United States Patent

[11] 3,570,481

[72] Inventor James W. Woodberry, Jr
Titusville, Fla.

[21] Appl. No. 769,806
[22] Filed Oct. 23, 1968
[45] Patented Mar. 16, 1971
[73] Assignee Cryogenic Systems, Inc.
West Hartford, Conn.
Continuation-in-part of application Ser. No. 641,956, May 29, 1967, now abandoned.

[54] **CRYOGENIC UNDERWATER BREATHING APPARATUS**
10 Claims, 4 Drawing Figs.

[52] U.S. Cl. 128/142.2, 62/52
[51] Int. Cl. B63c 11/22
[50] Field of Search .... 128/142.2, 142.4, 140, 142, 142.3; 62/51; 128/203; 62/50, 52, (Inquired)

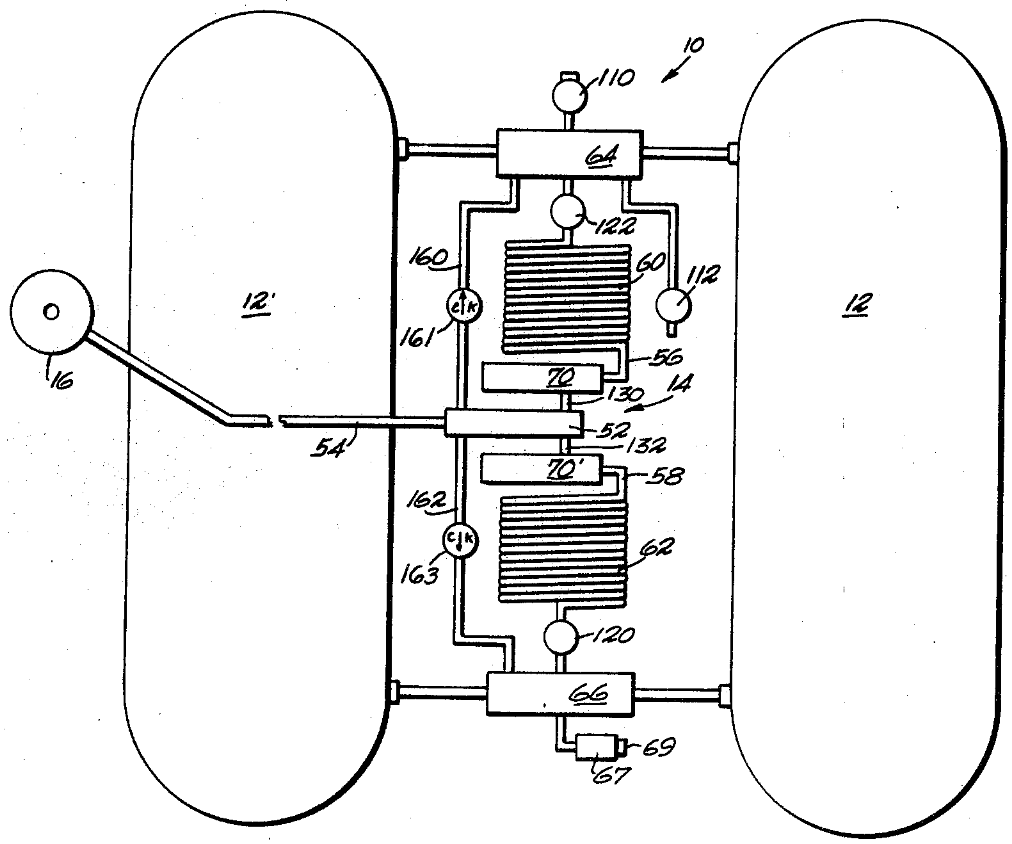
[56] **References Cited**

UNITED STATES PATENTS

3,097,497	7/1963	Fitt	62/52
3,205,670	9/1965	Carolan	62/52
3,366,107	1/1968	Frantom	128/142.2

Primary Examiner—Richard A. Gaudet
Assistant Examiner—G. F. Dunne
Attorney—Davis, Hoxie, Faithfull & Hapgood

ABSTRACT: Cryogenic underwater breathing apparatus includes a liquid state air storing vessel with outlet ports on antipodal, diametrically opposite ends thereof. Liquid air flows through a selected one of the tank output ports under gravity actuation depending upon the attitude of the tank, with the air being converted to a gaseous state in a heat exchanger and thence flowing to a reservoir and an output demand regulator for consumption. Regulator control valves are provided to maintain the end air product stored in the reservoir at a predetermined pressure above that of the ambient environmental medium.



2 Sheets-Sheet 1

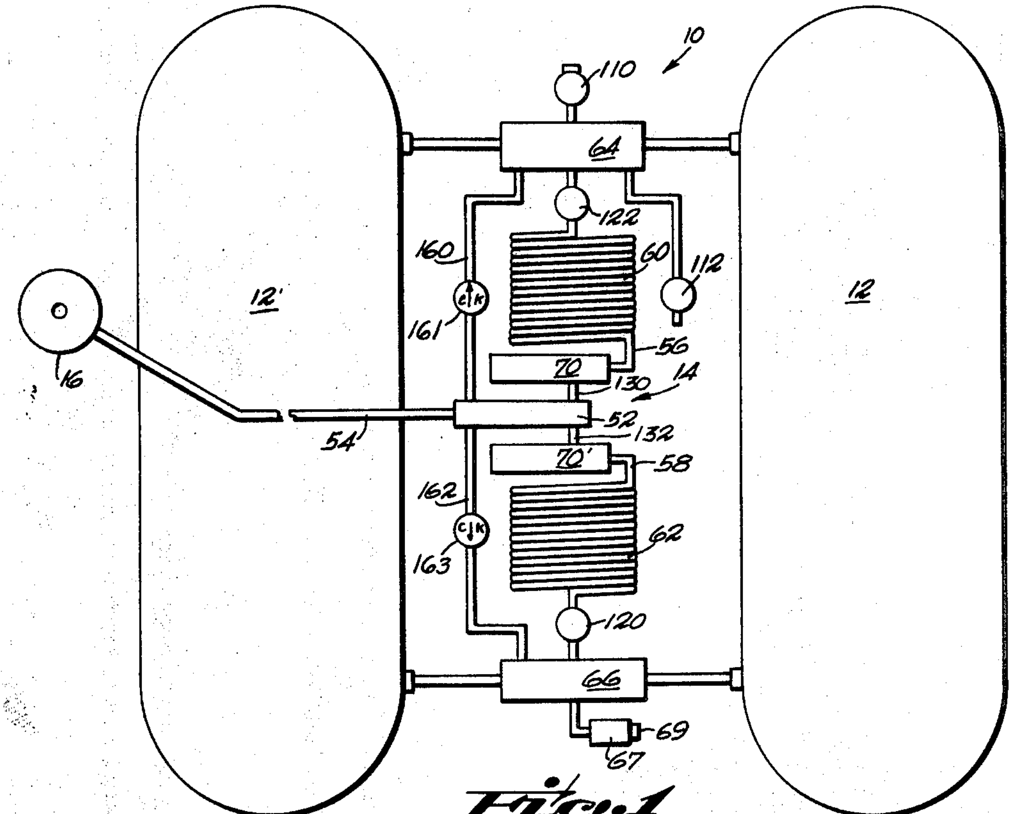


FIG. 1

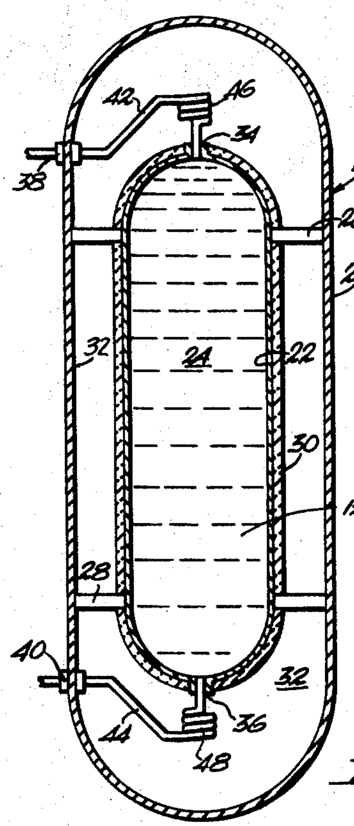


FIG. 2

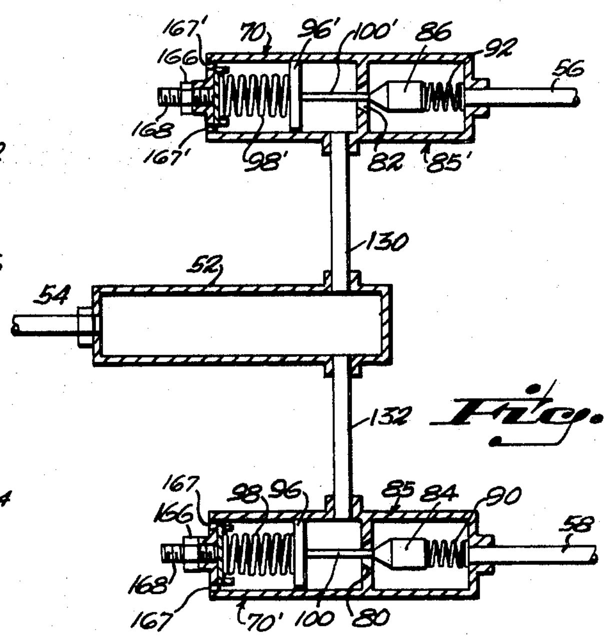


FIG. 3

INVENTOR.
JAMES W. WOODBERRY JR.

BY John Cyril Malloy

ATTORNEY.

Patented March 16, 1971 3,570,481

2 Sheets-Sheet 2

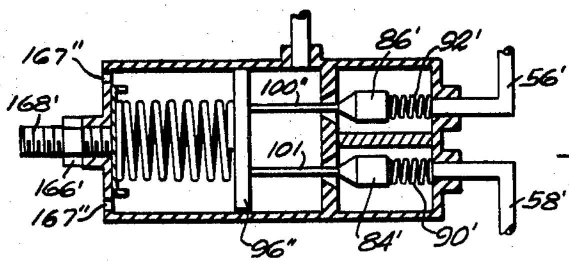


Fig. 4

INVENTOR.
JAMES W. WOODBERRY JR.
BY
John Cyril Malloy
ATTORNEY.

CRYOGENIC UNDERWATER BREATHING APPARATUS

DISCLOSURE OF INVENTION

This invention relates to an underwater life support system and, more specifically, to an underwater air supplying arrangement employing cryogenic, liquified air storage. This application is a continuation-in-part of my like-entitled application, Ser. No. 641,956, filed May 29, 1967, now abandoned.

Air has typically been carried by persons engaged in underwater activities such as military demolition and hazard fabrication, treasure hunting and salvage, scuba explorations, or the like in pressurized metallic air cylinders. However, the maximum permissible underwater stay for a user employing such pressurized cylinders is limited both by the restricted air capacity thereof for the range of permissible pressures, and by weight and bulk limitations which determine the maximum size and number of cylinders which may be transported.

It is thus an object of the present invention to provide an improved underwater breathing apparatus.

More specifically, an object of the present invention is the provision of an underwater breathing arrangement employing cryogenic liquid air storage adapted for extended underwater usage without requiring refilling, and wherein air is reliably supplied to the user by one of two parallel paths irrespective of the orientation of the apparatus.

It is another object of the present invention to provide breathing apparatus which is suitable for use in mediums in which breathing is not possible by humans without external mechanical assistance.

These and other objects of the present invention are realized in a specific, illustrative embodiment thereof which comprises at least one insulated vessel for storing a liquified, cryogenic air mixture. Two output ports are disposed at diametrically opposite ends of the vessel, with each port being connected to an output air reservoir by a manifold, a heat exchanger for converting stored air from a liquid to a gaseous state, and a pressure regulating control valve. A demand regulator is connected to the reservoir for extracting air therefrom under control of the system user as required.

Liquified air flows under the action of gravity through at least one vessel output port independent of the orientation of the composite underwater breathing arrangement. The air is then converted to vapor form, and develops a sufficient air pressure in the output reservoir to supply air to the user as required, with a portion of the vapor returning to the vertically raised end of the vessel to aid in replacing the volume of liquid which had been removed therefrom. The air reservoir is selectively connected for air charging to, or isolated from the air storing vessel under control of the regulator valves which, in turn, are responsive to both the air pressure within the output reservoir and to the pressure of the ambient medium.

It is thus a feature of the present invention that a small, compact underwater breathing apparatus include an insulated container for storing a very cold, liquified air mixture which, by reason of said insulation, permits maintenance of the stored liquified air at low pressures, and gravity actuated apparatus operative independent of the system attitude for expanding the liquified air into a relatively large volume of air in the gaseous state for breathing over a prolonged length of time in response to the demands of a user.

It is another feature of the present invention that underwater breathing apparatus for supplying air to a demand regulator held in the mouth of a user comprise a container including an inner vessel for storing a cryogenic liquified air mixture, an outer shell jacketing the vessel, spacer apparatus for separating the vessel and shell, insulation between the vessel and shell, the inner vessel having antipodal outlet ports, the shell having two openings, a conduit connecting each of the ports to a corresponding shell opening, apparatus for converting the liquified gas mixture to a gaseous state at a temperature suitable for breathing and for delivering the gas to the demand regulator via a reservoir, a tube connecting the reservoir and the regulator, the apparatus connecting the reservoir and each opening in the shell including a heat exchanger, a manifold and a regulating control valve, the control valves being adapted to maintain a pressure in the reservoir at all times a fixed increment above the ambient pressure, and a one-way vent valve, a fill valve and pressure relief valve connected to the inner vessel.

A complete understanding of the present invention and of the above and other features and advantages thereof may be gained from a consideration of the following detailed description of illustrative embodiments thereof presented hereinbelow in conjunction with the accompanying drawing in which:

FIG. 1 is a schematic plan view of an underwater breathing arrangement which embodies the principles of the instant invention;

FIG. 2 is a schematic, vertical sectional view of a liquid air storing container shown in the arrangement of FIG. 1;

FIG. 3 is a schematic sectional view of two pressure control valves and an air reservoir depicted in FIG. 1; and

FIG. 4 is a schematic sectional view of a modified form of a pressure control valve.

Referring to the drawings, wherein like reference characters designate like or corresponding parts throughout the various views, and referring particularly to FIG. 1, there is shown an underwater breathing apparatus **10** which includes a container **12** for storing a very cold, liquified air mixture. The container **12** supplies air to an output demand regulator **16** by way of apparatus **14**, particularly described hereinbelow, which converts the stored cryogenic air into gaseous form characterized by a temperature suitable for breathing.

The container **12** is illustrated in detail in FIG. 2, and includes an inner vessel **22** for storing a cryogenic liquified gas mixture within a hollow **24** defined thereby. An outer shell **26** jackets the inner vessel and is held in spaced relation by a spacer **28** so as to define a jacket space **32** about the vessel. Suitable insulation means such as the wrapping **30** about the inner vessel is provided and preferably a vacuum exists in the jacket space **32**. The inner vessel **22** is provided with antipodal ports **34** and **36** on diagonally opposite ends thereof, and the shell **26** is provided with companionate openings **38** and **40** which are respectively connected to the associated ports **34** and **36** through pipes **42** and **44** each of which is preferably provided with a coil **46** and **48** intermediate the opening and the port.

The apparatus **14**, depicted in FIGS. 1 and 3, comprises a reservoir **52** connected by a tube **54** to the demand regulator **16**, which is of any standard type permitting flow from a pressurized reservoir when there is a diminished pressure on the output side thereof. Structure including a first and a second conduit **56** and **58** connect each of the openings **38** and **40** of the outer shell and the reservoir **52** through a plurality of system elements. In particular, heat exchangers **60** and **62** are provided and mounted to be exposed to the underwater environment. In the preferred embodiment, the heat exchangers **60** and **62** comprise a coil, or a tube with a thin deflector plate of spiral configuration axially arranged therein for the purpose of breaking up the flow of liquid through the tube and for continuously deflecting it outwardly. As the air passes through the tube against the outer walls thereof, maximum heat exchange transpires between the very cold air and the much warmer underwater ambient medium (a temperature differential of several hundred degrees Fahrenheit). Also, manifolds **64** and **66** are included between the heat exchangers **60** and **62** and the openings **38** and **40** of the shell **26**.

Regulating control valves **70** and **70'** interconnect the heat exchangers **60** and **62** with the reservoir **52**, and serve to keep the air pressure in the reservoir a predetermined amount above the ambient underwater environmental pressure. The valves **70** and **70'** are depicted in detail in FIG. 3 and include a valve seat **82**, **80** and a seat-sealing member **86**, **84** contained in a valve chamber **85'**, **85** for movement between a left seated position and the valve open (right) position shown.

The requisite valve diaphragm or piston may, for purposes of this description, be considered as a plate 96', 96 which is spaced from the valve seat 82, 80 and provided with a biasing element comprising a spring 98', 98. The spring 98', 98 and the ambient pressure acting through valve apertures 167', 167 urge the plate 96', 96 to the right in FIG. 3 (valve open position). An operator arm 100', 100 is connected for movement with the associated plate 96', 96 and further connected to the seat-sealing member 86, 84. Also, a spring 92, 90 is provided to urge the member 86, 84 to the seated position when the pressures are balanced on both sides of the valve plate 96', 96.

When the pressure in the reservoir 52 is below the desired level given by the sum of the ambient pressure and a fixed increment thereover, the valves 70 and 70' are held open. More specifically, when this pressure insufficiency obtains, the forces on the left of the diaphragm plates 96' and 96 developed by the ambient environment acting through the valve opening 167' and 167 and by the compression springs 98' and 98 exceed the reservoir pressure to the right of the diaphragms. Accordingly, the diaphragm plates 96' and 96, the connecting arms 100' and 100, and the sealing members 86 and 84 are extended to the right, thus unblocking the valve seats 80 and 82.

Conversely, when the reservoir pressure is at or above the desired level, there is excess pressure on the right side of the diaphragm plates 96' and 96 thus constraining the valve members 86 and 84 to the left, thereby engaging the valve seats 82 and 80 and shutting the valves 70 and 70'. It will be apparent with reference to the alternative valve embodiment of FIG. 4 that a single diaphragm plate 96'' may actuate both operator members 100'' and 101 which are arranged in parallel to operate upon valve sealing members similar to those shown in FIG. 3. For purposes of brevity, the elements of the FIG. 4 valve embodiment have been designated with corresponding prime designations and, consequently, are not further described herein.

The manifold 64 (FIG. 1) is provided with a vent valve 110 and, also, a relief valve 112 which opens in response to an excessive pressure in the container to avoid damage to the system and injury to a user. The other manifold 66 is provided with a fill check valve 67 having a feed mouth 69 for charging liquid air into the inner vessel 22. A connector member on the terminal end of a hose, not shown, connected to a pressurized liquid air source is interconnected with the feed mouth 69 and the liquified air, under the pressure from the source, fills the manifold 66, the container 12, and the manifold 64. Completion of filling can be determined, for example, by noting liquid exhausting out of the vent valve 110 which is in the open position during filling. Thereafter, the vent valve 110 is closed; the fill check valve 67 also closes; and the hose from the source is disconnected.

In the preferred embodiment, on/off valves 120 and 122 are included between the manifolds 64 and 66 and the heat exchangers 60 and 62. The valves 120 and 122 are maintained in the "off" position during the filling operation so that the liquid air will not reach the coils 60 and 62 and, more importantly, the control valves 70 and 70' earlier described. The valves 120 and 122 are kept in the "off" position until the apparatus is ready for use, it having been found that this increases the period during which the liquid remains in that state or phase and wherein excessive internal pressures are avoided.

When ready for use, the on/off valves 120 and 122 are turned to the "on" position. Assuming the composite apparatus to be in the vertical orientation shown in FIG. 1, the liquid air will flow under the action of gravity out of the vessel 22 and into the manifold 66. The air will then pass through the open valve 120 and the heat exchanger 62 where it will be turned by the heat which it absorbs from the underwater medium into a gas. The vaporized air accumulates in the reservoir 52 and develops an increasing pressure within the initially open control valves 70 and 70'. In addition, a component of the air flow passes through the open valve seat 82 and returns through the conduit 56 and the manifold 64 to the upper portion of the tank 12 to equalize the tank pressure and to aid in replacing the displaced liquid with the relatively higher volume which is occupied when the liquid is in the gaseous state.

As is well-known, persons using apparatus of this type underwater assume various attitudes. When the attitude of the user is such that the apparatus on his back changes and the liquid is at the antipodal position in the tank or container 12 with respect to that just described and as shown in FIG. 1, the reverse of the flow just described will take place, gravity now forcing the air fluid through the manifold 64 and the heat exchanger 60 to the reservoir 52 to supply air to the regulator 16, with a component of the air returning through the heat exchanger 62 and the manifold 66 to the tank 12.

A second air storing tank 12' may be provided and arranged for connection in parallel with the first tank or container 12. This second tank 12' is of similar construction to the tank 12 and is connected at its respective openings to the manifolds 64 and 66 by any suitable linkage in accordance with the above-described purposes and operation. It will also be understood that a plurality of such tanks may be employed, the tanks being arranged in a parallel relation so that they are all interconnected with the manifolds.

In the preferred embodiment the tube 54 housing is an enlarged tube section and comprises the air reservoir 52. By this configuration, the tube 54 smooths out and evens the flow of delivered air from the respective control valves 70 and 70' to the demand regulator 16. Alternatively, the reservoir may be a hollow tube of increased cross-sectional area to compensate for surges or variations in the air flow.

Also, hoses 160 and 162 may be employed to interconnect the manifolds 64 and 66 and the reservoir 52. These hose connections include one-way check valves 161 and 163 for gas flow from the reservoir back to the respective manifold. It has been found that this return gas flow causes a smoother and more efficient operating apparatus.

Referring to FIG. 3, it will be seen that the energy stored in the biasing springs 98' and 98 may be increased by manipulation of a nut 166 on a threaded stem 168 to compress the springs so that additional forces are required in order to move the diaphragm plates 96' and 96. This has the effect of increasing operating pressure obtaining within the reservoir 52.

It will be apparent to those skilled in the art that, in lieu of the control valves 70 and 70' described in detail above, an orifice of predetermined size may be used. However, while this will deliver a controlled or predetermined amount of air for breathing, it will have the undesirable limitations of not being responsive to demand and being capable of delivering only a fixed maximum amount of air per unit of time.

While the regulators 70 and 70' are of the type which are exposed to the ambient pressure, it will be apparent that the same may be adapted for use at any selected absolute pressure by presetting the spring pressure, and by closing the vents 167' and 167 to the ambient medium.

It is to be understood that the above-described arrangements are only illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be apparent to those skilled in the art without departing from the spirit and scope of the present invention.

I claim:

1. An underwater breathing apparatus comprising vessel means for storing air in liquified form, two output ports disposed at antipodal locations on said vessel means, an air output reservoir, first heat exchanging means connecting one of said vessel output ports with said reservoir, second heat exchanging means connecting the other of said output ports with said reservoir, and demand regulator means connected to said reservoir for extracting air from said reservoir as end use requires.

2. A combination as in claim 1 further comprising valve means connected between said reservoir and each of said vessel output ports for isolating said reservoir from said vessel means when the pressure in said reservoir exceeds a threshold level.

3. A combination as in claim 2 wherein said valve means comprises pressure regulating control valve means including valve actuating means responsive to the pressure in said reservoir, the ambient pressure and a valve internal biasing force for selectively changing the state of said valve.

4. A combination as in claim 2 wherein said valve means comprises regulating control valves including a first chamber open to said vessel means, a second chamber open to said reservoir, a valve seating orifice between said chambers, plate means exposed on one side to the air pressure within said reservoir and exposed on the other side to the ambient pressure, means for mechanically biasing said plate means, valve seat-sealing means, and means connecting said plate means and said seat-sealing means.

5. A combination as in claim 2 wherein said vessel means comprises an inner vessel for storing liquified air, and outer jacket, spacer means for holding said vessel in a spaced relation within said jacket, and insulation disposed between said vessel and said jacket.

6. A combination as in claim 2 further comprising manifold means connected to each of said vessel output ports.

7. A combination as in claim 6 further comprising at least one additional liquified air storing vessel means connected to said manifold means, each of said vessel means being connected in parallel.

8. A combination as in claim 2 further comprising vent, fill, and pressure relief valves connected to said vessel means.

9. In combination in an underwater breathing apparatus, vessel means for storing air in liquified form, output ports disposed at opposite ends of said vessel means, at least one of said ports being surrounded in the area within said vessel means by liquid state air independent of the orientation of said vessel means under control of the force of gravity acting on the liquified air mass, common output air supplying means, first and second connecting means each including heat exchanging means arranged in a parallel relationship for respectively connecting said vessel output ports with said air supplying means, valve means included in said first and second connecting means for selectively permitting the flow of liquid state air to pass to one of said heat exchanging means and thence to said common output air supplying means, said valve means including means for selectively isolating said vessel means responsive to the pressure within said output air supplying means exceeding a threshold level with respect to the ambient pressure, said first and second connecting means being further connected together to define a conduit path between said vessel output ports.

10. A combination as in claim 9 wherein said heat exchanging means includes means for vaporizing and warming the liquified air supplied via said vessel output ports.