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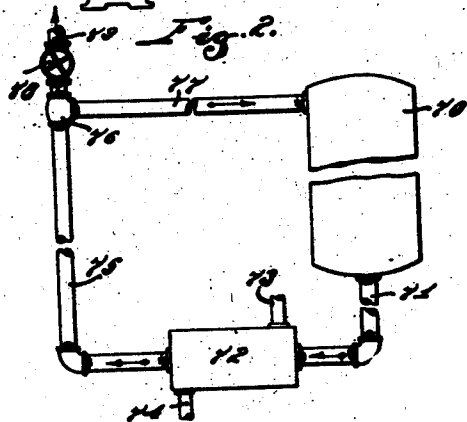
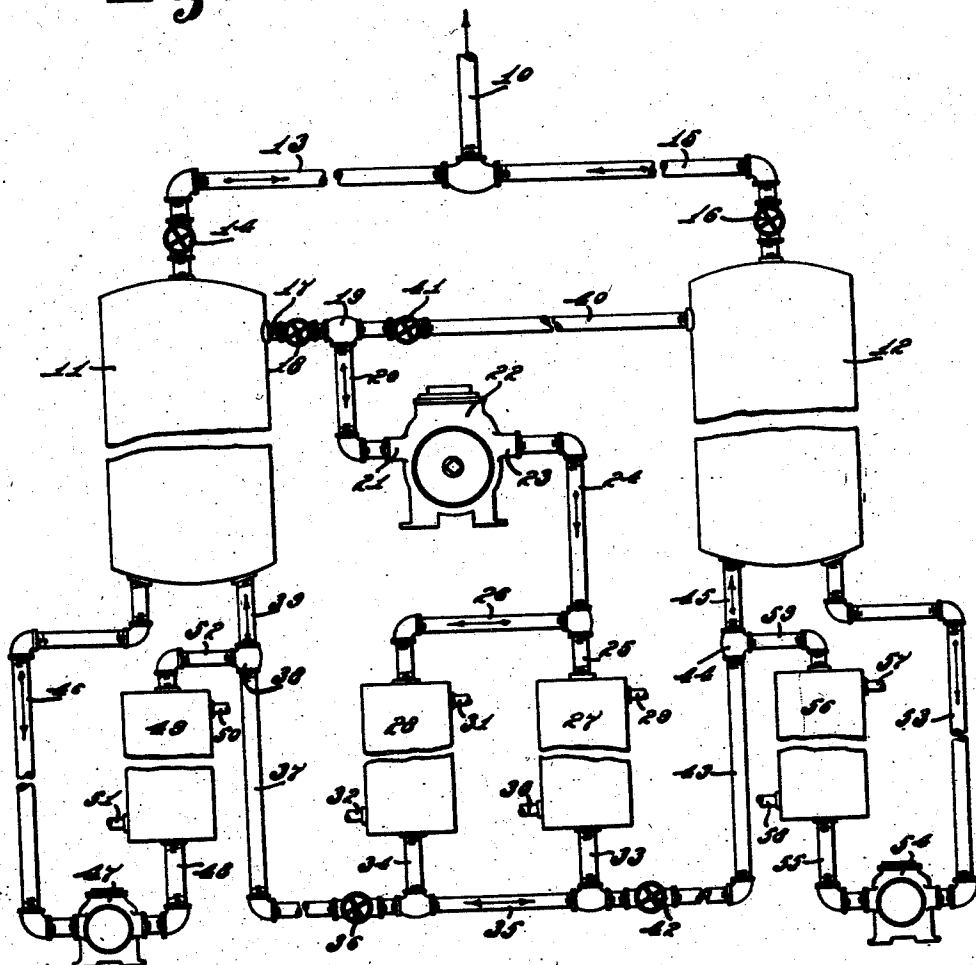
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METHOD OF AND APPARATUS FOR SUPPLYING GAS

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Fig. 1.



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METHOD OF AND APPARATUS FOR  
SUPPLYING GAS

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In certain commercial processes, it is necessary to supply a gas at specified rates and at specified temperatures. Specifically, the present invention is designed to provide a method of and apparatus for supplying carbon dioxide gas to a process at a pressure between specified limits and at a predetermined rate; but it will be apparent that the invention is applicable to the problem of supplying other gases in accordance with specified predetermined conditions.

More particularly, certain materials which are gaseous under atmospheric conditions may be handled more efficiently and effectively in one of their other phases. Carbon dioxide, for instance, may be most conveniently shipped and handled in its solid phase; and the present invention will be described in its application to carbon dioxide.

In one particular commercial process, it is required that gaseous carbon dioxide be supplied to the process at, for instance, the rate of 5 pounds per minute and at a pressure, for instance, between 200 pounds per square inch and 300 pounds per square inch. In order to accomplish this result, the solid must be converted to the gaseous phase, should preferably be held at the optimum pressure between, 200 pounds per square inch and 300 pounds per square inch, and must be released to the process at that optimum pressure and at the rate of 5 pounds per minute.

It is my present belief that the above objects can be most conveniently accomplished if all of the solid charged into a container is first converted from the solid phase to the liquid phase with, of course, a superimposed atmosphere of gaseous carbon dioxide, by warming the mass to cause the phase change; and if thereafter the temperature of the mass is raised to that value which will produce, within the container, the optimum pressure. If, now, the liquid is vaporized at a predetermined rate, gas may be withdrawn from the container at exactly that rate without varying the pressure conditions within the container.

To the accomplishment of the above and related objects, my invention may be embodied in the forms illustrated in the accompanying drawings, attention being called to the fact, however, that the drawings are illustrative only, and that change may be made in the specific constructions illustrated and described, or in the specific steps stated, so long as the scope of the appended claims is not violated.

Fig. 1 is a more or less diagrammatic view of an apparatus capable of use to carry out the intended functions of the invention; and

Fig. 2 is a diagrammatic illustration of another form of apparatus which will operate, with a considerably less degree of accuracy, to accomplish substantially the same purposes.

In Fig. 1, the pipe 10 represents a conduit leading to the process in which the gas produced is to be used. A first receiver 11 and a second receiver 12 are positioned in convenient proximity; and a pipe 13, controlled by a valve 14, connects the receiver 11 with the pipe 10 while a pipe 15, controlled by a valve 16, connects the receiver 12 with the pipe 10.

A conduit 17, controlled by a valve 18, leads from the upper portion of the receiver 11 to a T 19, to the stem of which is connected a pipe 20 communicating with the inlet 21 of a compressor 22. The outlet 23 of the compressor is connected by a pipe 24, having branches 25 and 26, with heaters 27 and 28 arranged in parallel. Steam is supplied to the heater 27 through the pipe 29 and the condensate is exhausted through the pipe 30; while similarly steam is supplied to the heater 28 through a pipe 31 and the condensate is exhausted through the pipe 32.

Pipes 33 and 34 leave from the heaters 27 and 28, respectively, to a conduit 35.

A valve 36 is interposed between the conduit 35 and the heaters 27 and 28, on the one hand, and a pipe 37, on the other hand, said pipe 37 leading to a T 38 which is connected by a pipe 39 with the bottom of the receiver 11.

A pipe 40, controlled by a valve 41, connects the upper portion of the receiver 12 with the T 19, and so with the compressor 22 and heaters 27 and 28. A valve 42 is interposed between said heaters and a pipe 43 which leads through a T 44 and a pipe 45 to the lower portion of the receiver 12.

Leading from the lower portion of the receiver 11 is a conduit 46 connected to the inlet of a pump 47 of stated liquid capacity. The outlet of said pump is connected by a pipe 48 with a heater 49 through which steam is circulated, being supplied through the pipe 50 and exhausted through the pipe 51. A pipe 52 connects the heater 49 with the T 38.

Similarly, a conduit 53 connects the lower portion of the receiver 12 with the inlet of a pump 54 which may be substantially identical with the pump 47. The outlet of said pump 54 is connected by a pipe 55 with a heater 56 through which steam is circulated by means of the pipes 57 and 58. A pipe 59 connects the heater 56 with the T 44.

The apparatus of Fig. 1 is operated to carry out

the process of the invention in the following manner.

All valves being closed, the receiver 11 is charged with a suitable mass of solid carbon dioxide, and is closed. Thereupon, the valve 18 and the valve 36 are opened, and the compressor 22 is started. Obviously, gaseous carbon dioxide will begin to collect in the receiver 11 as soon as the receiver is closed; so that when the compressor 22 begins to operate gas will be drawn from the receiver 11 and will be forced through the heaters 27 and 28 and back into the lower portion of the receiver 11, being warmed in its passage through the heaters. Thus, heat will be supplied to the mass of carbon dioxide within the receiver 11 to evaporate further carbon dioxide, whereby the pressure within the receiver is raised.

When the temperature of the solid carbon dioxide within the receiver 11 reaches the value of  $-70^{\circ}\text{F.}$ , the solid will begin to liquefy; and as more and more heat is supplied in the manner above described, that liquefaction will continue. Circulation of gas through the heaters 27 and 28 may be continued until all of the solid carbon dioxide has been liquefied; but, in order to accelerate the liquefaction, I prefer to begin the operation of the pump 47 rather promptly after the first liquid begins to form. By the operation of the pump 47, liquid will be drawn from the bottom of the receiver and forced through the heater 49 where it will be vaporized; and whence it will be forced through the pipe 52 to join the gas flowing in the pipe 39 to the receiver 11, thus aiding in the liquefaction of the solid.

The circulation of carbon dioxide will be continued not only until the solid has all been liquefied, but until the temperature within the receiver 11 has been brought to a value corresponding to the desired optimum pressure. For instance, if it is desired to maintain a pressure of 200 pounds per square inch within the receiver, the mass of carbon dioxide must be warmed to a temperature of  $-25^{\circ}\text{F.}$

When this condition has been reached, the valves 18 and 36 will be closed and (subject to an exception which will later be explained) the compressor 22 may be stopped.

We now have a mass of carbon dioxide, partly in the liquid phase and partly in the gaseous phase occupying the receiver 11 at a temperature of  $-25^{\circ}\text{F.}$  and at the pressure of 200 pounds per square inch. Obviously, if higher pressures are desired, they may be attained by continuing the heating operation above described until the temperature corresponding to the desired pressure is reached.

If, now, the valve 14 were opened, without further procedure, gas would begin to flow through the pipe 10 at the desired pressure; but that pressure would immediately begin to drop, and the temperature of the material within the receiver would likewise immediately begin to drop as a result of vaporization within the receiver; so that the desired optimum conditions would soon be lost.

In order to retain the optimum conditions, the pump 47 is continued in operation at a rate such as to circulate carbon dioxide in the amount which it is desired to deliver. That is, if it is desired, as above suggested, to supply gaseous carbon dioxide through the pipe 10 at a rate of 5 pounds per minute, the pump 47 will be operated to withdraw from the receiver 11, 5 pounds of liquid per minute. The liquid so withdrawn

is forced through the heater 49, where it is vaporized, and thence through the pipes 52 and 39 back into the receiver 11. Thus, without loss of temperature or pressure, 5 pounds of gas may be withdrawn each minute through the pipe 10 from the receiver 11. Obviously, this desired function might be accomplished by controlling the rate of operation of the heating means. That is, regardless of the rate at which liquid is circulated, its rate of evaporation may be controlled by controlling the effective operation of the heating means whereby the liquid is evaporated.

The operation of the pump 47 to effect gasification of the desired quantity of carbon dioxide at the desired rate is continued. In the meantime, a suitable mass of solid carbon dioxide is charged into the receiver 12 and the receiver is closed. The valves 41 and 42 are now opened and the compressor 22 is started. Circulation of gas generated in the receiver 12 through the heaters 27 and 28 is thus effected to carry out the same process in the receiver 12 as that above described in the receiver 11. After liquid begins to form in the receiver 12, the pump 54 is operated to withdraw liquid from the receiver 12, gasify it in the heater 56, and return it to the receiver. Eventually, optimum conditions will be created in the receiver 12 just as they were created in the receiver 11.

The masses of carbon dioxide charged into the respective receivers, and the flow rates and heating rates will be so proportioned that the preliminary preparation of the carbon dioxide in the receiver 12 will be completed substantially at the time when the available carbon dioxide in the receiver 11 has been exhausted. Obviously, if the gas must be supplied to the process through the pipe 10 at or above a predetermined minimum pressure, such as 200 pounds per square inch, there will be a considerable mass of residual gas left in the receiver 11 after all available gas has been exhausted. At that time, the valve 14 will be closed and the valve 16 will be opened so that the supply of gas through the pipe 10 will not be cut off. Thereafter, the valve 18 is opened so that the operation of the compressor 22 will withdraw gas from the receiver 11 and, since the valve 36 is closed and the valve 42 is open, will transfer that residual gas from the receiver 11 into the circulating system associated with the receiver 12. By this means, substantially all of the residual gas may be utilized.

In Fig. 2 there is illustrated a very much simplified system whereby the process of the present application, when broadly considered, may be carried out with considerably less accuracy, but at less expense. Solid carbon dioxide will be charged into the receiver 70 and the receiver will be closed. Gas generated within the receiver will tend to flow to the heater 72 which is supplied with steam through the pipe 73, condensate being exhausted through the pipe 74. That flow of gas to the heater 72 will even initially be primarily through the pipe 71. In the heater 72, the gas will be heated, whereby it will tend to flow upwardly through the pipe 75, T 76, and pipe 77 to the upper portion of the receiver 70. As this thermal flow continues, the solid in the receiver will ultimately be melted, and liquid, mixed with the gas, will begin to flow through the heating circuit. Eventually, all of the solid will have been melted; and thereafter the valve 18 may be opened to permit flow of gas to the process through the pipe 79. The rate of flow of gas through the pipe 79 will depend

upon the rate of continued vaporization in the heater 72.

I claim as my invention:

1. The method of supplying gas to a process at stated rates and pressures which comprises the steps of charging solidified material into a receiver, permitting a phase change which renders a portion of such material fluid, circulating such fluid through a heating chamber and back to the receiver, whereby the material remaining in the receiver is warmed and is caused to liquefy, subsequently circulating the liquid through a heating chamber to vaporize the same at a controlled rate, returning the vapor to said receiver, and permitting the gas so formed to flow from said receiver to such process.

2. The method of supplying gaseous carbon dioxide to a process at stated rates which comprises the steps of charging solid carbon dioxide into a receiver wherein such solid will vaporize, circulating the gas so formed through heating means and back to the receiver to warm the contents of the receiver to liquefy all of the solid, and thereafter drawing liquid from the receiver at stated rates and passing the same through a heater, whereby the liquid is vaporized, and supplying the gas so formed to the process.

3. The method of supplying gaseous carbon dioxide to a process at stated rates and pressures which comprises the steps of charging solid carbon dioxide into a receiver wherein such solid will vaporize, circulating the gas so formed through heating means and back to the receiver to raise the temperature of the remaining solid to  $-70^{\circ}$  F. and to melt the solid, thereafter further warming the carbon dioxide by fluid circulation through external heating means to produce an optimum pressure within the receiver, and thereafter vaporizing the liquid by circulation thereof, at stated rates, through external heating means, returning the gas so formed to the receiver, and supplying gas from the receiver to the process.

4. The method of supplying gaseous carbon dioxide to a process continuously at stated rates and pressures which includes practicing the steps of claim 3, then charging a second receiver with solid carbon dioxide and liquefying the same in said receiver by circulation of fluid between said second receiver and external heating means, thereafter further warming the carbon dioxide in said second receiver by fluid circulation through external heating means to produce an optimum pressure within said second receiver, all while gas is being supplied to the process from such first receiver, thereafter vaporizing liquid from such second receiver by circulation thereof at stated rates through external heating means, returning the gas so formed to said second receiver, and, after exhaustion of the available gas from said first receiver, supplying gas from the second receiver to the process.

5. The method of supplying gaseous carbon dioxide to a process continuously at stated rates and pressures which includes practicing the steps of claim 3, then charging a second receiver with solid carbon dioxide and liquefying the same in said receiver by circulation of fluid between said second receiver and external heating means, thereafter further warming the carbon dioxide in said second receiver by fluid circulation through external heating means to produce an optimum pressure within said second receiver, all while gas is being supplied to the process from such first receiver, thereafter vaporizing liquid from

such second receiver by circulation thereof at stated rates through external heating means, returning the gas so formed to said second receiver, and, after exhaustion of the available gas from said first receiver, supplying gas from the second receiver to the process and pumping residual gas from the first receiver into the circulating system of the second receiver.

6. Apparatus of the class described comprising a first receiver for solid carbon dioxide, a second receiver for solid carbon dioxide, a compressor connected to draw gas from said first receiver, heating means, and conduit means connected to lead gas from said compressor through said heating means and thence to said second receiver.

7. Apparatus of the class described comprising a receiver for solid carbon dioxide, heating means, a compressor connected to draw gas from said receiver and to force the same through said heating means and back to said receiver, other heating means, and a pump connected to draw liquid from said receiver, to force the same to and through said other heating means where such liquid is gasified, and to return such gas to said receiver.

8. Apparatus of the class described comprising a receiver for solid carbon dioxide, heating means, a compressor connected to draw gas from said receiver and to force the same through said heating means and back to said receiver, other heating means, conduit means leading from a point adjacent the bottom of said receiver through such other heating means and back to said receiver, and a pump disposed in said conduit means between said receiver and said other heating means.

9. Apparatus of the class described comprising a receiver for solid carbon dioxide, heating means, a compressor connected to draw gas from said receiver and to force the same through said heating means and back to said receiver, other heating means, conduit means leading from a point adjacent the bottom of said receiver through such other heating means and back to said receiver, and a pump having a stated liquid capacity disposed in said conduit means between said receiver and said other heating means.

10. Apparatus of the class described comprising a first receiver for solid carbon dioxide, a second receiver for solid carbon dioxide, a heat exchanger outside said receivers, means for supplying heat to such heat exchanger, a compressor, and valved conduit means for selectively connecting said compressor to withdraw gas from either of said receivers and to force the same through said heat exchanger and back to the selected receiver.

11. Apparatus of the class described comprising a first receiver for solid carbon dioxide, a second receiver for solid carbon dioxide, heating means outside said receivers, a compressor, valved conduit means for selectively connecting said compressor to withdraw gas from either of said receivers and to force the same through said heating means and back to the selected receiver, a second heating means, pump means connected to withdraw liquid from said first receiver and to force the same through said second heating means and back to said first receiver, a third heating means, and pump means connected to withdraw liquid from said second receiver and to force the same through said third heating means and back to said second receiver.

12. The method of deriving gaseous carbon dioxide from a reservoir containing such mate-

rial in non-vapor form which consists in establishing a circulation in a closed circuit of liquid carbon dioxide through said reservoir and through a separate chamber in series and heating such chamber according to the gas demand.

13. The method of deriving carbon dioxide gas from a reservoir containing such material in solid form which includes circulating externally heated dioxide gas through such reservoir until the pressure and temperature exceed the triple point, and thereafter circulating heated liquid dioxide through such reservoir while withdrawing the gas evaporated by the heating.

14. The method of deriving carbon dioxide gas from a reservoir containing such material in solid form which comprises heating the reservoir contents to the triple point, piping liquid dioxide from said reservoir to a separate chamber, evaporating the liquid therein by heating such chamber and passing the gas evaporated therein into heat transferring relation to said contents and thence to the point of delivery.

15. The method of deriving carbon dioxide gas from a reservoir containing such material in solid form which comprises heating the reservoir contents to or above the triple point, piping liquid dioxide from said reservoir to a separate chamber, heating said chamber and the liquid therein, returning the heated carbon dioxide from said chamber to said reservoir and thereby raising the reservoir pressure to a selected higher pressure, withdrawing gas at a rate to supply the load demand, and regulating the heating to maintain said higher pressure during withdrawal.

16. The method of deriving carbon dioxide gas from a heat insulated reservoir containing such material in solid form which comprises heating the reservoir contents by circulating the gas present with the solid carbon dioxide, through a separate heating chamber and back into the reservoir until liquid dioxide forms, then piping the liquid from the reservoir to the said heating chamber and returning the carbon dioxide to the reservoir in circulatory fashion, sufficient heat thus being transferred first, to convert the solid into liquid, second, to convert sufficient of the liquid into gas in order to build the pressure of the reservoir up to a selected range above 75 lbs. absolute, and third, to produce sufficient gas to supply the load demand within the range of pressures desired and regulating the heating conditions affecting said chamber during gas withdrawals to maintain such selected pressure.

17. The method of deriving carbon dioxide gas from a reservoir containing such material in solid form which includes heating a stream of carbon dioxide gas, circulating such heated stream through such reservoir until the pressure and temperature exceed the triple point, and thereafter maintaining such pressure and temperature conditions by heating carbon dioxide and passing the same through a circuit including said reservoir, while passing carbon dioxide gas from the reservoir to a point of delivery at such pressure.

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