

- [54] **HIGH PRESSURE GAS PRESSURIZATION SYSTEM**
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- [73] Assignee: **Westinghouse Electric Corporation**, Pittsburgh, Pa.
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- [52] U.S. Cl. **128/204**, 61/69 R, 62/86, 62/401, 98/1.5
- [51] Int. Cl. **A61m 16/00**
- [58] Field of Search 62/86, 87, 78, 401; 137/14, 137/209, 609; 128/204, 298, 28, 29, 30; 98/1.5; 239/551; 61/69 R

[56] **References Cited**

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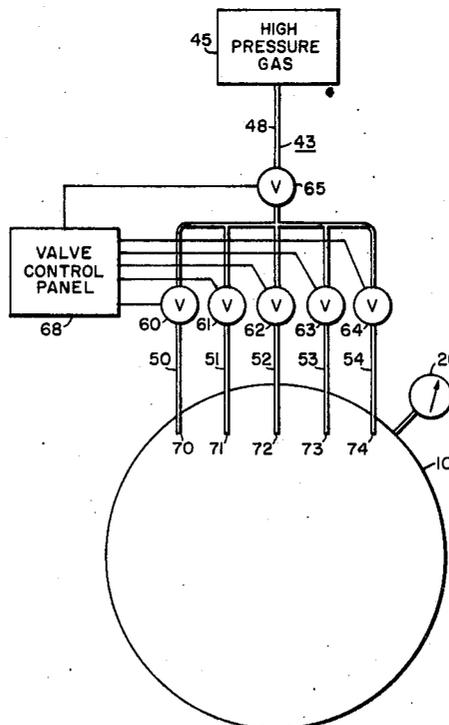
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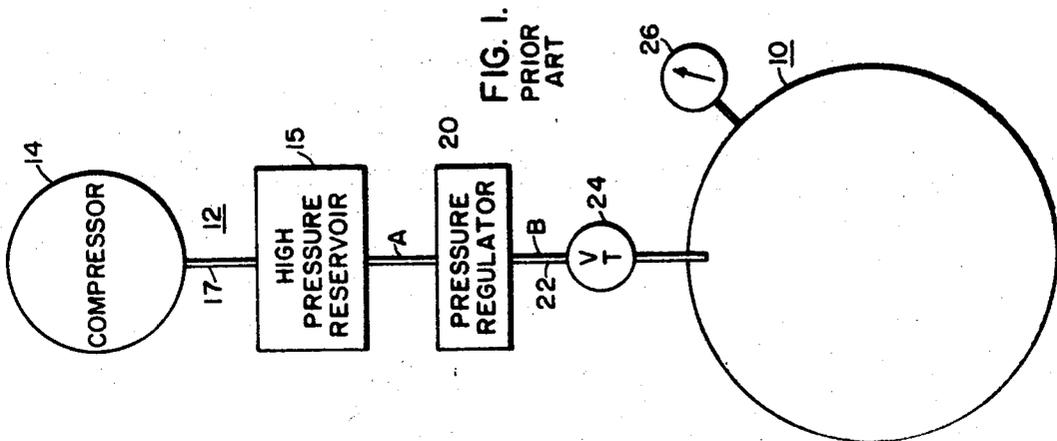
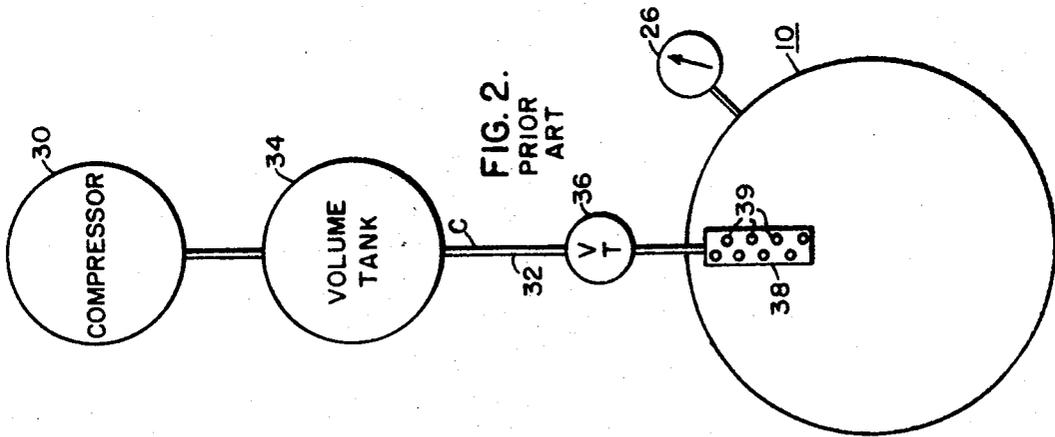
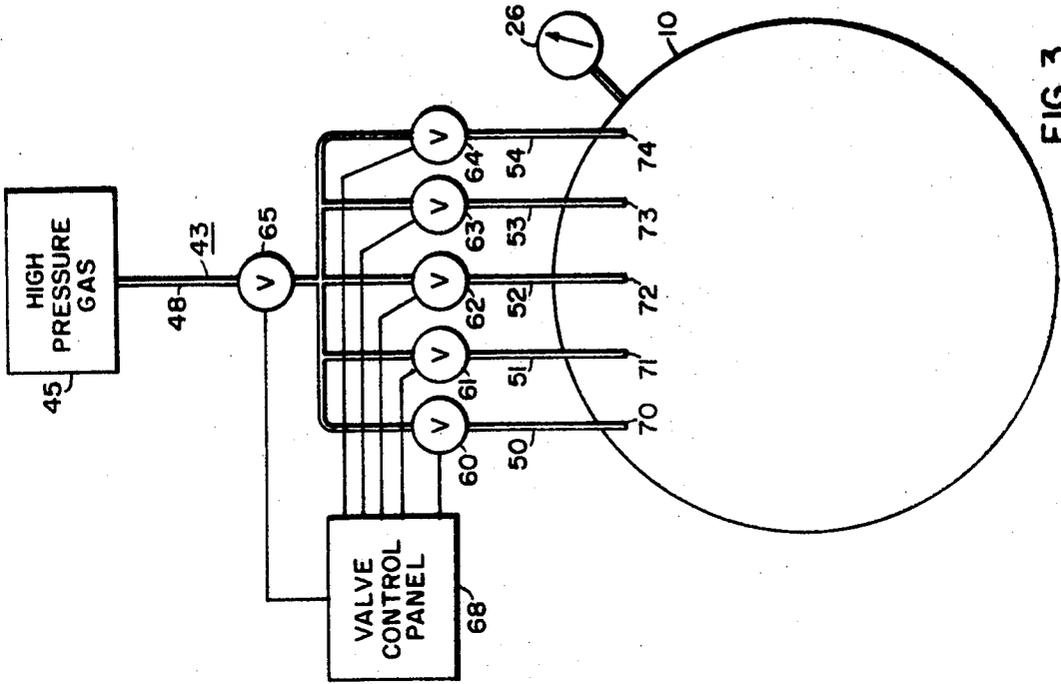
Primary Examiner—Albert W. Davis, Jr.
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[57] **ABSTRACT**

High pressure gas is fed into a hyperbaric chamber to be pressurized, directly through a series of pressure reducing orifices. The expansion of the high pressure gas that results, effects a cooling of the interior of the chamber.

12 Claims, 8 Drawing Figures





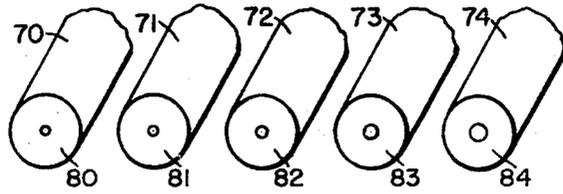


FIG. 4.

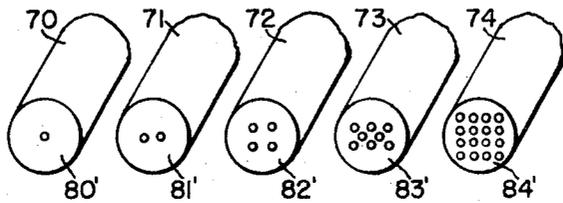


FIG. 5.

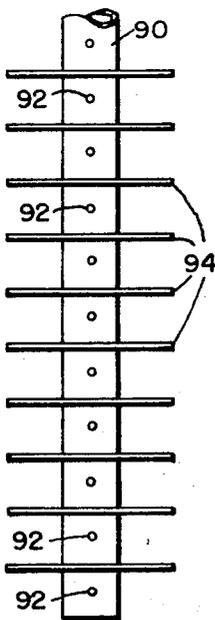


FIG. 6.

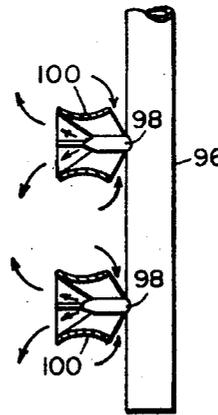


FIG. 7.

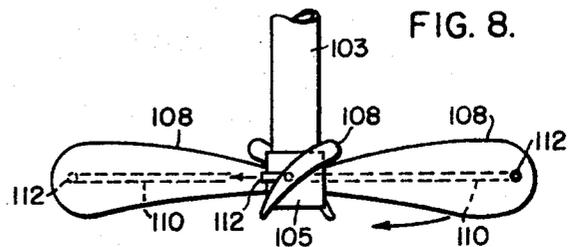


FIG. 8.

HIGH PRESSURE GAS PRESSURIZATION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

Hyperbaric chamber complexes.

2. Description of the Prior Art

Hyperbaric chambers, that is, chambers which are operated at greater than atmospheric pressure, are utilized in a variety of fields including the medical field and diving field. In operation, the internal pressure of the hyperbaric chamber is increased to a desired value by the admission of a compressed gas. For large chambers housing personnel the compressed gas may be in the form of air, or oxygen combined with an inert gas such as helium or hydrogen.

High pressure gas from a source is generally reduced to an intermediate pressure by means of a pressure regulator and is thereafter admitted into the hyperbaric chamber through a throttling valve. As more and more gas is admitted to the chamber to attain the desired pressure there is noticeable increase in temperature due to the heat of compression which occurs inside the chamber. Recorded incidents of 135° to 140° F. temperatures have caused the halt of fast pressurization for occupant safety and the occupants have been known to resort to holding a wet cloth over their mouth to prevent breathing hot gas.

Where the chamber additionally includes temperature sensitive instruments or equipment, the increase in temperature to these undesirable values often has a detrimental effect.

SUMMARY OF THE INVENTION

A gas pressurization system is provided which includes a hyperbaric chamber and a source of high pressure gas for pressurizing the chamber. High pressure conduit means connects the source and the high pressure gas with the inside of the chamber and pressure reducer means are connected with the conduit inside the chamber such that expansion of the high pressure gas takes place within the chamber.

The pressure reducer means takes the form of a plurality of different size orifices selectively connectable with the high pressure conduit means, to provide for variable rates of pressurization.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 illustrate prior art gas pressurization systems;

FIG. 3 is a sketch illustrating the preferred embodiment of the present invention;

FIGS. 4 and 5 illustrate different sized orifices which may be utilized on the ends of the conduits within the chamber of FIG. 3; and

FIGS. 6, 7 and 8 illustrate conduit terminations within the chamber of FIG. 3, for promoting better heat transfer.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is illustrated a prior art system including a hyperbaric chamber 10, and for clarity, various instrumentation, life support equipment and entrances have been omitted. Such chambers find wide application in the medical field for performing

research and medical operations, as well as the diving field for performing experiments at simulated ocean depths or as living quarters for divers who transfer into the chamber from a working depth in the water by means of a transfer chamber or capsule.

The chamber 10 is connected with a source 12 of high pressure gas which includes a compressor 14 and a high pressure reservoir 15 which may be comprised of a large number of high pressure cylinders connected to the compressor 14 by means of adequate piping 17.

The output at A of the high pressure reservoir 15 is generally thousands of pounds per square inch (psi) and this high pressure is reduced by means of pressure regulator 20 to an intermediate pressure of hundreds of psi, at point B. The conduit means 22 from the pressure regulator 20 feeds into the chamber 10 through a control or throttling valve 24 which is turned off when the gauge 26 reads the desired pressure.

Depending upon the rate of descent, or rate of pressurization, frost is often seen on the conduit and throttling valve while the temperature within the chamber rises to an uncomfortable level.

FIG. 2 illustrates another prior art gas pressurization system and includes a compressor 30 connected to the chamber 10 by conduit means 32. The connection is made by way of a storage or volume tank 34 and a throttling valve 36 which is closed when the gauge 26 displays the desired chamber pressure. The arrangement of FIG. 2 is somewhat different from the arrangement of FIG. 1 in that the compressor 30 supplying the volume tank 34 is of a relatively higher volumetric flowrate than compressor 14. The pressure at point C is high relative to the ambient pressure but is generally lower than, for example, a much higher pressure at point A in FIG. 1.

In order to insure for better mixing of the gas as it enters the chamber 10, some systems include a diffuser at the end of the conduit and within the chamber for breaking up the gas stream into a plurality of gas streams. FIG. 2 illustrates a typical diffuser 38 having a plurality of holes 39. Where relatively fast descent rates are desired, the arrangement of FIG. 2 suffers the same deficiencies as the arrangement of FIG. 1.

In FIG. 3, there is illustrated one embodiment of the present invention, which includes a chamber 10 to be pressurized to a certain value indicatable by the gauge 26. The chamber 10 is connected by conduit means 43 to a source of high pressure gas 45 which for purposes of illustration may include compressor and high pressure reservoir as illustrated in FIG. 1.

The conduit means 43 includes conduit 48 connected to, or which branches into a plurality of conduits 50 to 54 which enter the chamber 10.

The conduits 50 to 54 have respective valving means 60 to 64 in line therewith and preferably being of the type which operate in two positions, one being fully closed and the other being fully opened. A similar valve 65 is located in conduit 48 to allow or to block the passage of high pressure gas into the parallel branches. One type of valve which accomplishes this function is a motor operated ball valve and in order to control the opening and closing of the valves 60 to 65 from a remote position there is provided a control panel 68 whereby an operator may provide individual signals to open or close selected valves.

The ends 70 to 74 of the respective conduits 50 to 54 are disposed within the chamber 10 and include pressure reducer, or flow restriction means whereby the high pressure gas from the source 45 is discharged directly into the chamber through the pressure reducer means and the consequent expansion of the high pressure gas within the chamber effects cooling thereof, similar to the expansion of a gas in a refrigerator cooling cycle.

The rate of pressurization of the chamber 10 for a particular gas is dependent upon the mass flow rate of the gas into the chamber, which in turn is governed by selective operation of valves 60 to 64.

Additional reference should now be made to FIG. 4 which illustrates, in more detail, the ends 70 to 74 of the conduits within the chamber 10 of FIG. 3. Each conduit within the chamber has associated therewith a pressure reducer means such as orifice plates 80 to 84. Each orifice plate 80 to 84 has a respective pressure reducing aperture and if all apertures were of the same size, then by selective energization of ball valves 60 to 64, five different pressurization rates could be selected. The number of different pressurization rates is more than doubled in the present invention by the provision of different sized orifices, each having an area $A = 2^n(C)$, wherein n is a whole number between zero and the number of conduits minus 1, and C is a constant. For example, in FIG. 4 if orifice plate 84 is the fourth ($n=4$), orifice plate 83 is the third ($n=3$), orifice plate 82 is the second ($n=2$) orifice plate is the first ($n=1$), and orifice plate 80 is the zero ($n=0$), and arbitrarily making C equal to 1, then the area of each orifice or aperture, is as follows: for plate 80, $A=1$; for plate 81, $A=2$; for plate 82, $A=4$; for plate 83, $A=8$; and for plate 84 $A=16$. By selective choice of ball valves 60 to 64, 31 possible pressurization rates may be provided.

FIG. 5 illustrates orifice plates 80' to 84' each having an effective total aperture area equal to its counterpart of FIG. 4. This is accomplished by making an aperture of a certain diameter, for example, by drilling, in orifice plate 80', drilling two of those same diameter apertures in plate 81', four of those same diameter apertures in plate 82', eight in plate 83', and 16 in plate 84'. The apertures are relatively small to accomplish the pressure reducing gas expansion function. The orifice size varies with the size of chamber, desired rate of pressurization, the input pressure and the density of the gas utilized. By way of example for air at a pressure of 3,000 psi pressurizing a chamber of approximately 500 cu. ft. at a simulated descent rate of 6 ft. per minute, ball valve 60 (and 65) would be opened and the aperture within the chamber would have a diameter of 0.025 inches.

Due to the expansion of high pressure gas into the chamber with the consequent cooling, there may be a tendency for the orifice plates 80 to 84, or 80' to 84', to frost up. Accordingly, in accordance with the preferred embodiment of the present invention a heat exchange arrangement is provided for the conduit means within the chamber. FIG. 6 illustrates one such arrangement. Conduit 90 is disposed within the chamber to be pressurized, and includes a plurality of pressure reducing apertures 92 which may be drilled into the conduit 90 and arranged along the length thereof to also act as a diffuser for better gas mixing. The remaining conduits

within the chamber may have a greater or lesser number of apertures such that the total effective aperture area is in accordance with the previously given equation. Connected to the conduit 90 and disposed between adjacent apertures 92 are a plurality of heat exchanger means in the form of fins 94 providing a relatively large surface area for heat exchange purposes.

FIG. 7 is illustrative of another type of heat exchanger arrangement which may be utilized. Conduit 96 is a gas discharge conduit located within the chamber and includes a plurality of stubs or projections 98 having at the ends thereof a pressure reducer aperture. Disposed about each aperture is venturi tube 100 having a converging and diverging portion. When high pressure gas is discharged through the apertures in the stubs 98, chamber gas is caused to flow through the venturi tubes, as indicated by the arrows, to thereby promote gas flow for additional heat transfer, fins could be provided axially within the venturi tube 100 and mixing within the chamber.

Another gas mixing arrangement is illustrated in FIG. 8 wherein conduit 103 is disposed within the chamber and includes at the end thereof a high pressure swivel 105. Connected to the high pressure swivel is a plurality of blades or vanes 108 each having respective channel 110 therein connecting the conduit 103 with respective discharge orifices 112. Gas discharge through these orifices 112 causes the blades 108 to turn to thereby stir up the chamber gas to promote mixing thereof.

I claim as my invention:

1. A gas pressurization system comprising:
 - a. a hyperbaric chamber;
 - b. a source of relatively high pressure gas for pressurizing said chamber;
 - c. means including conduit means connecting said source with the inside of said chamber for delivering said gas to said chamber at substantially said same high pressure; and
 - d. relatively small aperture means connected with said conduit means within said chamber and being of such size that rapid expansion of said high pressure gas discharging through said relatively small aperture means provides cooling of said gas.
2. A system according to claim 1 wherein:
 - a. said conduit means includes a plurality of conduits each having pressure reducing orifice means within said chamber.
3. A system according to claim 2 which includes:
 - a. a plurality of valves, each for controlling gas flow in a respective one of said plurality of conduits.
4. A system according to claim 3 wherein:
 - a. said valves are of the type which are either fully opened or fully closed.
5. A system according to claim 2 wherein:
 - a. said plurality of conduits have respectively different sized pressure reducing orifices.
6. A system according to claim 5 wherein:
 - a. each said pressure reducing orifice has an area $A=2^n(c)$, where c is a constant and n is a particular conduit number between zero and the total number of conduits minus 1.
7. A system according to claim 2 wherein:

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a. at least two of said conduits include a plurality of similar sized pressure reducing orifices, with the second of said two having a greater number of said pressure reducing orifices.

8. A system according to claim 7 wherein:

a. the total effective orifice area of said plurality of pressure reducing orifices is $A=2^n(c)$, where c is a constant and n is a particular conduit number between zero and the total number of conduits minus 1.

9. A system according to claim 2 wherein:

a. at least one of said conduits includes a plurality of pressure reducing orifices disposed along the length thereof and which additionally includes

b. a heat exchanger means disposed along the length of said conduit.

10. A system according to claim 9 wherein:

a. said heat exchanger means comprises a plurality of

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fins disposed between adjacent pressure reducing orifices.

11. A system according to claim 2 wherein:

a. at least one of said conduits includes a plurality of projections each having pressure reducing orifice means, and which additionally includes

b. a plurality of venturi tubes, each disposed over a respective one of said projections.

12. A method of pressurizing a hyperbaric chamber from a high pressure gas source comprising the steps of:

a. discharging said high pressure gas directly into said chamber through at least one pressure reducing orifice of such a size that the rapid expansion of said high pressure gas discharging therethrough provides cooling of said gas; and

b. shutting off said discharge when a desired chamber pressure is attained.

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