

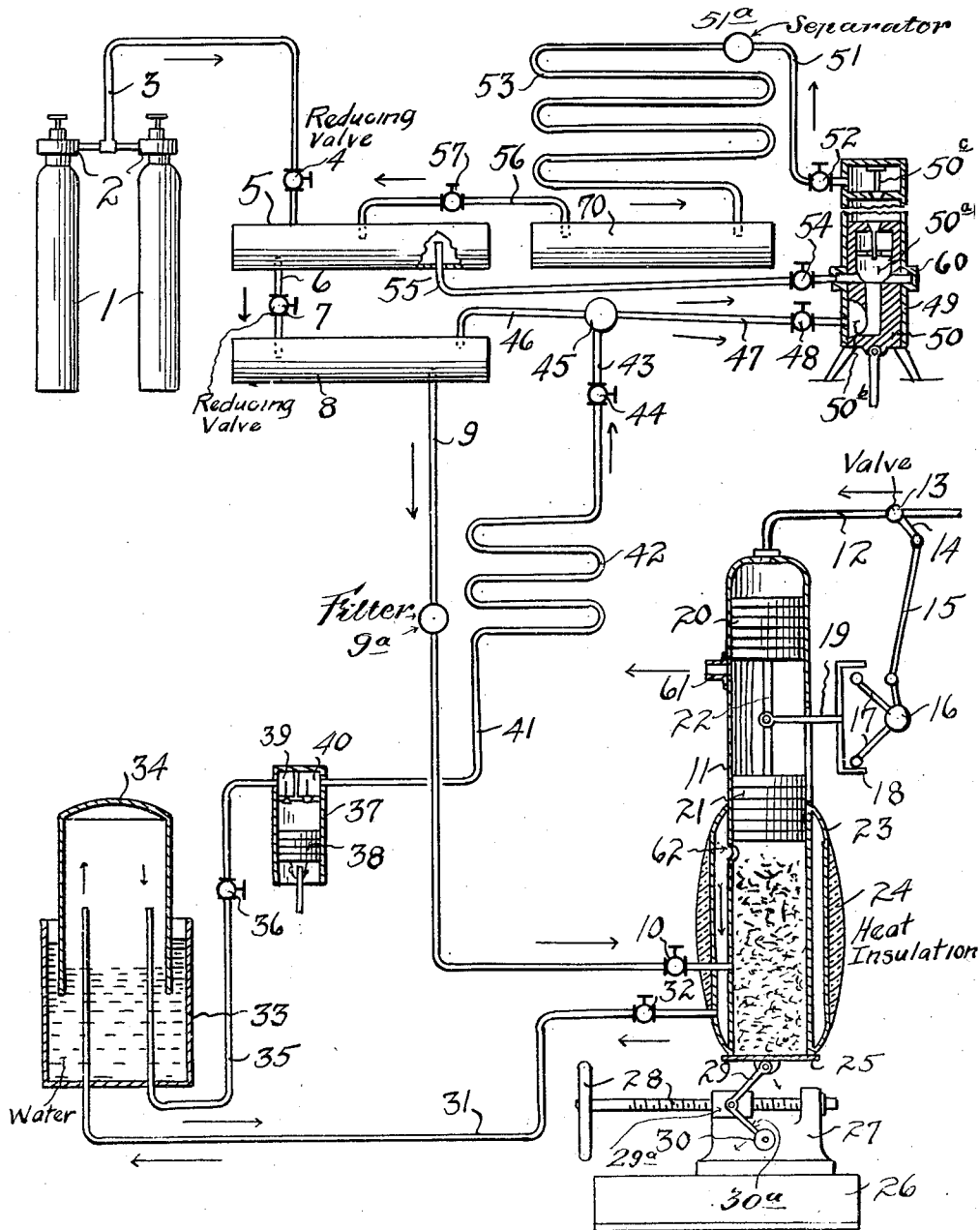
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APPARATUS FOR PRODUCING SOLID CARBON DIOXIDE

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APPARATUS FOR PRODUCING SOLID
CARBON DIOXIDE

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This invention relates in general to apparatus intended to produce from carbon dioxide gas solid carbon dioxide in the form of snow or ice which, if desired, when in the form of snow may be com-
pressed into blocks.

This invention has for its general object the provision of a system which is relatively simple in construction and operation for the efficient conversion of carbon dioxide gas into solid carbon dioxide.

A further object of this invention involves the idea of continually reconverting the gas formed in the system from the liquid therein back to a liquid form in which form it is used in the production of solid carbon dioxide.

Another object of this invention contemplates the combination of a gas source, a snow forming machine, and apparatus for reliequifying the gas formed in the system at several points and returning it to a point where it may again be delivered to the snow forming machine.

It is also the object of this invention to provide automatic means whereby liquid carbon dioxide can be reduced in its temperature by either internal or external cooling to nearly the temperature of its triple point and converting it into the solid condition by a final and sudden release of pressure.

This invention also has for its object additional features involving details of construction as will be more fully disclosed hereinafter.

The apparatus of this invention is also substantially automatic in its operation and, therefore, eliminates the necessity of undue manual control and supervision by an operator.

These and many other objects will appear from the following disclosure which are secured by means of this invention.

This invention resides substantially in the combination, construction, arrangement, and relative location of parts, as will appear more fully hereinafter.

Referring to the drawing—

The figure is a diagrammatic illustration with some parts in cross section illustrating the various elements of the system and their cooperative relationship.

Referring to the drawing, a detailed description of the arrangement will now be given. The gas source, which may be of any suitable kind, is shown for purposes of illustration as comprising two gas cylinders 1. The gas is maintained in these cylinders under a pressure sufficiently high to maintain it in liquid form at a temperature below 88°. However, temperatures above the criti-

cal for liquefaction do not at all interfere with the operativeness of this method. The cylinders 1 are provided with the valves 2 which are connected to a pipe 3 leading to a tank or container 5 through a reducing valve 4. The container 5 is connected to another tank 8 by means of a pipe 6 and another reducing valve 7. The pipe 9 leads through valve 10 from tank 8 to the inner chamber of the snow forming machine provided by the cylinder or drum 11. Interposed in pipe 9^a is a 10 filter for the elimination of solid impurities, as well as moisture, which latter would in this part of the system appear in the form of ice pellets.

The top of the cylinder 11 is connected by a pipe 12 having a control valve 13 therein. The valve 13 is operated by means of a lever 14 which is connected by a link 15 to a spider arrangement 16 having the diverging arms 17. These arms 17 are in contact with the U-shaped member 18 which is connected by the arm 19 to the piston rod 22. The piston rod 22 unites the two separated pistons 20 and 21 adapted to move longitudinally in the cylinder 11. The lower portion of the cylinder 11 is provided with an outer enclosing casing 23 which forms airtight connections therewith to provide an outer chamber, as clearly shown. The casing 23 is covered with any heat insulating material, as indicated at 24. The lower end of cylinder 11 is open and is provided with a removable cover or closure member 25 which is pivotally attached to the arm 29. The arm 29 is pivotally attached to a nut 29^a. Another arm 30^a is pivotally connected to the nut at the same point and to the fixed member 27 at 30. The member 27 is supported on the movable block 26. The space formed by the cylinder 11 and wall 23 is connected by a pipe 31 through valve 32 to a gasometer comprising an open ended container 33 and an inverted open ended container 34 which extends down into the water within container 33. The pipe 31 extends up into the inverted container 34 above the level of the water. This element represents the well known gasometer. Another pipe 35, likewise projecting into the inverted container 34 above the level of the water, extends through valve 36 to the suction chamber 38 in a compressor having the cylinder 37 and piston 38. In place of the compressor a positive pressure blower of any well known commercial type may be substituted.

The delivery chamber 40 of the compressor is connected by pipe 41 to an intercooler 42. The compressor has the usual two valves operating in opposite directions to permit admission of gas

from chamber 39 on the suction stroke and after compression the delivery of the gas to chamber 40. The intercooler 42 is merely a pipe coil cooled in any suitable manner, as, for instance, by cold running water. The intercooler is connected by pipe 43 through valve 44 to a mixing cylinder 45 which is nothing more than a closed drum or tank in which gases of higher and lower temperature but substantially equal pressure are mixed resulting in suction gas of comparatively low temperature entering the suction port of the dual effect compressor 49. Any water vapor entrained in the CO₂ gas will be cooled and condensed and can be drained off in either intercooler 42 or mixer 45. Oil as well as any other liquid, as well as solid impurities, can likewise be removed at these points. The mixing chamber 45 is connected to cylinder 8 by means of pipe 46 and to the dual effect compressor by means of pipe 47 through valve 48. The dual effect compressor comprises a cylinder 49 within which the piston 50 operates. The piston 50 is hollow and is provided near its lower end on one side with the recess 50^b connecting with the chamber 50^a within the piston. The piston 50 is provided at its upper end with a valve which opens upwardly. The upper end of cylinder 49 is provided with a chamber and a valve 50^c which opens upwardly. An annular ring 60 encircles the cylinder 49 and opens thereto by reason of the annular groove formed thereby. The annular groove is connected by means of pipe 55 through valve 54 to the cylinder 5. The chamber at the upper end of cylinder 49 is connected through valve 52, pipe 51, and oil, water and other impurities separator 51^a to the condenser coils 53 which, likewise, comprise a pipe coil cooled in any suitable manner. The condenser 53 is connected to the tank or cylinder 70 which in turn is connected to cylinder 5 by means of pipe 56 and valve 57.

Gas under considerable pressure is delivered from the source 1 to tank 5 through the reducing valve 4 so that the liquid and any gas formed is maintained within the tank 5 at a pressure of about four hundred pounds. Tanks 5 and 8 may be called "liquid coolers" since the liquid is considerably cooled in being delivered thereto through reducing valves 4, 57 and 7. The liquid then moves through pipe 6 and reducing valve 7 to tank 8 and suffers a further reduction in pressure to about one hundred pounds. It may be pointed out here that the reducing valves 4 and 7 may be any of the types now well known in this art of which examples are disclosed in my copending application Serial No. 314,644, filed October 24, 1928. The tank 8 is connected by means of pipe 9 to a cylinder 11 so that the liquid is delivered therefrom to the snow machine. If desired the pipe 9 may enter the cylinder 11 near or at the bottom thereof.

The CO₂ vapors generated in liquid coolers 5 and 8 during pressure reduction and liquid cooling therein are returned through the intermediate suction pipe line 55 and the low pressure suction pipe 46 and 47 to the corresponding intake port of the dual effect compressor 49. The vapor pressure in liquid coolers 5 and 8 can be effectively controlled and maintained by automatic valves 54 and 48. In the place of internally cooled liquid cooler 8 a liquid cooler of the type in which the liquid CO₂ may be cooled by external evaporation through intervening pipe or other heat conducting walls, while the pressure as in liquid cooler 5 is substantially maintained.

It is assumed that the pistons 20 and 21 are at or near the lower limit of their movement so that the inflowing liquid will fill cylinder 11 and raise the pistons against counter-pressure. The liquid flows in until the pistons reach the position shown in the drawing when port 62 is uncovered, which may be of substantial diameter to allow a free passage of the gas which will be formed adjacent piston 21 by reason of heat inflow and in spite of the controlling counter-pressure to flow into the space between cylinder 11 and wall 23, as well as all the other gas rapidly generated due to the sudden drop in pressure. The space between the inner and outer walls is connected by pipe 31 to the gasometer which is maintained at atmospheric or approximately atmospheric pressure. The port 62 being large permits an instantaneous or sudden drop in pressure on the liquid which causes it to crystallize or solidify and thereby flashes it into carbon dioxide snow or ice.

The upward movement of the pistons causes the spider arrangement, comprising the member 18 and divergent arms 17, to open valve 13. This affects a delivery of fluid pressure to the cylinder 11 above piston 20. The pistons thus descend and compress the solid carbon dioxide into a block. When sufficient compression has occurred the gate 25 may be moved by loosening the toggle arrangement through the agency of the hand wheel and threaded shaft 28. If the block does not fall out the pistons can be operated downwardly until the block is ejected. This may be effected by the hand operation of valve 13 or by a manually controlled pressure line also connected to the upper end of cylinder 11. It may also be arranged for automatic operation.

Port 61 is the exhaust port for cylinder 11 above piston 20. When piston 20 uncovers port 61 the pressure in the cylinder is exhausted. At this time the mechanism connected between the piston rod 22 and valve 13 is operated to close off the supply of fluid pressure to the cylinder. The gas formed by the sudden reduction in pressure in the snow machine is delivered to the gasometer and removed therefrom by the compressor comprising the cylinder 37 and piston 38. In place of the compressor a pressure blower may be used. The compressed gas is delivered to the intercooler, where it is cooled and, thence to the mixing cylinder where it mixes with any gas which has formed in cylinder 8. The mixed gas then passes through pipe 47 to the dual effect compressor.

The pressure of the gas is sufficient to flow up through piston 50 and open the valve therein to fill the cylinder space. The piston then ascends and allows the gas of superior pressure from liquid cooler 5 to flow into the compressor volume through 50^b, which is already filled with gas of lower pressure from liquid cooler 8 and mixing chamber 45, thereby raising the initial pressure to the pressure in cylinder 5, thereupon compressing it by the ascending piston 50 and discharging the gas through valve 50^c and line 51 controlled by stop valve 52 into condenser 53. Additional gas then rushes into the space above the piston by raising the valve therein. It will be understood that the initial gas compressed by the piston 50 is at a lower pressure than the gas which exists in tank 5. The piston continues its upward movement and compresses the mixture of gases to the desired point whence it is delivered through valve 50^c to the condenser 53. Here

it is sufficiently cooled at the pressure it is under to liquefy it. This liquid is delivered to tank 70 and finally to tank 5 through pipe 56. The dual effect compressor has been disclosed and described in greater detail in my copending application.

From the foregoing description the advantages and simplicity of this invention are apparent. At any point in the system where gas may be formed means is provided for returning it to a liquid state and delivering it to the point where it may again go through the system to serve a useful purpose.

I am, of course, well aware that numerous changes in the details of construction of the various elements, their relative arrangement and association and the conditions under which they may be operated will readily occur to those skilled in the art and I do not, therefore, desire to be strictly limited to the disclosure as given in the illustrative sense but rather to the principles of the invention and the scope of the apparatus defined by the appended claims.

What I seek to secure by United States Letters Patent is:

1. In an apparatus of the type described, the combination comprising a snow forming machine having an open ended cylinder, means for closing the open end of said cylinder, a movable piston in said cylinder, a fluid pressure connection in one end of said cylinder, a valve in said connection, means interconnecting said piston and valve for automatically operating the valve, means enclosing a portion of said cylinder for forming an annular space, said cylinder having a passage in the wall thereof for establishing communication between the interior of the cylinder and said annular space, a source of liquid carbon dioxide, a connection between said source and said cylinder whereby the liquid is adapted to move the piston upwardly, a gasometer connected to said annular space, and connections between said gasometer and said liquid source including compressors and coolers for reliquefying any gas formed in the system.

2. In apparatus for producing solid carbon dioxide, in combination, a source of liquefied carbon dioxide, means for reducing the pressure on the liquid carbon dioxide to cool the same, a receiver for the reduced pressure liquid, a recompressor, a connection from the receiver to said recompressor for conducting gas thereto from the receiver for compression and reliquefaction, a carbon dioxide solidifying chamber in communication with said receiver for receiving liquid therefrom for expansion and solidification of a portion thereof in said chamber, a connection from said chamber for conducting expansion gas therefrom to said recompressor, and a compressor in said latter connection for compressing the expansion gas from the solidifying chamber prior to delivery to the recompressor.

3. In apparatus for producing solid carbon dioxide, in combination, a source of liquid carbon dioxide, a plurality of liquid carbon dioxide receivers connected in series and supplied with liquid from said source, means for reducing the pressure on the liquid as it passes from each receiver to the next to lower the temperature of the liquid, a recompressor, connections from each liquid receiver to the recompressor for conducting gas from the receivers to the recompressor, means for liquefying the compressed gas from the recompressor and for returning such liquid to said receivers, a carbon dioxide solidifying chamber

receiving liquid from the last of said plurality of receivers and for expansion of liquid therein to solidify a portion thereof and gasify the remainder, a connection from said chamber to the recompressor for returning the expansion gas from the chamber to the recompressor, and means in said latter connection for compressing the expansion gas from the solidifying chamber and positively delivering the compressed gas to said recompressor.

4. In apparatus for solidifying carbon dioxide, a source of liquid carbon dioxide, means for reducing the pressure on the liquid from said source to lower the temperature thereof, a receiver for the reduced pressure and lowered temperature liquid, a recompressor, a connection for conducting the carbon dioxide gas formed in said receiver to the recompressor for compression and reliquefaction, a carbon dioxide solidifying chamber supplied with liquid from said receiver for expansion of the liquid to form a portion into solid and the remainder to gas in said chamber, a connection from said chamber for conducting expansion gas therefrom to the recompressor, means in said latter connection for compressing the gas from the solidifying chamber and positively delivering the same under pressure to the recompressor, and means for liquefying the compressed gas from the recompressor and for returning such liquid to said liquid receiver.

5. In apparatus for solidifying carbon dioxide, in combination, a source of liquid carbon dioxide, a liquid receiver, a connection from said source for supplying liquid to said receiver, means in said connection for reducing the pressure on the liquid to lower the temperature thereof, a second liquid receiver in communication with and receiving liquid from said first receiver, means for reducing the pressure of the liquid from said first receiver to the second receiver to further lower the temperature of the liquid, a recompressor, connections from said first and second liquid receivers, respectively, to said recompressor for delivering carbon dioxide gas at the respective receiver pressures to the recompressor for compression, means for liquefying the compressed gas from the recompressor and for delivering said reliquefied carbon dioxide to the first liquid receiver at substantially the pressure in said receiver, solidifying means for expanding liquid carbon dioxide from the second receiver to convert a portion of the liquid to solid and the remainder to gas, connections from said solidifying means to the gas connection between said second liquid receiver and the recompressor for returning the expansion gas to the recompressor, and means in said expansion gas returning connections for compressing the expansion gas to a pressure substantially that of the gas from the second liquid receiver.

6. In apparatus for solidifying carbon dioxide, in combination, a source of liquid carbon dioxide, carbon dioxide solidifying means supplied with liquid from said source for forming the liquid directly into solid and gaseous states by expansion of the liquid, means for cooling the liquid by reducing the pressure thereon prior to delivery to said solidification means, a gas recompressor in communication with and receiving gas formed in said liquid cooling means for compressing such gas for reliquefaction, connections between said solidifying means and the recompressor for conducting expansion gases to the recompressor for compression for reliquefaction, and means in said connections for compressing 75

the expansion gas from the solidifying means to raise the pressure thereof prior to delivery to the recompressor.

7. In combination in apparatus for solidifying carbon dioxide, a source of liquid carbon dioxide, means for directly forming the liquid by expansion into the solid and gaseous states, connections between said source and said means for supplying liquid to the latter, means in said connections for reducing the pressure on the liquid to cool the same, a gas recompressor in communication with said connections for withdrawing and compressing any gas formed by said liquid cooling means, means associated with said recompressor for liquefying the compressed gas therefrom and returning such liquid to said connections, connections from said solidifying means to the recompressor for conducting the expansion gas to the latter for recompression and reliquefaction, and a compressor in said latter connections for raising the pressure of the expansion gases delivered to the recompressor to a pressure substantially that at the intake of the recompressor.
8. In apparatus for solidifying carbon dioxide, the combination including a source of liquid carbon dioxide under high pressure, means for reducing the pressure on the liquid from said source to lower the temperature thereof, including a receiver for said reduced pressure liquid, a solidifying chamber connected to said receiver to receive reduced pressure liquid therefrom, means in said chamber for suddenly reducing the pressure of the liquid in the chamber to atmospheric to solidify a portion of the liquid and gasify the remainder, a recompressor connected to said reduced pressure liquid receiver for withdrawing any gas therefrom for recompression, connections between said solidifying chamber and the recompressor for conducting the expansion gas to the latter for recompression, and a compressor in said connections for raising the pressure of the atmospheric pressure expansion gas to substantially the pressure of the gas from said reduced pres-

sure liquid receiver, prior to delivery of such expansion gas to the recompressor.

9. In combination in apparatus for solidifying carbon dioxide, a source of carbon dioxide under high pressure, means for reducing the pressure of the liquid carbon dioxide from said source to a pressure above the triple point in order to lower the temperature of the liquid, said means including a reduced pressure liquid receiver, a recompressor in communication with said receiver for withdrawing gas therefrom to maintain the liquid pressure in said receiver, carbon dioxide solidifying means associated with said receiver and supplied with liquid therefrom for expansion of the liquid to a pressure below the triple point to form solid and gaseous carbon dioxide, a gasometer in communication with and collecting the expansion gas from said solidifying means, connections from said gasometer to the recompressor for conducting gas to the latter, and a compressor in said connections for raising the pressure of the below triple point expansion gas to the pressure substantially that of the gas from the liquid receiver.

10. In apparatus for solidifying carbon dioxide, the combination including an open end cylinder providing a carbon dioxide solidification and pressing chamber, means for closing the open end of said cylinder and forming the head against which solid carbon dioxide in the chamber is compressed, a movable piston in said cylinder, a fluid pressure connection in one end of said cylinder, a valve in said connection, mechanism actuated by said piston for automatically operating said valve, a source of liquid carbon dioxide, a connection between said source and the cylinder chamber for discharging liquid thereinto whereby the liquid forces the piston toward one end of the cylinder, and connections between said chamber and the liquid source including gas compressing means and condensers for reliquefying the expansion gas formed in said solidification chamber.

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