NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

October 15, 1970

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.	:	3,257,780
Corporate Source	:	General Dynamics Corp.
Supplementary Corporate Source	:	Convair Astronautics Division
NASA Patent Case No.	:	XLE-00586

Please note that this patent covers an invention made by an employee of a NASA contractor. Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of. . . ."

Gayle Parker

Gayle Parker

Enclosure:
Copy of Patent

FACILITY FORM 602

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(ACCESSION NUMBER)	(THRU) 00
15 (PAGES)	(CODE) 15
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

N71-15968

June 28, 1966 | JAMES E. WEBB | 3,257,780
ADMINISTRATOR OF THE
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
ZERO GRAVITY SEPARATOR

Filed Oct. 18, 1963 | 5 Sheets-Sheet 1

N71-15968 40%

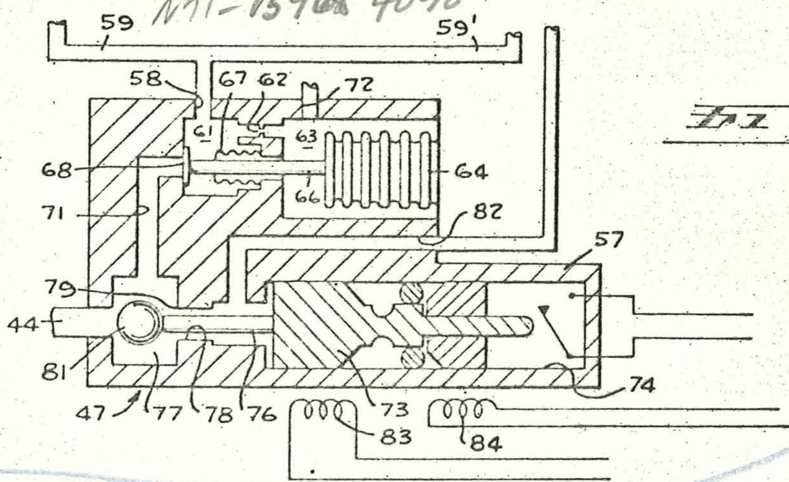


Fig. 3

Fig. 4

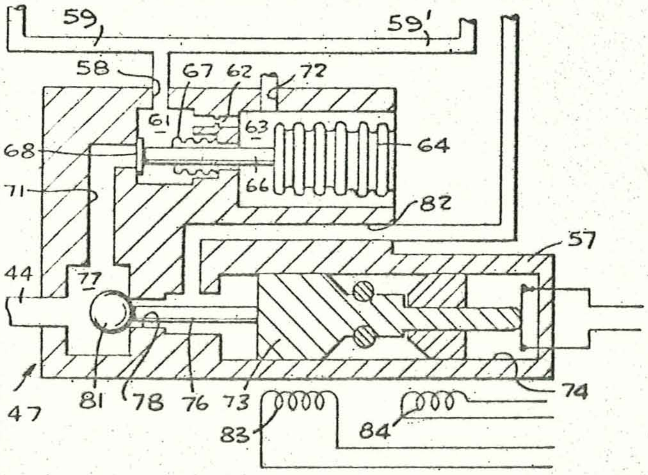
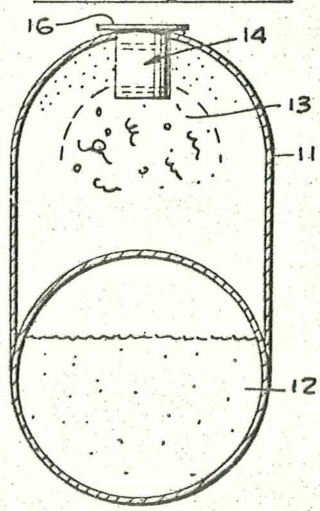


Fig. 1



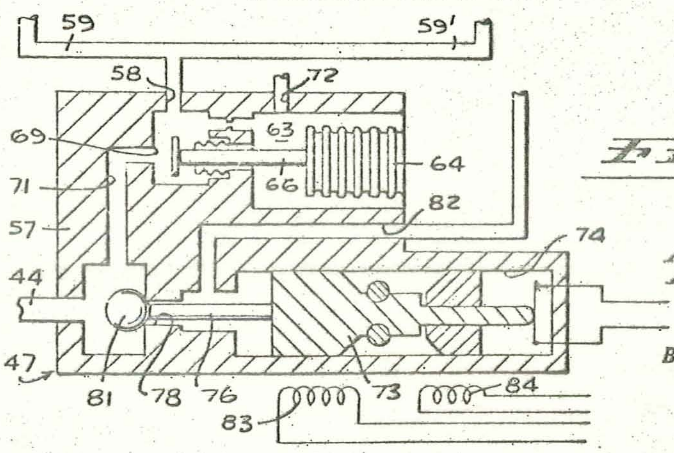


Fig. 5

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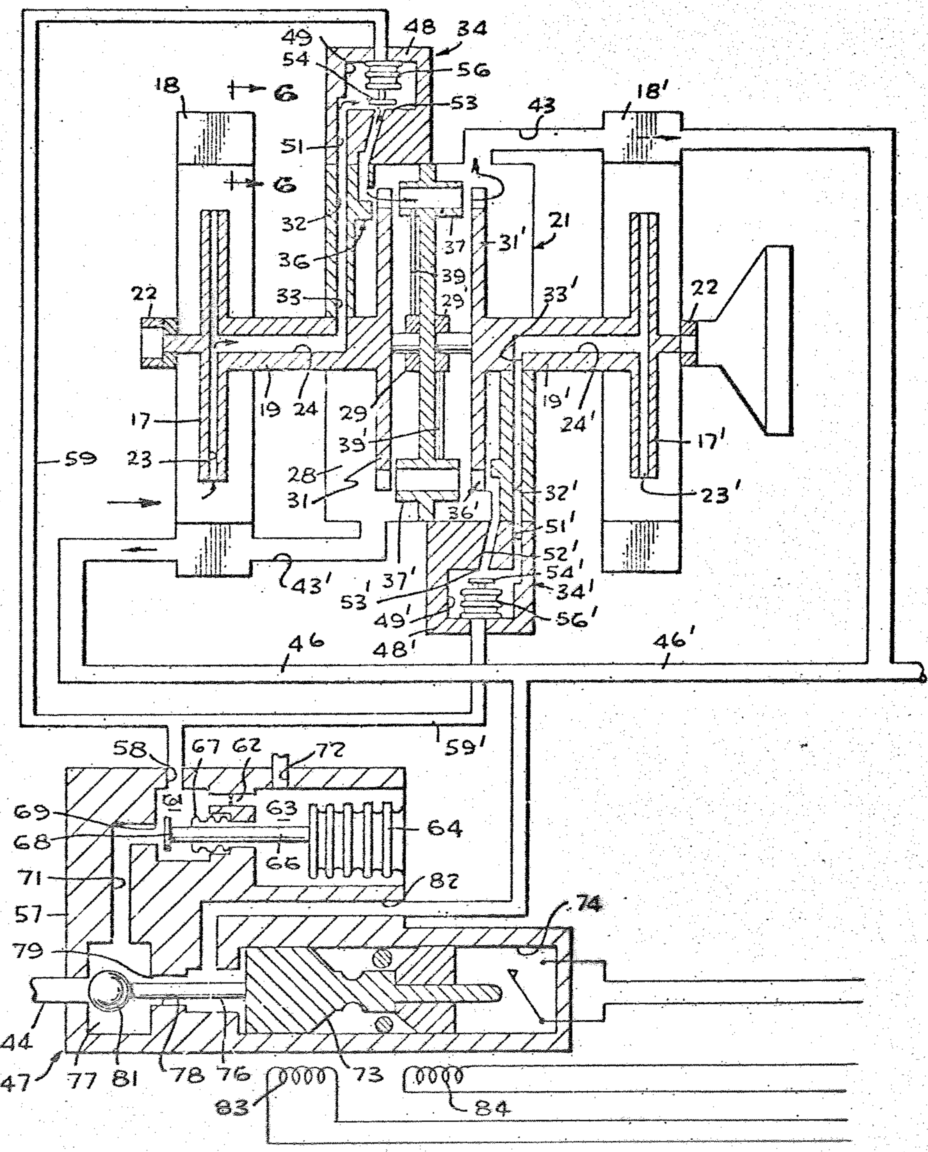

Fig. 2

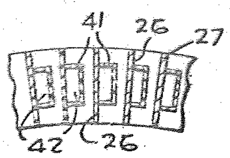

Fig. 6

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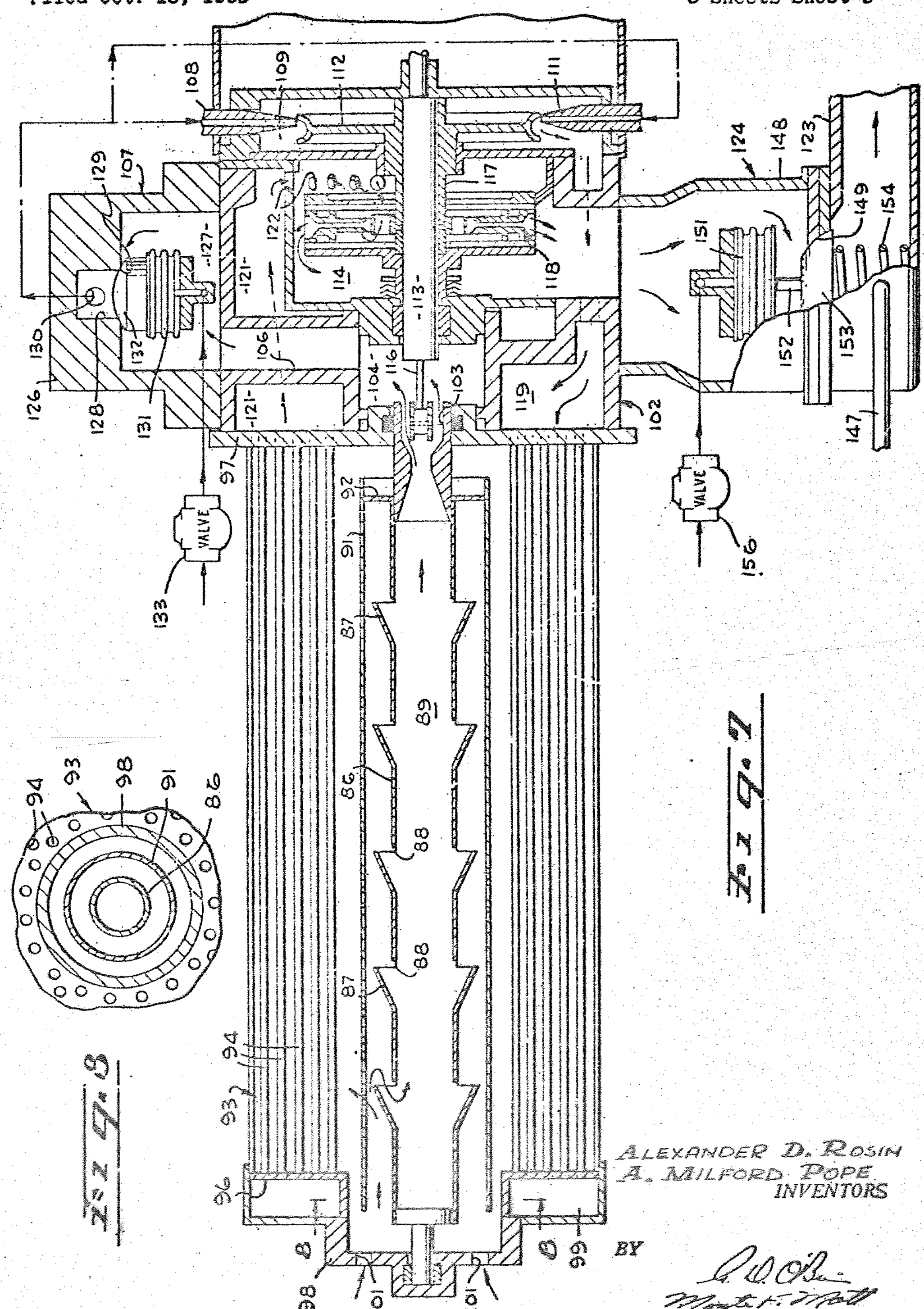

Fig. 7

Fig. 8

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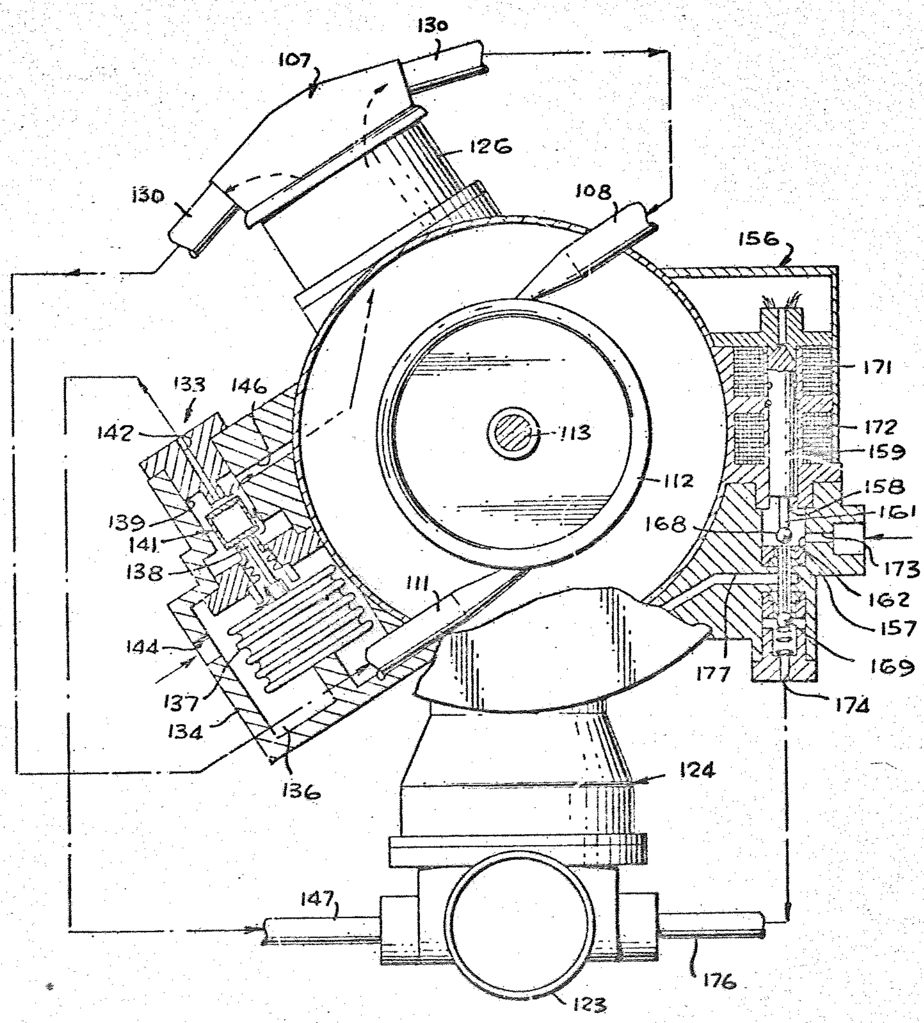

Fig. 9

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3,257,780

ZERO GRAVITY SEPARATOR

Filed Oct. 18, 1963

5 Sheets-Sheet 5

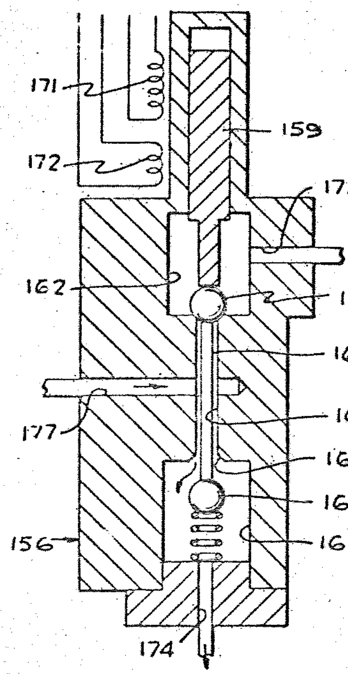

Fig. 10

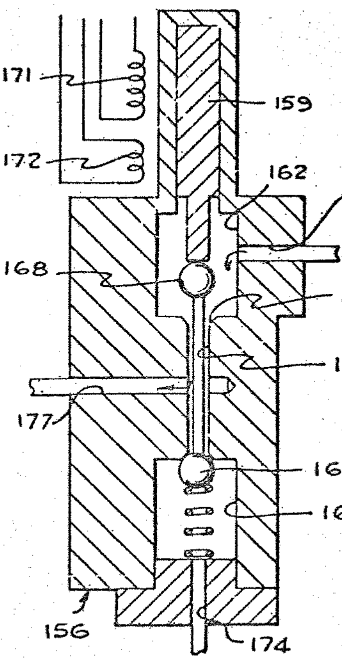

Fig. 11

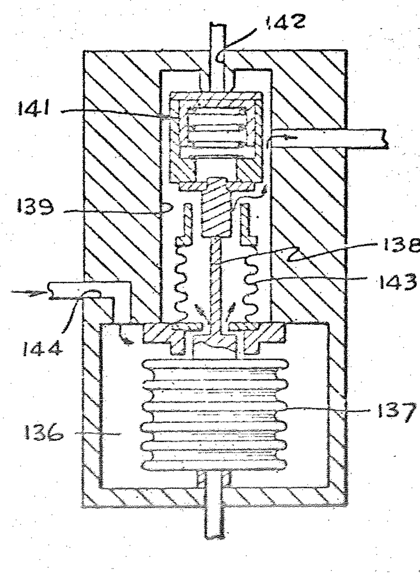

Fig. 12

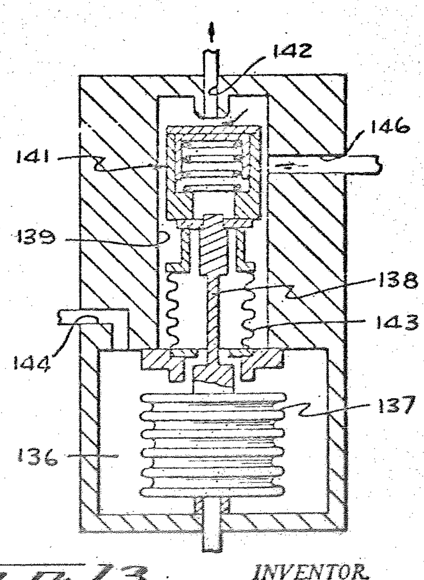

Fig. 13

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N71 15968

United States Patent Office

3,257,780

Patented June 28, 1966

3,257,780

ZERO GRAVITY SEPARATOR

James E. Webb, Administrator of the National Aeronautics and Space Administration with respect to an invention of Alexander D. Rosin and A. Milford Pope

Filed Oct. 18, 1963, Ser. No. 317,391

14 Claims. (Cl. 55—160)

The present invention relates generally to apparatus for separating mixtures of gases and liquids from each other, and is more particularly directed to apparatus for separating gas from a liquid in which the gas is suspended under zero gravity conditions, and thereafter venting the gas while retaining the liquid.

In various applications it is necessary to separate mixtures of gases and liquids. For example, it is frequently desirable to separate liquid petroleum from gas products suspended therein or to separate the constituents of a fluid in a double-phase condition, i.e., gases entrained in a liquid. The latter application of liquid and gas separation has recently become of particular importance in the conduct of various space missions. More particularly, under conditions of weightlessness, or zero gravity, as experienced by space vehicles during various missions, cryogenic materials, such as liquid hydrogen contained in the fuel tank of the vehicle, absorb heat energy through radiation from the earth and sun, and this influx of heat energy raises the temperature of the cryogenic material sufficiently to cause boil-off. Due to the weightlessness, the gas generated due to boil-off remains suspended in the liquid and, accordingly, a double-phase fluid is contained within the tank. Inasmuch as the gas generated from boil-off results in increased tank pressure, it is necessary to vent the tank pressure to a safe minimum. In order to vent the tank pressure without venting liquid, it is, of course, necessary to separate the gas from the liquid and vent the gas while returning the liquid to the tank.

It is, therefore, an object of the present invention to provide a gas-liquid separator having particular application in the venting of pressure of a space vehicle fuel tank containing cryogenic material which exists as a double-phase fluid under zero gravity conditions.

Another object of the invention is to provide gas-liquid separation and gas venting apparatus for employment in a region containing double-phase fluid, which apparatus is so arranged that the gas, prior to being vented, extracts heat from the liquid returned to the containment region to reduce the tendency of the liquid to convert to the double-phase condition.

Still another object of the invention is the provision of separation and venting apparatus of the class described which is operable in response to pressures in the region containing the double-phase fluid in excess of a predetermined safe minimum pressure, while being inoperable in response to pressures in the region less than the predetermined minimum.

It is yet another object of the invention to provide apparatus of the class described which includes control means for selectively activating or inactivating the apparatus such that the apparatus may be normally maintained in an inactive state while being activated for pressure responsive operation only when certain external conditions prevail, such as when a space vehicle is in a particular attitude.

Another object of the invention is to provide liquid-gas separating and gas venting apparatus wherein moving parts are cooled by the separated gas prior to venting thereof.

It is a further object of the invention to provide separator apparatus of the class described which may be readily arranged to have a minimum of angular momentum during its operation.

A still further object of the invention is to provide zero gravity liquid-gas separating and gas venting apparatus which requires substantially no external power in its operation.

Additional objects and advantages of the invention will become apparent upon consideration of the following description taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a schematic illustration of a space vehicle fuel tank equipped with liquid-gas separating and gas venting apparatus in accordance with the present invention in the upper regions thereof, cryogenic material contained within the tank being depicted as traveling upwardly into the region of the separator under zero gravity condition;

FIGURE 2 is a schematic illustration of one form of the invention;

FIGURES 3–5, inclusive, are schematic illustrations of a valve arrangement employed in the embodiment of FIGURE 2 under varied operating conditions;

FIGURE 6 is a fragmentary sectional view taken at line 6—6 of FIGURE 2, illustrating the vane arrangement of a heat exchanger of the apparatus;

FIGURE 7 is a schematic illustration of a modified form of the invention;

FIGURE 8 is a sectional view taken at line 8—8 of FIGURE 7, illustrating particularly the heat exchanger of the modified apparatus;

FIGURE 9 is a schematic illustration of the apparatus of FIGURE 7 as rotated 90°;

FIGURES 10 and 11 are similar fragmentary views on an enlarged scale schematically illustrating a control valve of the apparatus illustrated in FIGURES 7–9 under varied operating conditions; and

FIGURES 12 and 13 are similar fragmentary views on an enlarged scale schematically illustrating a pilot valve of the apparatus of FIGURES 7–9 in varied conditions of operation.

Referring now to FIGURE 1 of the drawing, the invention will be seen to be illustrated with respect to a space vehicle fuel tank 11 containing a cryogenic material, such as liquid hydrogen, as generally indicated at 12. It is assumed that boil-off of the cryogenic material has occurred such that gas also exists within the tank 11. Moreover, the tank is subjected to zero gravity conditions such that the material exhibits weightlessness and travels upwardly in the fuel tank. As a result, the gas generated by boil-off is entrained in the liquid and, accordingly, provides a double-phase fluid, as indicated at 13, in the upper regions of the tank. In order to accomplish separation of the gas from the liquid and to vent the gas from the tank without venting liquid so as to maintain the tank pressure at a safe minimum, gas-liquid separating and gas venting apparatus 14, in accordance with the present invention, is located in the upper regions of the fuel tank 11. In this regard, the apparatus 14 may be advantageously associated with or attached to the fuel tank manhole or cover plate 16, so as to be suspended therefrom into the upper regions of the tank. The double-phase fluid 13 thus enters the apparatus 14 and, by means outlined hereinafter, is separated into liquid and gas, the liquid being returned to the tank, while the gas is vented therefrom. Although the apparatus of the invention is particularly described with reference to space vehicle fuel tanks under zero gravity conditions, it will become apparent that the apparatus may be advantageous employed in a comparable manner in various other equivalent environments.

Considering now the apparatus 14, mentioned above with respect to FIGURE 1, as to its basic aspects with reference to the several forms thereof illustrated particularly in FIGURES 2 and 7, respectively, it will be noted that the apparatus includes separator means which are adapted for communication with a region containing a gas and liquid mixture, for example, the upper portions of the fuel tank 11 under conditions of zero gravity. The separator means includes a member which is mounted for driven movement and is positioned to intercept the liquid-gas mixture. This member in its movement propels the liquid of the mixture through liquid flow passages of a heat exchanger disposed adjacent the separator member. The separator member is further arranged to channel the gas of the mixture to an expansion motor, such as a turbine, which is coupled in driving relation to the separator member to effect the movement thereof. The gas expands in motivating the expansion motor and is consequently cooled to a considerable extent. The apparatus further includes means for receiving the expanded gas from the expansion motor and conveying same to gas passages of the heat exchanger which are in heat exchange relation with the liquid passages thereof. During the flow of gas through the gas passages of the heat exchanger, the liquid is hence thereby cooled in passing through the liquid passages for return to the tank, or other region containing the double-phase fluid. A vent is provided which is adapted for disposition exteriorly of the region containing the gas and liquid mixture. For example, the vent may extend through the cover plate 16 of the fuel tank 11. The gas passages of the heat exchanger are communicated with the vent, and subsequent to passage of the gas through the heat exchanger, the gas is ported through the vent exteriorly of the region containing the gas and liquid mixture. It will be appreciated that aside from accomplishing venting of the pressure of a region containing a gas and liquid mixture to a safe minimum while retaining the liquid in the region, the apparatus provides the added advantage of cooling the liquid to reduce the tendency thereof to convert to the double-phase condition. The apparatus may also be advantageously provided with pressure sensitive relief valve means in the flow path from the separator member to the expansion motor to control the flow of gas thereto in response to the absolute pressure existing in the tank 11, or other containment region. More particularly, the valve means may be arranged to prevent communication with the expansion motor responsive to tank pressures less than a predetermined minimum safe level, and to establish communication to the expansion motor in response to pressures equal to or greater than the predetermined minimum safe level. The valve means thus is operable to activate the separator and venting apparatus when the tank pressure becomes excessive to thereby relieve the pressure, while inactivating the apparatus when the tank pressure is tolerable. The valve means may further advantageously include control valve means for selectively switching the apparatus between an active state of pressure responsive operation, and an inactive state wherein the apparatus is inoperable irrespective of the pressure existing in the tank. The control valve means may be arranged, for example, to activate the apparatus for pressure sensitive operation only when the space vehicle is in a particular attitude, or when certain other predetermined conditions exist.

Considering now the separator and venting apparatus generally outlined above in greater detail as to a particular embodiment thereof and referring to FIGURE 2, there will be seen to be provided a double-ended arrangement wherein components of the opposite ends thereof counter-rotatae in order to reduce angular momentum of the overall apparatus to negligible level. Inasmuch as both ends of the double-ended arrangement are identical, only one end is hereafter described in detail with the like components of the other end being identified by like primed reference numerals. More particularly, the left end, as viewed in FIGURE 2, of the double-ended separator and venting apparatus includes a circular separator disc 17, which serves as the separating member of previous mention, and is concentrically disposed within an annular heat exchanger 18. More particularly, the disc 17 is coaxially secured to a shaft 19 which is journaled for rotation between an end of the heat exchanger and a turbine housing 21 coaxially aligned with the heat exchanger. In this regard, a journal bearing 22 may be supported centrally of the annular heat exchanger 18, as by means of a spider, or the like (not shown), to provide an end mounting for the shaft 19 while yet enabling fluid to enter the central opening of the heat exchanger for separating action by the disc 17. More particularly, the disc 17 is provided with a plurality of radially extending gas inlets 23 in terminal communication with a gas flow passage 24 which extends longitudinally through the shaft 19. Thus, gas entering the central openings of the heat exchanger 18 from a region containing a mixture of gas and liquid flows into the gas inlets 23 of the disc 17 to the longitudinal flow path 24 of the shaft 19. When the disc is rotating, liquid entering the central opening of the heat exchanger 18 strikes the rotating disc and is thrown or propelled radially outward to the surrounding heat exchanger. As shown in FIGURE 6, the heat exchanger includes a plurality of circumferentially spaced radial vanes 26 defining a plurality of radial liquid passages 27 through the heat exchanger. Liquid propelled outwardly by the rotating disc consequently passes through the passages 27 and is returned to the tank or other region containing the gas and liquid mixture. It will be thus appreciated that the separator disc 17 in its rotation is operable to separate the gas from the liquid of the mixture and to direct the liquid through the heat exchanger 18 with beneficial results subsequently described herein.

The turbine housing 21 is provided with a central chamber 28 centrally of which a bearing 29 is mounted to journal the corresponding end of shaft 19. A turbine 31 disposed in the chamber 28 is coaxially secured to the shaft 19 so as to be rotatable therewith, and it will be thus appreciated that the turbine comprises the expansion motor means of the separator and gas venting apparatus. In order to convey the separated gas from the flow passage 24 of the shaft 19 into motivating relation to the turbine 31, the housing 21 is provided with a radial flow passage 32 which is in sealed relation to the shaft 19 while permitting rotation thereof and communicates with radial outlets 33 which extend from the flow passage 24. The passage 32 is communicated with the chamber 28, preferably through a relief valve 34 which is subsequently described in detail herein and which is secured to the turbine housing 21. Gas delivered from the valve 34 is preferably fed to a nozzle box 36, or the like, disposed in the housing 28 in a position to direct the gas upon the vanes of the turbine 31, in driving relation thereto. Thus, with flow established through the relief valve from the flow passage 24 of the shaft 19, the gas drives the turbine 31, which in turn drives the shaft 19 and separator disc 17 secured thereto. Similarly, gas entering the other end of the apparatus is directed through the gas inlets 23′ of the separator disc 17′ to the longitudinal flow passage 24′ of shaft 19′, and is channeled through relief valve 34′ to the nozzle box 36′, which is located in the chamber 28 on the opposite side thereof from nozzle box 36 at a position diametrically opposed thereto. The gas directed from the nozzle box 36′ upon the vanes of the turbine 31′ effects rotation thereof, which in turn rotates the shaft 19′ and the separator disc 17′ connected thereto. The vanes of turbine 31′ are oppositely pitched from the vanes of turbine 31 such that the gas streams directed from nozzle boxes 36 and 36′ cause the turbines to rotate in mutually opposite directions. The gas directed from the nozzle boxes expands and is cooled to some extent in driving the respective turbines but still retains a significant quantity of energy.

In order that the residual energy of the gas streams subsequent to driving the turbines 31 and 31' be effectively utilized and the gas be further expanded and cooled, means are preferably provided to channel each of the gas streams, subsequent to its driving one turbine, into motivating relation with the other turbine such that the residual energy of the gas stream contributes to the rotation thereof. More particularly, orifices 37 and 37' are advantageously mounted with the chamber 28, as by means of a spider 38, at a position longitudinally intermediate the turbines 31 and 31'. The longitudinal passages of the orifices 37 and 37' are respectively aligned with the outlets of the nozzle boxes 36 and 36'. Orifice 37 thus receives the gas directed from nozzle box 36 subsequent to its driving of the turbine 31 and channels the gas into driving relation to turbine 31' to thus contribute to the rotation thereof in the opposite direction, the vanes of this turbine being oppositely pitched as previously noted. Similarly, the gas stream directed from nozzle box 36' is received by orifice 37' subsequent to its driving of the turbine 31', and is channeled through the orifice into driving relation to the turbine 31 to contribute to the rotation thereof. It should also be noted, as an important adjunct of the invention, that gas flow passages 39 and 39' are communicated with the orifices 37 and 37' and extend into the bearings 29 and 29'. Portions of the gas streams flowing through the orifices are thus conveyed to the bearings to effect cooling thereof.

Subsequent to driving both turbines 31 and 31', the gas streams directed from the nozzle boxes 36 and 36', as expanded and cooled to a considerable extent, are directed through the heat exchangers 18' and 18, respectively, to effect cooling of the liquid propelled therethrough. More particularly, channels 41 are provided longitudinally of each heat exchanger to define gas flow passages 42 longitudinally therethrough. Flow paths 43 and 43' communicating with the chamber 28 at positions adjacent turbine 31 and orifice 37' and adjacent turbine 31' and orifice 37 then serve to convey the expanded cool gas to the gas flow passages 42 of the respective heat exchangers 18' and 18. Inasmuch as the gas is quite cool, substantial heat is extracted from the liquid propelled outwardly through the liquid flow passages 26 of the heat exchangers for return to the tank 11, or equivalent region containing gas and liquid mixture. By virtue of the cooling of the liquid returned to the tank, the tendency of the liquid to convert to the double-phase condition is significantly reduced.

In order that the gas flowing through the heat exchangers 18 and 18' may be ported exteriorly of the tank, or other region containing gas and liquid mixture, an outlet vent 44 is disposed exteriorly of the region. The gas passages of the heat exchangers are in turn communicated with the vent 44 by means including outlet flow paths 46 and 46' which communicate with the vent 44, in the present instance through a control valve 47. The control valve is operatively associated with the relief valves 34 and 34' in such a manner that in an activating state of the control valve, gas flow to the turbines 31 and 31', and hence operation of the over-all apparatus, is controlled by the pressure within the tank or other region containing the gas and liquid mixture. The control valve 47 is further arranged such that in an inactive state of the valve, the over-all apparatus is rendered inoperable irrespective of the pressure existing in the region of the mixture.

Considering now the valving arrangement employed in the embodiment of FIGURE 2 in greater detail, it will be noted that the relief valves 34 and 34' respectively include valve bodies 48 and 48' having chambers 49 and 49' therein. The valve bodies further include inlet ports 51 and 51' which communicate the flow passages 32 and 32' with the chambers 49 and 49'. In addition, outlet ports 52 and 52' in the valve bodies communicate the chambers 49 and 49' with the nozzle boxes 36 and 36' disposed in the turbine chamber 28. The outlet ports 52 and 52' respectively include seats 53 and 53' which are engageable by plug members 54 and 54' carried by accordion members or bellows 56 and 56' respectively mounted within the relief valve chambers 49 and 49'. The bellows are expansively and contractively movable to respectively engage the plug members 54 and 54' with the seats 53 and 53', and to disengage the plug members therefrom, depending upon whether the pressure acting at the exterior of the bellows is less than, or greater than the pressure acting at the interior thereof. Thus, when the pressure of gas introduced to the relief valve chambers 49 and 49' through the inlet ports 51 and 51' exceeds the pressure acting interiorly of the bellows 56 and 56', the bellows contract to move the plug members 54 and 54' out of engagement with the seats 53 and 53', thereby establishing flow to the nozzle boxes 36 and 36'. As a result, the turbines 31 and 31' are driven to, in turn, drive the shaft and separator discs 17 and 17', i.e., the apparatus is rendered operable to conduct its separating and gas venting functions. Conversely, when the gas pressure in the relief valve chambers 49 and 49' is less than the pressure acting interiorly of the bellows 56 and 56', the latter expansively move the plug members 54 and 54' into sealed engagement with the seats 53 and 53'. Gas flow to the nozzle boxes 36 and 36' for driving of the turbines 31 and 31' is thus prevented and the apparatus is rendered inoperable.

Expansive and contractive movement of the relief valve bellows 56 and 56' is herein regulated by the control valve 47 which is arranged to appropriately control the pressures at the interiors of the bellows in accordance with the pressure existing in the tank, or other region containing the gas-liquid mixture. More particularly, the control valve 47 includes a valve body 57 having a pilot control port 58 communicated by flow paths 59 and 59' with the interiors of the relief valve bellows 56 and 56'. The control port 58 communicates with a pilot chamber 61 provided in the control valve body 57 and this chamber is communicated by means of a leak 62 with a control pressure chamber 63. An accordion member 64 is mounted in the chamber 63 and a stem 66 extends therefrom into the pilot chamber 61, a dynamic seal being provided between the stem and chambers as by means of a bellows 67. A valve member 68 is carried at the end of the stem 66 in the pilot chamber 61 for engagement with a seat 69 therein defining the entrance to an outlet passage 71 therefrom. In addition, an inlet port 72 communicates with the control pressure chamber 63 which is adapted for communicable connection with the tank or other region containing the gas and liquid mixture. Thus, the tank pressure is transmitted to the control pressure chamber 63 via the inlet port 72. Moreover, the accordion member 64 is so arranged that for tank pressures less than a predetermined minimum safe level, the accordion member is in expanded condition which maintains the valve member 68 in sealed engagement with the seat 69 to thus close the outlet passage 71. When the tank pressure as transmitted by the inlet port 72 to the control pressure chamber 63 is equal to or exceeds the predetermined safe minimum level, the accordion member 64 contracts to thereby disengage the valve member 68 from the seat 69 and open the outlet passage 71. It is to be noted that the outlet passage 71 is communicated with the vent 44, which in the instance of a space vehicle undergoing a space mission is disposed in a vacuum. Under other environmental conditions, the vent is otherwise ported to a region having relatively low pressure compared to that existing within the tank. Thus, when the valve member 68 is disengaged from the seat 69 under conditions of excessive pressure in the tank as transmitted to the control pressure chamber 63, the pilot chamber 61, and therefore the interiors of the relief valve bellows 56 and 56' communicated therewith, are vented through the outlet passage 71 and vent 44 to vacuum or other extremely low pressure. Thus, the gas flowing into the relife valve chambers 49 and 49' is at a substantially greater pressure than the pressure existing interiorly of the bellows. Accordingly, communication is established through the relief valves 34 and 34' to the nozzle boxes 36 and 36' for driving the turbines. However, when the tank pressure as transmitted to the control pressure chamber 63 is not excessive and the accordion member 64 engages the valve member 68 with the seat 69 to close the outlet passage 71, this tank pressure also exists within the pilot chamber 61 by virtue of the leak 62 between the control pressure chamber and the pilot chamber. Thus, tank pressure is at this time maintained within the interiors of the relief valve bellows 56 and 56' and this pressure is greater than the gas pressure acting within the relief valve chambers on the exteriors of the bellows. The plug members 54 and 54' are consequently engaged with seats 53 and 53' to thus prevent the flow of gas to the turbine actuating nozzle boxes 36 and 36', thus rendering the over-all apparatus inoperable.

To facilitate selective switching of the apparatus between active pressure controlled, and inactive states, the control valve 47 includes a solenoid actuated piston 73 mounted for reciprocation within a cylinder bore 74 provided in the control valve body 57. A stem 76 projects coaxially from the piston 73 into an outlet chamber 77 through a communicating passage 78 having walls outwardly spaced from the stem. A seat 79 is provided in the outlet chamber 77 about the termination of the passage 78. A plug member 81 secured to the end of the stem 76 is engageable with the seat 79 in response to solenoid actuated movement of the piston 73, to the right as viewed in FIGURE 2. An inlet passage 82 in communication with passage 78 is coupled to the outlet flow paths 46 and 46' from the heat exchangers 18 and 18', while the outlet passage 71 from pilot chamber 61 and the vent 44 are both communicated with the outlet chamber 77. Solenoids 82 and 83 in association with the control valve body 57 are provided to effect movement of the piston 73 between activating and inactivating positions wherein the valve member 81 is respectively in engagement with, and disengaged from the seat 79, in response to appropriate energization of the solenoids. When the solenoid actuated piston 73 is in its active position with the valve member 81 disengaged from the seat 79, as shown in FIGURE 2, the outlet chamber 77, and therefore the vent 44, are communicated with the outlet flow passages 46 and 46' from the heat exchangers through the inlet passage 82 and passage 78. Thus, operation of the apparatus proceeds under the pressure sensitive control of the accordion member 64 in response to the pressure in the tank or other region containing the gas and liquid mixtures. When the solenoid actuated member 73 is in its inactive position, however, and the valve member 81 engages the seat 79, communication is blocked between passage 78 and the outlet chamber 77. Therefore, even though the relief valves 34 and 34' are controlled to establish gas flow to the turbine actuating nozzle boxes 36 and 36', the outlet flow of gas from the heat exchangers is blocked from the vent 44 and therefore gas flow through the over-all apparatus is prevented to render same inoperable.

From the foregoing, it will be appreciated that the control valve 47 may assume four separate conditions of control of the separating and gas venting apparatus. More particularly, in one condition as depicted in FIGURE 2, the solenoid actuated valve means of the control valve is in active venting position and the pilot valve means is opened due to an excessive tank pressure sensed in the control pressure chamber 63. In this condition of the control valve 47, the relief valves 34 and 34' are responsively opened to permit pressure relieving gas flow through the apparatus to the outlet port 44 in the manner hereinbefore described.

A second condition of the control valve is illustrated in FIGURE 3 wherein the solenoid actuated valve means is in active venting position, but the pilot valve means is in closed inactivating position by virtue of the tank pressure sensed in the control pressure chamber 63 being non-excessive. As a result, the relief valves are responsively closed, and gas flow to the turbines is prevented to thereby render the apparatus inactive. However, inasmuch as the solenoid actuated valve means is in active venting position in this second condition, upon a buildup of tank pressure to an excessive level, the valve reverts to the first condition and gas is ported to the vent 44.

A third condition of the control valve is illustrated in FIGURE 4 wherein the solenoid actuated valve means has been actuated to inactive position while the pilot valve means is likewise in closed, apparatus inactivating position due to the sensed tank pressure being nonexcessive.

In the fourth condition of the valve, as illustrated in FIGURE 5, the pilot valve means is in open apparatus activating position due to an excessive tank pressure and the relief valves are, accordingly, also opened. However, the solenoid actuated valve means is still in its inactive position wherein the valve member 81 is in engagement with the seat 79 to block communication between the outlet chamber 77 and the passage 78. Accordingly, despite the pilot valve being in apparatus activating position, the apparatus is rendered inactive by virtue of the solenoid actuated valve means preventing gas flow to the vent 44.

Considering now a single-ended embodiment of liquid-gas separating and gas venting apparatus in accordance with the invention and which is also somewhat modified in further respects from the embodiment hereinbefore described, reference is now made to FIGURE 7. As shown therein, the separator member is provided as an elongated hollow shaft 86 which has a plurality of outwardly extending vanes 87 at longitudinally spaced positions thereof which encompass radial gas inlets 88 which extend through the shaft wall to its hollow interior 89. A perforated shroud or tube 91 is mounted in concentric outwardly spaced relation to the shaft 86, and a baffle 92 is provided between the shaft and shroud at one end thereof while the other end is open to permit the inflow of gas and fluid mixture to the annulus between the shaft and shroud. The assembly of shaft and shroud is concentrically disposed within a hollow elongated cylindrical heat exchanger 93 comprising a nest of spaced longitudinally extending tube 94 mounted in an annular array between end plates 96 and 97. The tubes extend through the end plates, and a cap 98 is coaxially secured to the end plate 97 in such a manner as to define an annulus 99 communicating the tubes 94 extending through this end plate. The shaft 86 is journaled centrally of the cap 98 at one end while the other end of the shaft extends through, and is journaled centrally in the end plate 97. The shaft is closed at its end adjacent the cap 98 and the cap includes perforations as indicated at 101 to admit gas and liquid to the annulus between the shaft 86 and shroud 91. With the shaft in rotation, the liquid upon striking the vanes 87 is propelled outwardly through the shroud perforations and through the spaces between the tubes 94 of the heat exchanger 93 to be thereby returned to a tank or the like within which the apparatus is disposed. Entering gas flows around the vanes 87 in the manner indicated by the serpentine-shaped arrows of FIGURE 7 and through the inlets 88 to the hollow shaft interior 89.

A turbine housing 102 is coaxially secured to the end plate 97 of the heat exhanger 93 and end openings 103 from the hollow interior 89 of shaft 86 communicate with a chamber 104 in the turbine housing. A passage 106 extends from the chamber 104 to convey gas, introduced to this chamber from the hollow shaft interior 89, to a relief valve 107, subsequently described in detail, where the gas is divided into two portions. One portion of the gas is conveyed from the relief valve to a first nozzle 108 which extends into a turbine chamber 109 provided in the housing 102. The other portion of gas from the relief valve is conveyed to a second turbine nozzle 111 which extends into the turbine chamber 109 in opposed transversely offset relation to the nozzle 108 as best shown in FIGURE 9. Gas is directed from the nozzles upon the vanes of a turbine 112 rotatably mounted within the chamber 109, thereby effecting rotation of the turbine. In the rotatable mounting of the turbine, a shaft 113 is preferably journaled coaxially of the turbine chamber 109 and extends through a chamber 114, interposed between the chamber 109 and the chamber 104, and into the latter chamber. A suitable coupling 116 then couples shaft 113 to hollow shaft 86. The turbine 112 includes an integral sleeve shaft 117 which is concentrically rotatably disposed upon the shaft 113 and extends into the chamber 114. A magnetic friction clutch 118 disposed in chamber 114 is provided to couple the sleeve shaft 117 of the turbine to the shaft 113. The tubine 112 is thus coupled in driving relation to the hollow shaft 86 with the magnetic clutch 118 providing increased acceleration characteristics of the turbine.

The gas directed from the turbine nozzles 108 and 111 is expanded and cooled in driving the turbine 112 and the hollow vaned shaft 86 coupled thereto and the expanded cooled gas is channeled from the turbine compartment 109 to a manifold chamber 119 provided in the housing 102 at a position of communication with the tubes 94 extending through the end plate 97 from a semi-circular half sector of the heat exchanger. The expanded cool gas thus flows through the tubes of this sector and at the opposite ends of these tubes into the annulus 99 which channels the gas to the ends of the tubes of the remaining semi-circular half sector of the heat exchanger. The opposite ends of the tubes of this latter sector which extend through the end plate 97 communicate with a chamber 121 provided in the housing 102. The gas is conveyed from this chamber through a plurality of inlets 122 which serve to communicate the chamber 114 therewith. The chamber 114 is communicably coupled to an outlet vent 123 by means of a shut-off valve 124, subsequently described in detail herein. Thus, the expanded cool gas from the turbine chamber 109 makes a dual pass through the heat exchanger 93 to therein cool the liquid propelled outwardly through the heat exchanger from the vanes 87 of the hollow shaft 86. The gas is thereafter returned to the turbine housing and channeled through the chamber 114 to cool the magnetic clutch 118 enroute to the vent 123.

Considering now the valving arrangement employed with the embodiment of FIGURES 7–9, it is to be noted that the relief valve 107 includes a body 126 having a chamber 127 communicated with the passage 106 for conveying the gas received in chamber 104 from the interior 89 of the shaft 86. A recess 128 is provided in the body 126 which communicates with the chamber 127 and is provided with a valve seat 129 thereat. A pair of outlet ports 130 communicate with the recess 128 in order to divide the gas flow therefrom into the two portions which are respectively applied to the turbine nozzles 108 and 111. A bellows 131 is mounted within the chamber 127 and carries a plug 132 which is engageable with the seat 129 upon expansion of the bellows and is disengaged from the seat upon contraction of the bellows. As in the instance of the relief valves 34 and 34' of the embodiment of FIGURE 2, expansion and contraction of the bellows 131 of relief valve 107 is controlled by the pressure differential between the gas acting on the exterior of the bellows and the pressure interiorly thereof. In the instant embodiment, the interior pressure of the bellows 131 is controlled by means of a pilot valve 133 in a manner similar to that described with respect to the pilot valve means of the previous embodiment.

The pilot valve 133, as will be best seen from FIGURES 9, and 12 and 13, is arranged to apply tank pressure to the interior of the relief valve bellows 131 when the tank pressure is less than a predetermined minimum safe level, and to vent the interior of the relief valve bellows to vacuum or other relatively low environmental pressure when the tank pressure exceeds the predetermined minimum. To this end, the pilot valve includes a body 134 having a control pressure compartment 136 within which there is mounted an accordion member 137. A stem 138 projects from the accordion member 137 into a pilot chamber 139 provided in the valve body and a valve closure member 141 is secured to the end of the stem. With the accordion member 137 in expanded condition, the member 141 is in sealed engagement with an outlet port 142 communicating with the pilot chamber at a position of alignment with the stem 138, as indicated in FIGURE 12. When the accordion member 137 is in contracted condition, however, the closure member 141 is disengaged from the outlet port 142 as shown in FIGURE 13. In addition, the closure member 141 is disposed in closed sealing relation to the interior of a bellows 143 which is mounted within the pilot chamber 139 and communicated with the control pressure chamber 136, when the accordion member 137 is in the contracted position of FIGURE 13. However, when the accordion member 137 is expanded, the interior of the bellows 143 is ported to the pilot chamber 139, as indicated in FIGURE 12. An inlet port 144 is communicated with the control pressure chamber 136 to facilitate communicable connection thereof to the tank. A pilot port 146 is provided in communication with the pilot chamber 139 and is connected to the interior of the relief valve bellows 131. The accordion member 137 is adjusted such that when the tank pressure applied to the control pressure chamber 136 through the port 144 is greater than a predetermined safe minimum, the accordion member is contracted and the closure member 141 is disengaged from the port 142 and disposed in sealed closing relation to the interior of the bellows 143 as shown in FIGURE 13. Thus, the interior of the relief valve bellows 131 is ported through the pilot port 146 to the pilot chamber 139 and this chamber is ported through outlet port 142 to a vent pipe 147 which communicates with the vent 123 as best shown in FIGURE 7. The interior of the relief valve bellows is thus at this time ported to vacuum or other low pressure and the pressure of the gas within the chamber 127 of the relief valve hence contracts the bellows to disengage the plug 132 from the seat 129, thereby establishing flow of gas to the turbine nozzles 108 and 111. The turbine 112 is thus driven and the apparatus is rendered operable to produce its liquid-gas separating and gas venting functions. When the tank pressure is below the predetermined safe minimum, this pressure acting in chamber 136 upon accordion member 137 is insufficient to contract same and, accordingly, the accordion member is in expanded position as indicated in FIGURE 12. The closure member 141 is therefore in sealed closing engagement with the outlet port 142 and is disengaged from the bellows member 143 whereby the pilot chamber 139 is communicated with the chamber 136. Tank pressure consequently exists in the pilot chamber 139 and is applied through the pilot port 146 to the interior of the relief valve bellows 131. The pressure of the gas in the relief valve chamber 127 acting on the exterior of the bellows 131 is insufficient to contract same against the tank pressure existing in its interior. Accordingly, the relief valve bellows 131 is in expanded position to sealably engage the plug 132 with the seat 129 and prevent flow of gas to the turbine nozzles 108 and 111. Thus, the apparatus is rendered inoperable in the conduct of its separating and gas venting functions.

Considering now the shut-off valve 124 in greater detail, it is to be noted that this valve includes a housing 148 which is communicated at its upper end with the chamber 114 and communicated at its lower end with the vent 123 through a port including a valve seat 149 facing into the vent. The shut-off valve includes a bellow 151 which is mounted within the housing 148 and has a stem 152 projecting therefrom with a plug 153 at its end. The plug is disposed within the vent 123 and is engageable with the seat 149. A spring 154 disposed within the vent acts upon the plug to normally urge same into sealing engagement with the seat and to normally maintain the bellows 151 in a contracted condition.

To provide selective opening and closing of the shut-off valve 124, the valving arrangement of the embodiment of FIGURES 7–9 is further provided with a control valve 156 which is arranged to selectively control the pressure within the interior of the bellows 151 between a level which is overbalanced by the force of the spring 154, and a level which overbalances the spring. More particularly, with the interior pressure of the bellows 151 relatively low, the force of the spring 154 opposing this pressure is sufficiently large to urge the plug 153 into sealed engagement with the seat 149. With a relatively high pressure existing within the bellows interior, this pressure opposes and overbalances the force of the spring 154 to thus effect expansion of the bellows and movement of the plug out of engagement with the seat, thereby porting the interior of the housing 148 to the vent 123. Preferably, the control valve 156 is of the solenoid actuated variety and includes a valve body 157 having a cylinder bore 158 with a piston 159 mounted for solenoid actuated reciprocation therein. A stem 161 projects from the piston into a chamber 162 and also extends through a passage 163, in spaced relation to the walls thereof, into a chamber 164 communicated with the chamber 162 through the passage. Valve seats 166 and 167 are provided at the opposite ends of the passage 163 which respectively face into the chamber 162 and the chamber 164. Plugs 168 and 169 are carried by the stem 161 and are respectively engageable with the seats 166 and 167. In one solenoid actuated position of reciprocation of the piston 159 as determined by appropriate energization of solenoids 171 and 172 carried by the body 157, plug 168 is in engagement with seat 166 while plug 169 is disengaged from seat 167, as depicted in FIGURE 10. In another position of reciprocation of the piston, plug 168 is disengaged from seat 166 while plug 169 is engaged with seat 167, as depicted in FIGURE 11. The chamber 162 is provided with an inlet port 173 which is arranged for communicable connection to the tank, and the chamber 164 is provided with an outlet port 174 which is coupled by means of a vent pipe 176 into communication with the vent 123. The control valve is further provided with a control port 177 which is communicated with the intermediate region of the passage 163 and is communicated with the interior of the shut-off valve bellows 151. Thus, with the control valve actuated to the position indicated in FIGURE 10, the chamber 162 is blocked from passage 163 while the interior of the shut-off valve bellows is communicated through pilot port 177, passage 163, chamber 164, outlet port 174, and vent pipe 176, with the vent 123. The interior of the shut-off valve bellows is accordingly ported to vacuum or other low environmental pressure such that the bellows is contracted by the force of the spring 154 and the plug 153 is engaged with the seat 149 to thereby block communication between the chamber 114 and the vent 123. Gas flow through the apparatus is accordingly prevented irrespective of the condition of the pilot valve 133 as depicted in either of FIGURES 12 and 13. The apparatus is, accordingly, locked in an inactive state. With the piston 159 of the control valve actuated to the position depicted in FIGURE 11, however, the chamber 164 is blocked from communication with the passage 163, and tank pressure is applied through the inlet port 173, chamber 162, passage 163, and control port 177 to the interior of the shut-off valve bellows 131. The tank pressure at the interior of the bellows is sufficient to overbalance the force of the spring 154 to thereby disengage the plug 153 from the seat 149 and thereby communicate the chamber 114 with the vent 123. In this condition of the control valve, operation of the apparatus is controlled by the pilot valve 133 in accordance with the pressure existing within the tank in the manner previously described. More particularly, where the tank pressure is excessive, the pilot valve 133 effects opening of the relief valve 107 to thereby actuate the apparatus for gas-liquid separating and gas venting service. Where the tank pressure is not excessive, the pilot valve effects closure of the relief valve to thereby render the apparatus inactive.

Although the present invention has been described hereinbefore with respect to several preferred embodiments, it will be appreciated that various variations and modifications may be made therein without departing from the true spirit and scope of the invention, and thus it is not intended to limit the invention except by the terms of the following claims.

What is claimed is:

1. A zero gravity separator comprising an annular heat exchanger adapted for mounting within the upper regions of a tank containing a fluid in double-phase liquid and gas condition, said heat exchanger having liquid flow passages extending radially therethrough, said heat exchanger having gas flow passages extending longitudinally thereof in heat exchange relation to said liquid flow passages and terminating in a vent pipe adapted for porting exteriorly of said tank, a turbine housing secured to said heat exchanger and having a sealed chamber therein, a turbine journaled for rotation within said chamber, a separator disc coaxially disposed within said heat exchanger, said disc having a plurality of gas inlets extending radially thereof, a shaft coaxially connecting said disc and said turbine, said shaft having a longitudinal passage communicating with the gas inlets of said disc and having a radially extending outlet spaced therefrom, means defining a relief valve body in association with said turbine housings, said valve body having a flow path extending therethrough including a valve seat, nozzle means disposed within said turbine housing in communication with one end of said flow path through said valve body for directing gas therefrom into motivating relation to said turbine, means defining a flow path in sealed rotation permitting relation to said shaft and communicating said outlet of the shaft passage with the second end of said flow path through said valve body, a pressure sensitive valve member mounted within said valve body and engageable with said seat, said valve member movable between a position in engagement with said seat and a second position out of engagement therewith in response to gas pressures in said tank respectively less than and greater than a predetermined pressure, and means communicating the turbine chamber with said gas passages of said heat exchanger.

2. A zero gravity separator comprising a turbine housing having a sealed chamber therein, a pair of turbines journaled in said chamber for independent coaxial rotation in opposite directions, first nozzle means disposed within said chamber for directing gas upon said first turbine to effect rotation thereof, second nozzle means disposed within said chamber for directing gas upon said second turbine to effect rotation thereof, means within said chamber defining a first orifice longitudinally intermediate said first and second turbines in alignment with said first nozzle means to receive gas directed therefrom subsequent to driving of said first turbine and direct the gas in driving relation to said second turbine, means defining a second orifice longitudinally intermediate said first and second turbines in aligned relation with said second nozzle means for receiving gas directed therefrom subsequent to driving of said second turbine and directing the gas into driving relation to said first turbine, first and second annular heat exchangers secured to said turbine housing respectively in coaxially outwardly spaced relation to said first and second turbines, said first and second heat exchangers each having liquid flow passages extending radially therethrough and gas flow passages extending longitudinally thereof in heat exchange relation with said liquid flow passages, first and second separator discs respectively coaxially mounted for rotation within said

first and second heat exchangers, said first and second discs respectively having radially extending gas inlets, first and second shafts respectively coaxially connecting said first disc and said first turbine and said second disc and said second turbine, said first and second shafts respectively having longitudinal passages communicating with the gas inlets of said first and second discs and having gas outlets intermediate said first disc and first turbine and intermediate said second disc and said second turbine, means defining a first flow passage in sealed rotation permitting relation to said first shaft and communicating the outlet thereof with said first nozzle means, means defining a second flow path in sealed rotation permitting relation to said second shaft and communicating the outlet thereof with said second nozzle means, a third flow path communicating a region of said chamber adjacent said second turbine and said first orifice with said gas passages of said second heat exchanger, a fourth flow path communicating a region of said chamber adjacent said first turbine and said second orifice with said gas passages of said first heat exchanger, and means communicating the gas passages of said first and second heat exchangers with an outlet vent.

3. A zero gravity separator according to claim 2, wherein said first and second turbines are journaled in bearings within said chamber and means defining flow paths between said first and second orifices and said bearings for gas cooling the latter.

4. A zero gravity separator according to claim 2, further defined by a first relief valve body carried by said turbine housing and including a valve chamber and inlet and outlet passages communicating said first flow path and first nozzle means through said chamber, said outlet passage of said valve body including a valve seat, an accordion valve member mounted within said valve chamber for expansive and contractive movement into and out of engagement with said seat, a second relief valve body carried by said turbine housing having a sealed chamber and inlet and outlet passages communicating said second flow path and said second nozzle means through said chamber, said outlet passages of said second valve body having a valve seat, a second accordion valve member mounted within said chamber of said second valve body for expansive and contractive movement into and out of engagement with said seat of said outlet passage thereof, and pilot valve means coupled to the interiors of said first and second accordion valve members for selectively controlling the pressures therein between levels greater than and less than the pressure of gas in the chambers of said first and second valve bodies.

5. A zero gravity separator according to claim 4, further defined by said turbine housing and said first and second heat exchangers being contained within a closed tank and said outlet vent being ported exteriorly of said tank, and by said pilot valve means communicating the interiors of said first and second accordion valve members with said outlet vent and the interior of said tank respectively in response to pressures in said tank greater than and less than a predetermined pressure.

6. A zero gravity separator according to claim 5, further defined by a control valve body having a pilot chamber and a control pressure chamber communicated through a leak passage, said control valve body having a pilot port communicating with said pilot chamber and coupled to the interiors of the first and second accordion valve members in the chambers of said first and second relief valve bodies, said control valve body having an outlet passage communicating said pilot chamber with said outlet vent and a valve seat in the pilot chamber at the entrance of said outlet passage, said control valve body having an inlet port communicating said control pressure chamber with the interior of said tank, a pressure sensing accordion member mounted in said control pressure chamber, a closure member connected to said pressure sensing accordion member and disposed in said pilot chamber for engagement with said seat therein, said pressure sensing accordion member movable between first and second positions wherein said closure member is engaged with and disengaged from the seat in said pilot chamber respectively in response to pressures in said control pressure chamber less than and greater than said predetermined pressure, said pilot chamber, said control pressure chamber, said outlet passage, said pilot port, said inlet port, and said accordion member with closure member connected thereto thereby comprising said pilot valve means, said control valve body having an outlet chamber communicated with said outlet vent and an inlet passage communicating the gas passages of said first and second heat exchangers with said outlet chamber, said outlet chamber having a valve seat at the termination of said inlet passage therein, a solenoid actuatable piston mounted for reciprocation in said control valve body and having a closure member connected thereto respectively engaged with and disengaged from said seat in said outlet chamber in response to reciprocation of said piston between first and second positions, and solenoid means for selectively reciprocating said piston between said first and second positions.

7. A zero gravity separator comprising an elongated hollow cylindrical heat exchanger adapted for mounting within the upper regions of a tank containing a fluid in double-phase liquid and gas condition, said heat exchanger having a plurality of longitudinally extending gas flow passages with the passages of one semicircular half sector of the heat exchanger communicated at one end with the passages of the other half sector of the heat exchanger to thereby circulate gases in one longitudinal direction through the first half sector of the heat exchanger and then in the opposite longitudinal direction through the second half sector of the heat exchanger, said heat exchanger having liquid flow passages extending radially therethrough, a hollow shaft journaled for rotation coaxially within said heat exchanger with one end of the shaft being closed and the other end being opened to define a flow path longitudinally therethrough, said shaft having a plurality of longitudinally spaced outwardly extending vanes encompassing radial gas inlets communicated with said flow path, said shaft upon rotation propelling liquid introduced to the hollow interior of said heat exchanger from said tank outwardly through said liquid flow passages for return to said tank and channeling gas introduced to the hollow interior of the heat exchanger through said gas inlets of said shaft to the flow path extending longitudinally thereof, a turbine coaxially connected in driving relation to said shaft to effect said rotation thereof, means communicating with said flow path of said shaft for directing gas therefrom into motivating relation to said turbine, said gas being expanded and cooled in motivating said turbine, means channeling expanded gas from said turbine to said gas passages of the first half sector of said heat exchanger, and means for venting the gas passages of the second half sector of said heat exchanger exteriorly of said tank.

8. A zero gravity separator according to claim 7, further defined by magnetic friction clutch means coupling said turbine to said shaft, and means for channeling gas from the gas passages of said second half sector of said heat exchanger into cooling relation to said clutch means prior to venting of said gas.

9. A zero gravity separator according to claim 7, further defined by a relief valve communicating said flow path of said shaft with said turbine, said relief valve including an accordion valve member for blocking communication between the flow path and turbine in response to expansion of the member and establishing communication between said flow path of said shaft and said turbine in response to contraction of the accordion member; and a pilot valve including a pilot port connected to the interior of said accordion member of said relief valve, said pilot valve having an outlet port communicated with

said vent and an inlet port adapted for communication with said tank, said pilot valve operable to communicate the inlet and pilot ports thereof in response to pressures at the inlet port less than a predetermined pressure and to communicate the outlet and pilot ports thereof in response to pressures at the inlet port greater than said predetermined pressure.

10. A zero gravity separator according to claim **9**, further defined by a shut-off valve communicating the gas flow passages of said second half sector of said heat exchanger with said vent, said shut-off valve including an accordian valve member for establishing communication between the gas flow passages of the second half sector of the heat exchanger and said vent upon expansion of the shut-off valve accordion member in response to relatively high pressure in the interior thereof while blocking communication between the gas flow passages of the second half sector of said heat exchanger and said vent upon contraction of the shut-off valve accordion member in response to relatively low pressure in the interior thereof, and control valve means for selectively porting the interior of said shut-off valve accordion member to said tank and said vent respectively to thereby establish said relatively high and low pressures therein.

11. A zero gravity separator comprising a turbine housing adapted for mounting within the upper regions of a tank containing fluid in double-phase gas and liquid condition, said turbine housing having first, second and third chambers therein sealed from each other and coaxially aligned, said housing having an inlet flow passage communicating with said second chamber and first and second outlet flow passages respectively communicating with said first and second chambers, a turbine journaled for rotation coaxially within said first chamber, first and second turbine nozzles disposed at diametrically opposed positions of said first chamber adjacent said turbine, a hollow elongated cylindrical heat exchanger coaxially secured to said turbine housing adjacent said third chamber thereof, said heat exchanger having longitudinal gas passages with the gas passages of a first semicircular half of the heat exchanger communicating at a first end thereof with said first outlet passage of said turbine housing and the gas passages of the second semicircular half of the heat exchanger communicating at the first end thereof with said inlet passage of said turbine housing, said gas passages of said first half of said heat exchanger communicated with the gas passages of said second half of said heat exchanger at the second ends thereof, said heat exchanger having liquid passages extending radially therethrough in heat exchange relation with said gas passages, a hollow shaft coaxially disposed within the hollow interior of said heat exchanger and journaled for rotation between the opposite ends thereof, said shaft closed at the second end of heat exchanger and communicating at the first end of said heat exchanger with said third chamber of said turbine housing, said shaft having a plurality of longitudinally spaced outwardly extending vanes encompassing radial gas inlets communicating with the hollow shaft interior, said shaft upon rotation thereby propelling liquid outwardly through said liquid passages of said heat exchanger and channeling gas into said gas inlets to the hollow shaft interior for passage to the third chamber of said turbine housing, a magnetic friction clutch disposed within said second chamber of said turbine housing and coaxially coupling said turbine to said shaft, and a vent adapted for positioning exteriorly of said tank and communicably connected to said second outlet passage of said turbine housing, said turbine housing having a flow path communicating said third chamber and said turbine nozzles, whereby fluid entering the hollow interior of said heat exchanger is separated by said shaft with the liquid being propelled outwardly through the liquid passages of said heat exchanger and the gas being channeled through the hollow interior of said shaft to said third chamber of said turbine housing, said gas is directed from said third chamber to said turbine nozzles and emanates therefrom to drive said turbine which in turn effects rotation of said shaft while the gas expands and is cooled in driving said turbine, the cooled gas is directed from the first chamber of said turbine housing through the gas passages of said heat exchanger to thereby cool the liquid directed through the liquid passages thereof, the gas is directed from the gas passages of the heat exchanger to the second chamber of said turbine housing to therein cool said clutch, and is directed from the second chamber to said vent for porting exteriorly of said tank.

12. A zero gravity separator according to claim **11**, further defined by a relief valve body carried by said turbine housing and having a relief valve chamber with communicating inlet and outlet passages, said outlet passage of said relief valve body having a valve seat, said inlet and outlet passages of said relief valve body respectively communicated with said third chamber of said turbine housing and said turbine nozzle, an accordion valve member mounted within said relief valve chamber and expansively movable into engagement with said seat and contractibly movable out of engagement therewith, a pilot valve body carried by said turbine housing having a pilot chamber and a control pressure chamber, said pilot valve body having an outlet port communicating said pilot valve chamber with said vent and a pilot port communicating the pilot valve chamber with the interior of the accordion valve member disposed in said relief valve chamber, said pilot valve body having an inlet port for communicating said control pressure chamber with said tank, accordion valve means mounted within said control pressure chamber for movement between a first position wherein said control pressure chamber is communicated with said pilot chamber and said outlet port is closed and a second position wherein communication between said control pressure chamber and said pilot chamber is blocked and said outlet port is open, said accordion valve means movable to said first position in response to pressures in said control pressure chamber less than a predetermined pressure and movable to said second position in response to pressures in said control pressure chamber in excess of said predetermined pressure, a shut-off valve body carried by said turbine housing having a shut-off valve chamber with an inlet passage communicating with said second chamber of said turbine housing and an outlet passage communicating with said vent, said outlet passage of said shut-off valve housing including a seat, an accordion valve member disposed within said shut-off valve chamber for contractive movement into engagement with said seat and expansive movement out of engagement therewith, a control valve body carried by said turbine housing having an inlet port, an outlet port, and a pilot port, said inlet port of said control valve body adapted for communication with said tank, said outlet port of said control valve body communicated with said vent, and said pilot port of said control valve body communicated with the interior of the accordion member disposed within said shut-off valve chamber, a solenoid actuatable piston within said control valve body movable between a first position establishing communication between said pilot port and said outlet port and a second position establishing communication between said pilot port and said inlet port, and solenoid means associated with said control valve body for selectively actuating said piston.

13. A zero gravity separator comprising hollow cylindrical heat exchanger means adapted for mounting within the upper regions of a tank containing a fluid in double-phase liquid and gas condition, said heat exchanger means having liquid flow passages extending radially therethrough, said heat exchanger means having gas flow passages extending longitudinally thereof in heat exchange relation to said liquid flow passages and communicating with a vent for disposition exteriorly of said tank; separator means including at least one separator element mounted for rotation coaxially within said heat exchanger means, each separator element being adapted to propel liquid introduced from said tank to the hollow interior of said heat exchanger means radially outward through said liquid flow passages in response to rotation of the element, each separator element having circumferentially disposed gas inlets extending inwardly into communication with a common gas flow path for receiving gas introduced from said tank to the hollow interior of said heat exchanger means; a turbine connected in driving relation to each separator element to effect said rotation thereof; flow means communicating with said flow path of each separator element for directing gas therefrom into motivating relation to said turbine connected thereto, said gas being expanded and cooled in motivating said turbine; valve means in operable relation to said flow means for permitting flow therethrough in response to pressures in said tank in excess of a predetermined pressure and blocking flow through the flow means in response to pressures in said tank less than said predetermined pressure; and means for channeling expanded gas from said turbine to said gas passages of said heat exchanger means, said gas thereby cooling said liquid returned to the tank through the liquid passages of said heat exchanger means prior to venting of the gas exteriorly of the tank.

14. A zero gravity separator according to claim 13, further defined by said valve means including control means for selectively opening and closing communication between said gas passages of said heat exchanger means and said vent.

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