

Oct. 22, 1963

H. E. TAYLOR ETAL
LIQUID VAPOR SEPARATOR

3,107,988

Filed Sept. 12, 1960

4 Sheets-Sheet 1

FIG. 1

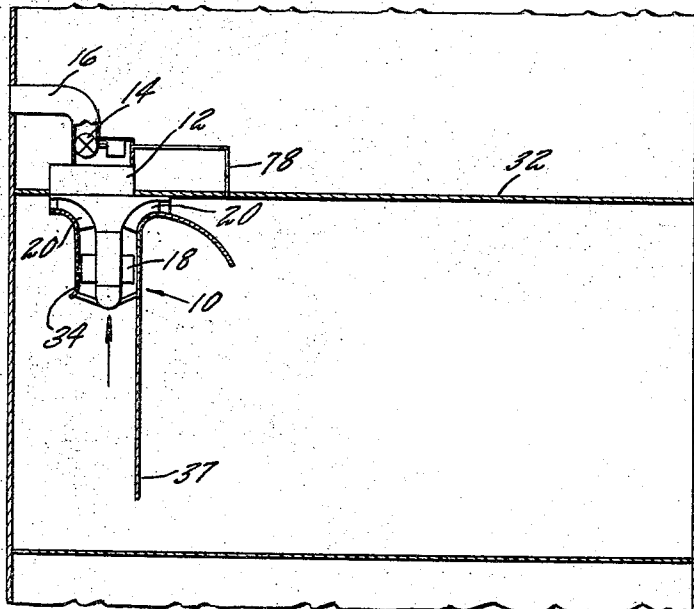
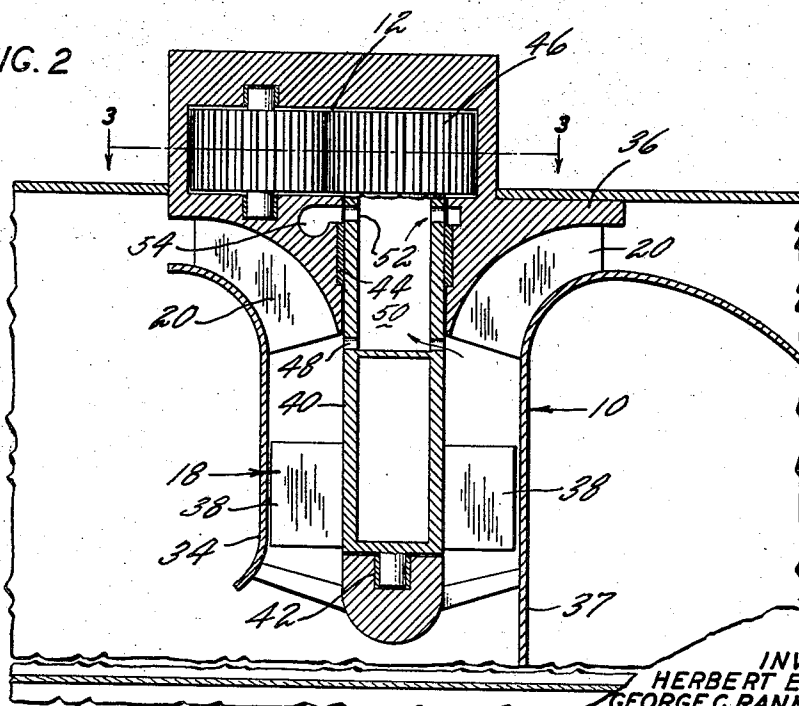


FIG. 2



INVENTORS
HERBERT E. TAYLOR
GEORGE C. RANNENBERG
MARTIN R. MACKLIN

BY *Harris C. Luther*
ATTORNEY

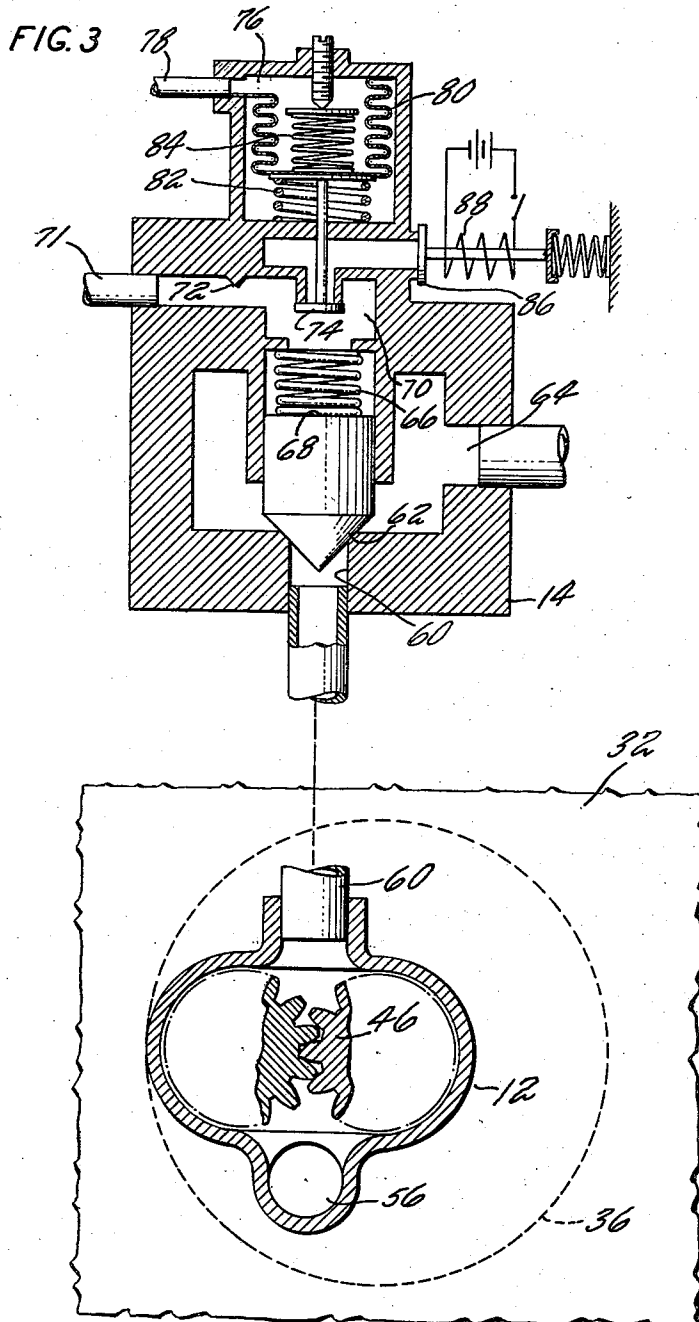
Oct. 22, 1963

H. E. TAYLOR ET AL
LIQUID VAPOR SEPARATOR

3,107,988

Filed Sept. 12, 1960

4 Sheets-Sheet 2



INVENTORS
HERBERT E. TAYLOR
GEORGE C. RANNENBERG
MARTIN R. MACKLIN

BY *Harris G. Zucker*
ATTORNEY

Oct. 22, 1963

H. E. TAYLOR ET AL
LIQUID VAPOR SEPARATOR

3,107,988

Filed Sept. 12, 1960

4 Sheets-Sheet 3

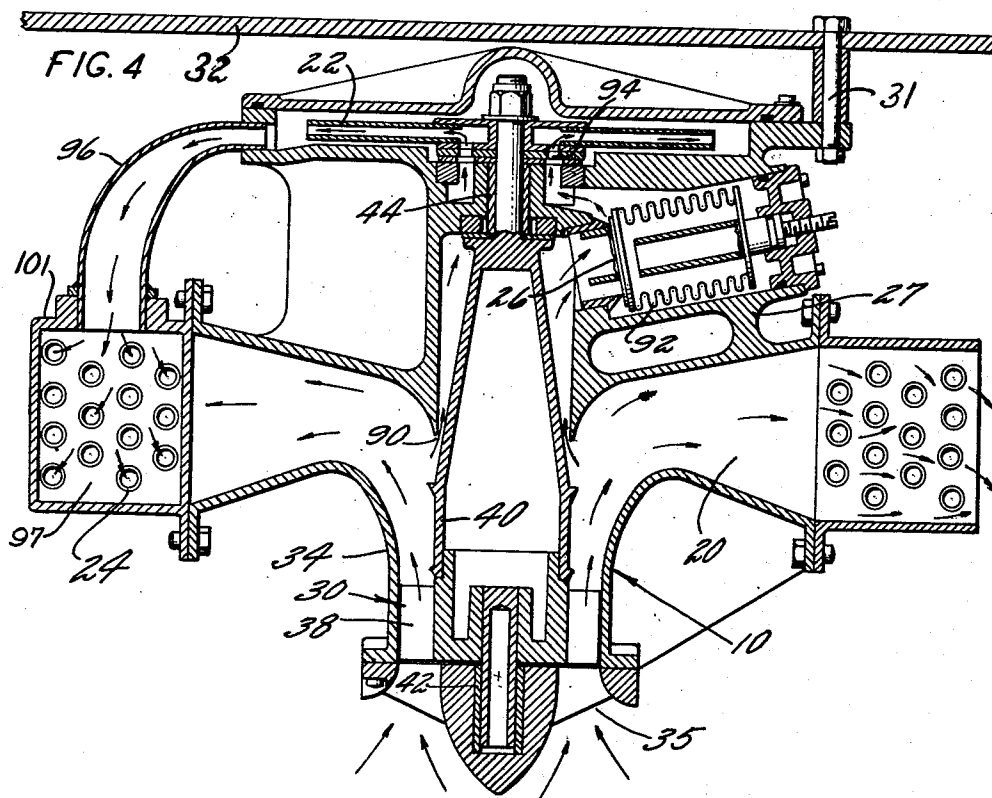
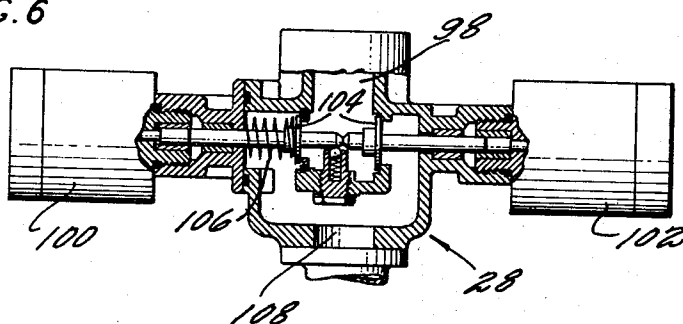


FIG. 6



INVENTORS
HERBERT E. TAYLOR
GEORGE C. RANNENBERG
MARTIN R. MACKLIN

BY *Harris E. Luther*
ATTORNEY

Oct. 22, 1963

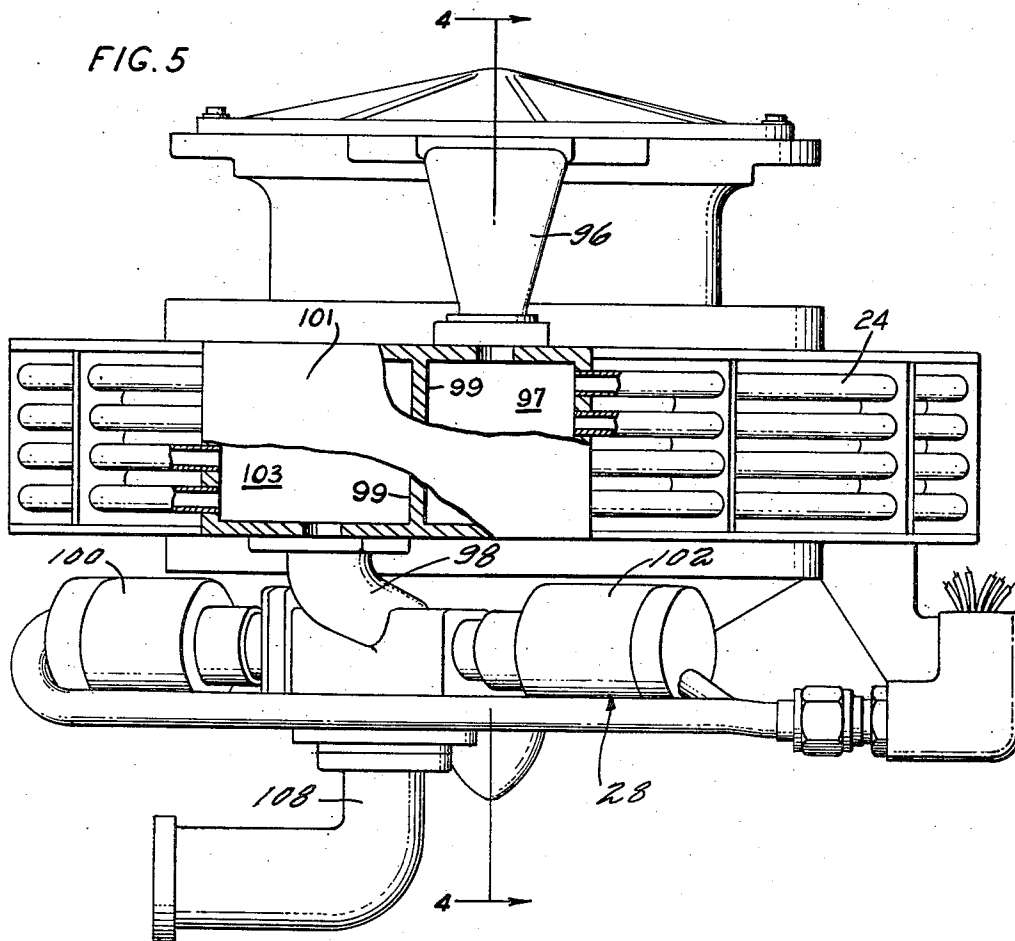
H. E. TAYLOR ET AL
LIQUID VAPOR SEPARATOR

3,107,988

Filed Sept. 12, 1960

4 Sheets-Sheet 4

FIG. 5



INVENTORS
HERBERT E. TAYLOR
GEORGE C. RANNENBERG
MARTIN R. MACKLIN

BY *Harris C. Luther*
ATTORNEY

1

3,107,988

LIQUID VAPOR SEPARATOR

Herbert E. Taylor, Longmeadow, and George C. Rannen-
berg, Agawam, Mass., and Martin R. Macklin, Bloom-
field, Conn., assignors to United Aircraft Corporation,
East Hartford, Conn., a corporation of Delaware

Filed Sept. 12, 1960, Ser. No. 55,339

8 Claims. (Cl. 55-311)

This invention relates to tank venting mechanism and particularly to mechanism utilizing energy in the vent stream for separating vapor from liquid in the stream, comprising a heterogeneous mixture of vapor and liquid such as would be present in a tank of cryogenic material, such as liquid hydrogen, in a zero gravity field.

In the interest of fuel or liquid conservation in a receptacle containing a volatile cryogenic material, such as liquid hydrogen, it is desirable to vent only the vapor or gas from the receptacle and retain the liquid. The receptacle may be subject to radiant heat from the sun or other heat source which will tend to heat the liquid and change some portions of the liquid to the vapor state with a consequent increase in the pressure in the receptacle. Because the vapor and liquid are intermingled and there is no well-defined separation under some conditions, such as a zero gravity field, a vent located anywhere in the tank would vent both vapor and liquid indiscriminately and mechanism supported anywhere in the tank would, under those conditions, be submerged in the mixture.

An object of this invention is to provide vent control mechanism which will select the vapor as the material to be vented from a pressurized container of a heterogeneous mixture of vapor and liquid, and retain the liquid.

Other objects and advantages will be apparent from the following specification and the accompanying drawings in which:

FIGURE 1 is a schematic showing of the vent and separator installed in a receptacle.

FIGURE 2 is a sectional view of the vent motor and separator.

FIGURE 3 is a plan view of the motor showing the pressure regulating valve and control.

FIGURE 4 is a sectional view on line 4-4 of FIGURE 5 of a modified form of motor, separator, and relief valve, installed in a receptacle with the outlet valve removed.

FIGURE 5 is a front elevation showing the connections to the heat exchanger and the control valve.

FIGURE 6 is a sectional view of the control valve.

The device shown in FIGURES 1 to 3 essentially consists of a centrifugal separator indicated generally at 10 powered by a positive displacement motor 12 and a pressure regulating and shut-off valve 14. This mechanism is all arranged in a tank vent 16. The vent separator is composed of an axial flow fan 18 for establishing the centrifugal field in separating the liquid and gas. A diffuser 20 is provided for reducing the velocity of the fluid flow returning to the tank. The gas separated by the centrifugal field created by the fan 18 is used to power the positive displacement gear motor 12 and is then vented overboard through the pressure regulating valve 14. All leakage paths through the vent separator

2

have been located upstream of the valve 14 so that the valve leakage will be the only leakage from the system.

The modification shown in FIGS. 4, 5, and 6 while broadly similar to the device shown in FIGS. 1-3 consists of a centrifugal separator indicated generally at 10, powered by a simple reaction turbine 22, a tube-type heat exchanger 24, a pressure regulating valve, and a solenoid operated shut-off valve 28 all, as shown in FIGS. 4, 5 and 6, supported in a receptacle from one of the walls 32 of the receptacle by suitable means, such as bolts 31, and under zero gravity conditions submerged in the mixture in the receptacle. The separator is composed of an axial flow fan for establishing the centrifugal field and in separating the liquid and gas. The gas to be vented is separated by the fan and passed through the direct acting, pressure regulator 26 located in the main housing 27 of the assembly before it enters the turbine 22. Because a temperature drop is experienced by the gas in passing through the turbine 22, and because some liquid droplets may be present, a heat exchanger 24 is incorporated to transfer heat from the mixture inside of the tank or receptacle to the cooled gas being vented. A shut-off valve 28 is provided down-stream of the heat exchanger 24 in the vented gas line. This valve 28 is solenoid-actuated and manually controlled to both the open and closed positions. A switch on the valve may be used to indicate the valve position.

Referring now to FIGURES 1 to 3, the tank or receptacle to be vented is indicated at 32, and the vent 16 connects the interior of the tank with the exterior thereof. The separator mechanism including the separator 10 and the motor 12 is located in the vent 16 and forms a part thereof. The vent and separator mechanism may be supported in the tank in any suitable manner such as on one of the tank walls or from any other suitable support. A duct 34 forming part of the vent 16 is supported in the tank from the main body 36 of the separator and forms the outer casing for the fan 18 and may be partitioned from the remainder of the tank by a baffle 37 if desired. Fan blades 38 are supported on a shaft 40 which is supported in bearings 42 and 44 and is directly connected with one of the gears 46 of the gear motor 12. The fan 18 is designed to impart a swirling motion to the fluid received in the duct 34 and assists the pressure difference between the inside and the outside of the tank in moving the fluid through the duct 34. The swirling motion will act as a centrifuge to drive the heavier or liquid particles toward the periphery of the duct, thus displacing the lighter or gaseous particles toward the fan shaft 40. Due to the pressure difference between the inside and the outside of the tank, the gas particles will be forced through the orifice 48 into the hollow interior 50 of the shaft 40, and will be vented through the orifice 52 to the annulus 54 and then through duct 56 to the gear motor or expansion device 12. The expansion device will be driven by these pressurized gases and drive the shaft 40 and the fan 18. The liquid particles centrifuged to the outside of the duct 34 together with excess gas which did not pass through orifice 48 will pass through the diffuser 20 to efficiently change their velocity into static pressure and will then be discharged directly back into the portion of the tank surrounding the separator. If the flow en-

tering the duct 34 is large enough to contain sufficient gas, it will be possible to separate this gas from the mixture of liquid and gas to drive the expansion device 12 without the loss of any or any appreciable amount of liquid. Any excess of gas, beyond that required to drive the motor 12, will of course be returned to the portion of the tank surrounding the separator along with the separated liquid.

The gas discharged from the motor 12 is led through the portions 60 of the vent 16 to the pressure regulating and shut-off valve 14. The valve 14 comprises a spring-pressed valve member 62 blocking the passage 60 from the outlet passage 64 of the vent 16 leading overboard or to ambient. Plunger 62 in addition to being urged to closed position by spring 66 is also urged to closed position by fluid pressure acting on the surface 68 of the plunger 62. Fluid is led through line 71, from the passage 56 leading to the gear motor, into the chamber 70 to act on the surface 68. A restriction 72 limits the rate of flow of fluid to the chamber 70. Fluid may be vented to ambient, by connections not shown, from the chamber 70, faster than it is admitted past restriction 72, by the valve 74 controlled by pressure in the bellows 76 which is connected by conduit 78 with the tank 32. Bellows 80, the outside of which is connected, by connections not shown, with ambient, is balanced between springs 82 and 84 and as this device is intended to operate in the outer atmosphere where the pressure is substantially zero the pressure outside of the bellows is substantially zero. A valve 86 controlled by solenoid 88 is used to block the exit passage from the valve 74 and thus hold the valve 62 in closed position, when desired.

The modification as shown in FIGURES 4 to 6 is broadly similar to that shown in FIGS. 1-3 and differs from that previously described mainly in the location of the pressure regulating valve between the separator and the turbine and the incorporation of a heat exchanger in the turbine exhaust. Also FIGURES 2 and 4 differ in the type of expansion device shown. FIGURE 2 shows positive displacement; FIGURE 4, a turbine. The actual configuration of expansion device used in any particular application is dependent on considerations such as cost and efficiency. The fan 30 having blades 38 supported on a shaft 40 is located similar to that shown in FIGS. 1-3 in a duct 34, a portion of which acts as a casing for the fan. The shaft 40 is supported in bearings 42 and 44 and has the turbine wheel 22 secured to the upper end thereof. The fan 30 imparts a swirling motion to the mixture of gas and liquid received in the duct 34 and acts as a centrifuge to force the liquid towards the outer periphery of the duct 34 and discharge it through the diffuser 20. A heat exchanger 24 is arranged around the outer periphery of the diffuser 20 and the liquid and excess gas discharged by the fan 30 passes through this heat exchanger, around the exterior of the heat exchanger tubes, on its way back to the portion of the tank surrounding the separator 10. Gas to be vented is separated from the mixture of gas and liquid by the centrifuge action of the fan and passes through the orifice 90 around the outside of shaft 40 and under the spring-pressed poppet valve 26, supported on evacuated bellows 92. After opening and passing the poppet valve 26, the gas passes through orifice 94 through the interior of the turbine rotor 22 to be discharged at its periphery. The discharged gas which is cooled due to expansion through the turbine and because of the work done in turning the fan is led through duct 96 to a chamber 97, partitioned off by a partition 99, in a manifold 101 and thence to the interior of the tubes of the heat exchanger 24. After passing through the heat exchanger and cooling the liquid and gas being returned from the separator to the portion of the tank surrounding the separator, the discharged gas is led through a chamber 103 formed in the manifold 101 by the partition 99 and then through duct 98 to the shut-off valve

28. Alternatively the heat exchanger may be located in duct 35 to cool the mixture before it enters the separator. This valve 28 comprises a pair of solenoids 100 and 102, operating a double poppet shut-off valve 104 having a spring 106 urging it to closed position. Gas discharged by the poppet valve is led through duct 108 overboard or to a location outside of the tank. The vent from the inside to the outside of tank 32 in this modification consists of the duct 34 submerged in the tank 32, the orifice 90, the valve 26, orifice 94, rotor 22, duct 96, tubes of heat exchanger 24, duct 98, valve 28 and duct 108 discharging outside the tank.

While the above described mechanism is intended as the normal means for relieving excess pressure in the tank, it will be appreciated that additional or safety relief valve mechanism may be provided to provide a vent in the event of failure of the normal venting mechanism.

It is to be understood that the invention is not limited to the specific embodiments herein illustrated and described, but may be used in other ways without departure from its spirit, and that various changes can be made which would come within the scope of the invention which is limited only by the appended claims.

We claim:

1. Pressure relief means for a storage tank for a pressurized mixture of gas and liquid comprising, a vent passage submerged in said tank and connecting the inside with the outside of said tank, a centrifuge in said tank, forming a part of said passage, receiving gas and liquid from said tank and separating said received gas and liquid and having a continuously open outlet in said tank returning liquid from said centrifuge to the mixture in the portion of the tank surrounding said centrifuge, and having a gas outlet in said passage, a motor actuated by the flow of gas discharged from said centrifuge through said gas outlet and passage for operating said centrifuge, means blocking said vent passage and means responsive to the pressure in said tank controlling said blocking means.

2. Vent means as claimed in claim 1 in which the blocking means is located between the centrifuge and the motor.

3. Vent means as claimed in claim 2 including a second blocking means blocking the discharge from said motor and a second means for controlling said second blocking means.

4. Vent means as claimed in claim 1 in which the blocking means is located at the discharge of said motor.

5. In combination, a centrifuge and a fluid motor drivingly connected with said centrifuge arranged in series in a normally closed storage container pressure relief vent adapted to vent gas from a pressurized heterogeneous mixture of gas and liquid in said container when the pressure in said container exceeds a predetermined amount, said centrifuge having a mixture inlet in said container for receiving a stream of said mixture from said container, a gas outlet in said vent, and a gas and liquid outlet in said container, means conducting gas separated from said mixture stream by said centrifuge and urged through said gas outlet and vent by the pressure difference between the inside and outside of said container to said motor to power said motor and drive said centrifuge, and means for returning, from said centrifuge to said container, through said gas and liquid outlet, excess gas and separated liquid from said mixture stream and a pressure responsive valve in said vent in series with said centrifuge and motor.

6. A combination as claimed in claim 5 in which said valve controls said conducting means.

7. A combination as claimed in claim 5 including a shut-off valve down stream of the said combination.

8. A storage device adapted to contain a volatile liquid in a zero gravity environment, a vent passage in the wall of the device having an inlet submerged in the inherent mixture of liquid and gas freely floating in said device and

5

including pressure responsive means responsive to the pressure inside said device for releasing gases from said device upon the vapor pressure in the device reaching a predetermined value, means responsive to the flow of fluid in said vent passage for extracting power therefrom, fan means in the device operatively connected to said power extracting means for pumping the inherent mixture of liquid and gas freely floating in the device, said fan means including a centrifuge for agglomerating the liquid particles, and means for returning said liquid particles from said combined fan and centrifuge to a predetermined region within said device.

5

10

1,822,659
2,216,939
2,758,672
2,864,461
2,868,324
2,897,917
2,954,841
2,958,394

3,835

6

References Cited in the file of this patent

UNITED STATES PATENTS

Kirsch ----- Sept. 8, 1931
Dodge ----- Oct. 8, 1940
Anderson ----- Aug. 14, 1956
Dueker ----- Dec. 16, 1958
Anderson ----- Jan. 13, 1959
Hunter ----- Aug. 4, 1959
Reistle ----- Oct. 4, 1960
Woodmansee ----- Nov. 1, 1960

FOREIGN PATENTS

Great Britain ----- A.D. 1875