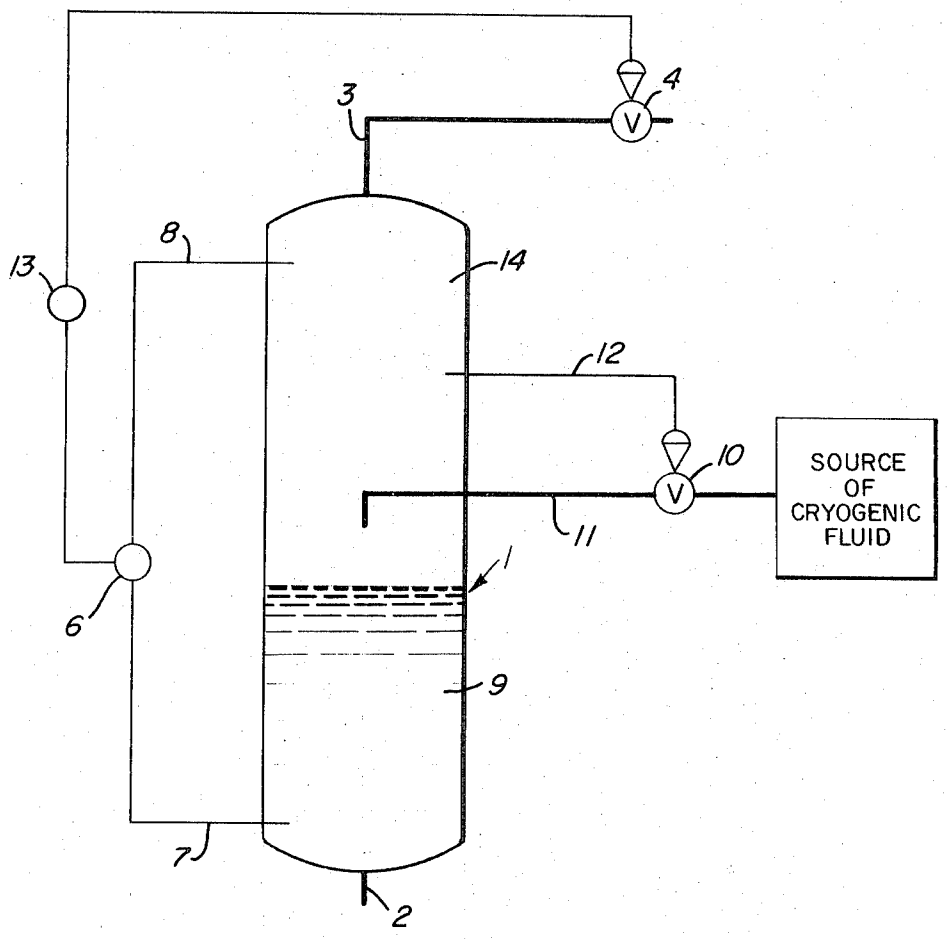
Primary Examiner—Meyer Perlin
Assistant Examiner—Ronald C. Capossela
Attorney, Agent, or Firm—Bernard Lieberman

[57] **ABSTRACT**

A system for maintaining a liquid head of cryogen in a separator vessel for a 2-phase cryogenic fluid comprising in combination a separator vessel having discharge lines for liquid and vapor in the bottom and top sections, respectively; a diaphragm-operated vent valve disposed in the vapor discharge line; and a pressure regulating valve to control the flow of cryogen from the source of cryogenic fluid to the separator vessel. A pneumatic computing relay is connected to the vessel in combination with an amplifier to actuate the vapor vent valve such that the valve will open and close in response to changes of liquid level in the vessel.

2 Claims, 1 Drawing Figure




3
4
V
8
13
14
12
10
V
SOURCE
OF
CRYOGENIC
FLUID
11
1
6
9
7
2

PHASE SEPARATOR FOR CRYOGENIC FLUID

This invention relates, in general, to a level controller for cryogenic liquids, and more particularly to an automatic liquid level control for use in a cryogenic fluid phase separator.

In conventional 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 which discharges the cryogen over the intended area of use. As heat gradually leaks into the storage tank and as the cryogenic liquid loses pressure in flowing through the distribution lines, vaporization occurs within the refrigeration system resulting in a two-phase (vapor-liquid) cryogenic fluid.

The presence of vapor in the discharged cryogen is, for the most part, undesirable because 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. Thus, the uniform refrigeration of products on a production-line basis becomes particularly difficult, since the refrigeration capacity and quantity of the discharged cryogen is unpredictable. Control is made additionally difficult because of the volume difference between the vapor and liquid phases, resulting in fluctuating mass flow through a control valve or orifice. Consequently, phase separators are commonly placed upstream of the discharge nozzle in an attempt to remove all the vapor from the refrigerant prior to discharging same over the preselected area to be refrigerated.

One of the principal problems associated with the phase separation of cryogenic fluids relates to automatically controlling the level of liquid cryogen in the separator. While there are many satisfactory forms of level control for ordinary fluids, cryogenic liquids pose unique problems. At the extreme low temperatures of such liquids, components of mechanical devices, such as float valves, frequently freeze to adjacent elements and become inoperative. Electrical systems may also be undesirable in that they generate heat and thereby accelerate evaporization losses. Differential pressure transmitters and pressure controllers specifically designed for maintaining and controlling liquid level are commercially available and are known to operate effectively in maintaining a constant liquid head of cryogen in a vessel; however, in many instances their relatively high cost makes the use of such automatic equipment impractical.

OBJECTS

Accordingly, it is an object of the present invention to provide apparatus for controlling the level of a cryogenic liquid in a separator.

A further object of the invention is to provide a relatively inexpensive system of automatic control for maintaining the level of a cryogenic liquid in a separator within predetermined upper and lower limits.

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:

a system for maintaining a liquid head of cryogen in a separator vessel for a 2-phase cryogenic fluid comprising in combination:

1. a separator vessel, partially filled with a 2-phase cryogenic fluid forming a vapor phase in the top section and a liquid phase in the bottom section thereof, having discharge lines for liquid and vapor in said bottom and top sections, respectively, and a conduit connecting said vessel to a source of cryogenic fluid;
2. a pressure regulating valve disposed in said conduit for controlling the flow of cryogenic fluid from said source to said separator vessel, said regulating valve being responsive to the vapor phase pressure in said vessel so as to close said valve when said vapor phase pressure exceeds the desired operating pressure in said vessel;
3. a pneumatic diaphragm-operated vapor venting valve of the air to close type disposed in said vapor discharge line for controlling the flow of vapor from the separator vessel;
4. a pneumatic computing relay for actuating said diaphragm-operated valve, said relay being connected to the separator vessel to sense the differential pressure caused by the varying liquid head, the relay having one pressure signal line in the top vapor phase section of the vessel and a second pressure signal line in the bottom liquid phase section; and
5. an amplifier for multiplying the output signal of said computing relay by a factor of from about 3:1 to 6:1, said relay having its bias adjusted such that at the maximum allowable liquid head in the vessel the resulting amplified signal from the relay is at least equal to the maximum operating pressure in the diaphragm operating range thereby enabling the vapor venting valve to open and close in response to the changing liquid level in the vessel and produce a corresponding change in the vapor phase pressure of said vessel such that the flow rate of cryogen into the vessel will be regulated so as to continually maintain a liquid head therein.

The term "computing relay" as used herein refers to a conventional relay capable of transmitting a signal T consisting of the difference of two loading pressures, A and B, plus a fixed bias K such that: $T = A-B+K$.

The "diaphragm operating range" of the vent valve, as that term is used throughout the specification and claims, refers to the pressure range required to stroke the valve from open to close or vice versa. Thus, an "air to close" type valve is normally fully closed when the pressure signal to the diaphragm is at the extreme upper end of its operating range (e.g., 15 psi for a 3–15 psi range) and normally fully open when said signal is at or below the extreme lower end of the range (e.g., 3 psi for the aforementioned operating range). An "air to open" valve, on the other hand, is normally fully open at the extreme upper end of its operating range and normally fully closed at the lower end. Although the diaphragm operating range is not a critical parameter of the invention, nevertheless, a rating of 3–15 psi or 6–30 psi is preferred because the majority of commercially available pneumatic valves are presently designed to operate within one of these two pressure ranges.

The "maximum allowable liquid head" in the vessel refers to the liquid head corresponding to the minimum

vapor head space in the vessel necessary for allowing the vapor and liquid phases to efficiently disengage. The liquid level in the separator should preferably not exceed a height equal to the vertical dimension of the vessel minus 2.5 times the vessel diameter. For most effective operation, the vessel inner diameter should be sized at about 3 inches for a liquid throughput of 100 lb/hr and about 6–8 inches for a flow of 1,000 lb/hr of liquid.

DRAWINGS

FIG. **1** is a schematic drawing illustrating a preferred system for automatically controlling the liquid level of cryogen in a phase separator.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, phase separator **1** is shown containing liquid discharge line **2** and vapor discharge line **3** in the bottom and top sections thereof, respectively. Diaphragm-operated vapor vent valve **4** controls the flow of vapor being vented through the vapor discharge line **3.** Pneumatic computing relay **6** is connected to vessel **1** so as to sense the change in pressure caused by the varying liquid head in the vessel. Accordingly, relay signal lines **7** and **8** are connected to the bottom and top sections, respectively of vessel **1** such that pressure signal line **7** is responsive to fluctuations in the level of cryogenic liquid **9** while signal line **8** measures the pressure in the vapor phase **14.** The measured pressure differential reflects changes in liquid head in the vessel. The bias adjustment of relay **6** is set such that at the maximum allowable liquid head in vessel **1,** the output signal to vent valve **4** is sufficient to fully close said valve. That is to say, for an air to close type valve, the actuating signal to the valve diaphragm must be at least equal to the maximum operating pressure in the diaphragm operating range, while for an air to open type valve, the corresponding signal must be no greater than the minimum operating pressure in the diaphragm operating range.

Diaphragm-operated pressure regulating valve **10** controls the flow of cryogen through inlet line **11** in response to the vapor phase pressure in separator vessel **1.** The operating pressure in the separator is set by adjusting the stroke on pressure regulating valve **10** such that for an air to close type valve, the valve just starts to open at the desired operating pressure. In other words, at pressures above the desired operating pressure, the regulating valve **10** will be completely shut. Pressure regulating valve **10** is preferably selected such that its diaphragm pressure need not vary over the full operating range (e.g., 3–15 psi) in order to maintain vessel **1** at the desired operating pressure. The characteristics of valve **10** should be such that a very small change in diaphragm pressure will result in a very large change in flow through the valve. For example, if phase separator **1** is designed for flows up to 1,000 lbs/hr and a separator pressure of 8 psig is desired, than the pressure regulating valve **10** should be selected such that with a diaphragm pressure of 8 psig, the valve just starts to open and with a diaphragm pressure of about 7 psig, the valve will pass the maximum required flow, 1,000 lbs/hr. If the desired operating pressure is within the operating range of valve **10,** said valve may be actuated directly by the vapor phase pressure in vessel **1.** That is, pressure signal line **12** may be connected directly to the valve **10,** as shown in the drawing, thereby avoiding the necessity of using a pressure controller to sense the separator pressure and provide a signal to valve **10.**

Amplifier **13** multiplies the output signal of relay **6** by a factor of from about 3:1 to 6:1 with the resulting amplified signal being used to actuate the diaphragm-operated vapor vent valve **4.** For most effective operation, signal amplification should not exceed a factor of 6:1, since beyond that, even relatively small changes in liquid will result in large variations in the output signal to the diaphragm, thereby creating unstable operating conditions for vapor vent valve **4.**

In operation, a **2**-phase cryogenic fluid from a storage tank (not shown) at a pressure of from about 20–200 psig enters vessel **1** through inlet line **11** wherein it is depressurized to about 4–10 psig, the cryogenic fluid under going phase separation to form liquid phase cryogen **9** in the bottom section of said vessel and vapor phase cryogen **14** in the top section of said vessel. The pressure in the separator vessel is preferably maintained as low as possible, since the lower the pressure, the greater the amount of vapor produced and hence, the less the amount of vapor remaining in equilibrium with the liquid. Saturated liquid phase cryogen **9** is discharged, upon demand, through liquid discharge line **2** while vapor phase cryogen **14** is vented to the atmosphere through vapor discharge line **3.** If the level of liquid phase cryogen **9** begins to rise in vessel **1,** such as, for example, when the demand is suddenly reduced, the pressure differential measured by signal lines **7** and **8** increases due to the added head of liquid in the vessel. This results in a greater signal being sent to vent valve **4,** the effect of which is to partially close the valve relative to its previous position. This causes the vapor phase pressure within vessel **1** to increase which, in turn, causes pressure regulating valve **10** to partially close, reducing the flow of cryogen through inlet line **11.** As the liquid level continues to rise, the incoming flow of cryogen is progressively reduced to the point where it equals the discharge flow through line **2,** thereby stabilizing, once again, the level of liquid cryogen in vessel **1.** At the maximum allowable liquid level in the vessel, vapor vent valve **4** will close completely. The resultant rapid pressure build-up in vessel **1,** will cause pressure regulating valve **10** to fully close, thereby discontinuing the flow of cryogenic fluid into the separator vessel **1.** The incoming flow of cryogen will thereafter only be resumed when the liquid level in the vessel becomes sufficiently low to allow the vapor phase pressure in the vessel to fall below the desired operating pressure. At that point, pressure regulating valve **10,** will, once again, open so as to maintain a constant liquid head within the vessel **1.**

EXAMPLE

A phase separator, such as shown in FIG. **1,** was used in conjunction with a source of liquid nitrogen at a pressure of 75 psig and a flow rate of 690 lbs/hr. The vessel pressure was maintained at 10 psig. The separator vessel had a diameter of 6 inches and a length of 43 inches. The maximum allowable liquid level was 25 inches. A conventional relay was used with the bias settings shown in Table I for both an air to open and air to close type vent valve in the vapor discharge line. The output signal of the relay was amplified by a factor of 6:1. Saturated liquid phase cryogen was continually withdrawn from the bottom of the vessel for a period of about **1** hour. The operating pressure of the vessel

and the level of liquid nitrogen was maintained substantially constant throughout the run.

TABLE I

VALUES OF OPERATING VARIABLES FOR LIQUID LEVEL CONTROL IN PHASE SEPARATOR

Separator Level			Bias Setting	Relay	Signal After	Vent Valve
Inches LN_2	Inches H_2O	(A–B) Psi	"K" on Relay	Output	Amplifier	Position
FOR AIR TO OPEN VENT VALVE						
25.0	20.19	−0.727	+1.227	0.5	3.0	Closed
18.0	14.53	−0.524	+1.227	0.703	4.2	10% Open
0	0	0	+1.227	1.227	7.4	35% Open
FOR AIR TO CLOSE VENT VALVE						
25.0	20.19	+0.727	+1.773	2.5	15.0	Closed
18.0	14.53	+0.524	+1.773	2.297	13.8	10% Open
0	0	0	+1.773	1.773	10.6	35% Open

SIGNAL TO VENT VALVE (psi) = 6 [(A–B) + K] Amplification factor = 6:1

What is claimed is:

1. A system for maintaining a liquid head of cryogen in a separator vessel for a 2-phase cryogenic fluid comprising in combination:

1. a sealed separator vessel, partially filled with a 2-phase cryogenic fluid forming a vapor phase in the top section and a liquid phase in the bottom section thereof, having discharge lines for liquid and vapor in said bottom and top sections, respectively, and a conduit connecting said vessel to a source of cryogenic fluid;
2. a pressure regulating valve disposed in said conduit for controlling the flow of cryogenic fluid from said source to said separator vessel, said regulating valve being responsive to the vapor phase pressure in said vessel so as to close said valve when said vapor phase pressure exceeds the desired operating pressure in said vessel;
3. a pneumatic diaphragm-operated vapor venting valve of the air to close type disposed in said vapor discharge line for controlling the flow of vapor from the separator vessel;
4. a pneumatic computing relay for actuating said diaphragm-operated valve, said relay being connected to the separator vessel to sense the differential pressure caused by the varying liquid head, the relay having one pressure signal line in the top vapor phase section of the vessel and a second pressure signal line in the bottom liquid phase section; and
5. an amplifier for multiplying the output signal of said computing relay by a factor of from about 3:1 to 6:1, said relay having its bias adjusted such that at the maximum allowable liquid head in the vessel the resulting amplified signal from the relay is at least equal to the maximum operating pressure in the diaphragm operating range thereby enabling the vapor venting valve to open and close in response to the changing liquid level in the vessel and produce a corresponding change in the vapor phase pressure of said vessel such that the flow rate of cryogen into the vessel will be regulated so as to continually maintain a liquid head therein.

2. A system for maintaining a liquid head of cryogen in a separator vessel for a 2-phase cryogenic fluid comprising in combination:

1. a sealed separator vessel, partially filled with a 2-phase cryogenic fluid forming a vapor phase in the top section and a liquid phase in the bottom section thereof, having discharge lines for liquid and vapor in said bottom and top sections, respectively, and a conduit connecting said vessel to a source of cryogenic fluid;
2. a pressure regulating valve disposed in said conduit for controlling the flow of cryogenic fluid from said source to said separator vessel, said regulating valve being responsive to the vapor phase pressure in said vessel so as to close said valve when said vapor phase pressure exceeds the desired operating pressure in said vessel;
3. a pneumatic diaphragm-operated vapor venting valve of the air to open type disposed in said vapor discharge line for controlling the flow of vapor from the separator vessel;
4. a pneumatic computing relay for actuating said diaphragm-operated valve, said relay being connected to the separator vessel to sense the differential pressure caused by the varying liquid head, the relay having one pressure signal line in the top vapor phase section of the vessel and a second pressure signal line in the bottom liquid phase section; and
5. an amplifier for multiplying the output signal of said computing relay by a factor of from about 3:1 to 6:1, said relay having its bias adjusted such that at the maximum allowable liquid head in the vessel the resulting amplified signal from the relay is at least equal to the minimum operating pressure in the diaphragm operating range thereby enabling the vapor venting valve to open and close in response to the changing liquid level in the vessel and produce a corresponding change in the vapor phase pressure of said vessel such that the flow rate of cryogen into the vessel will be regulated so as to continually maintain a liquid head therein.

* * * * *