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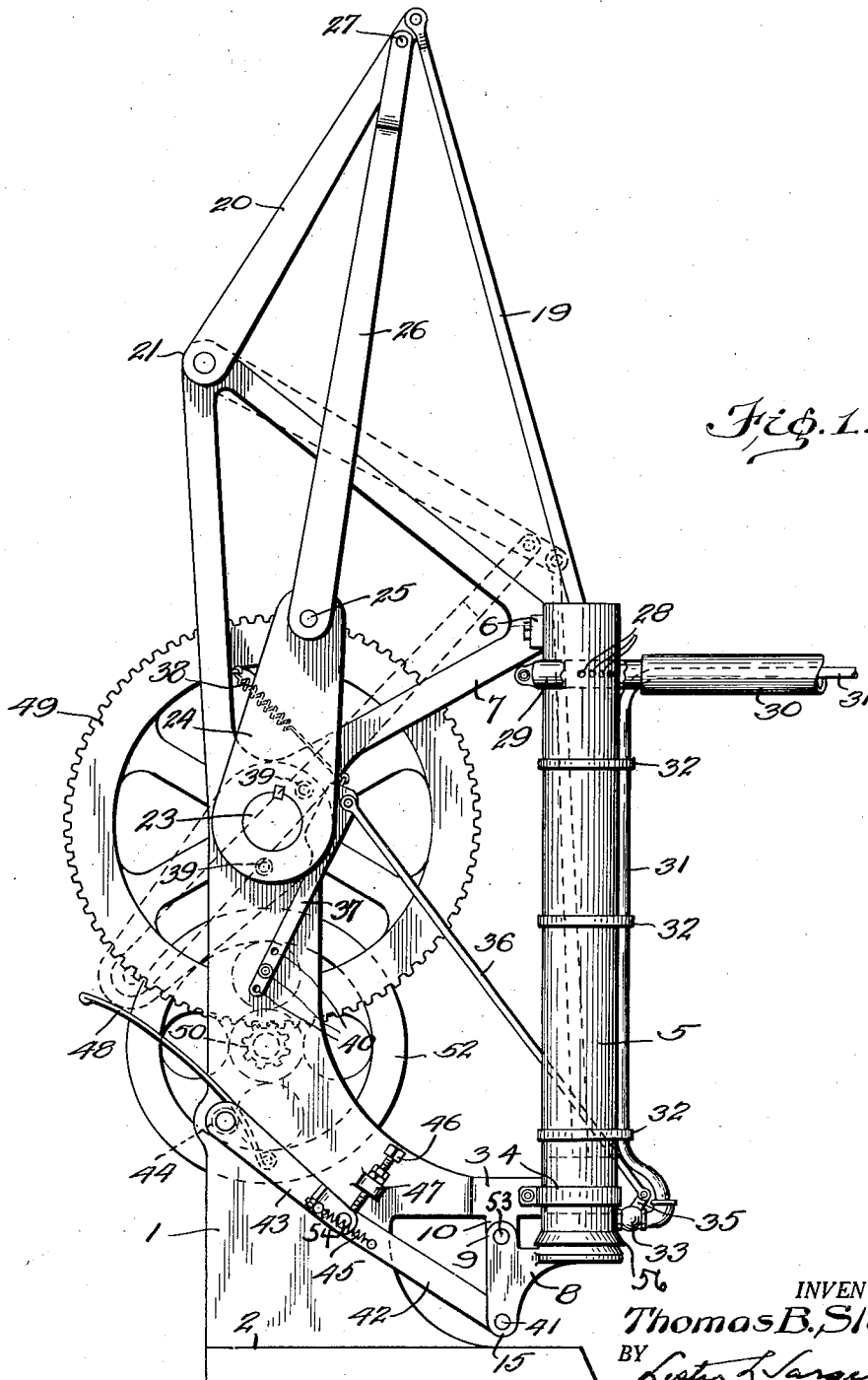
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METHOD AND MACHINE FOR CONVERTING CARBON DIOXIDE TO A SOLID

Filed June 10, 1924

3 Sheets-Sheet 1



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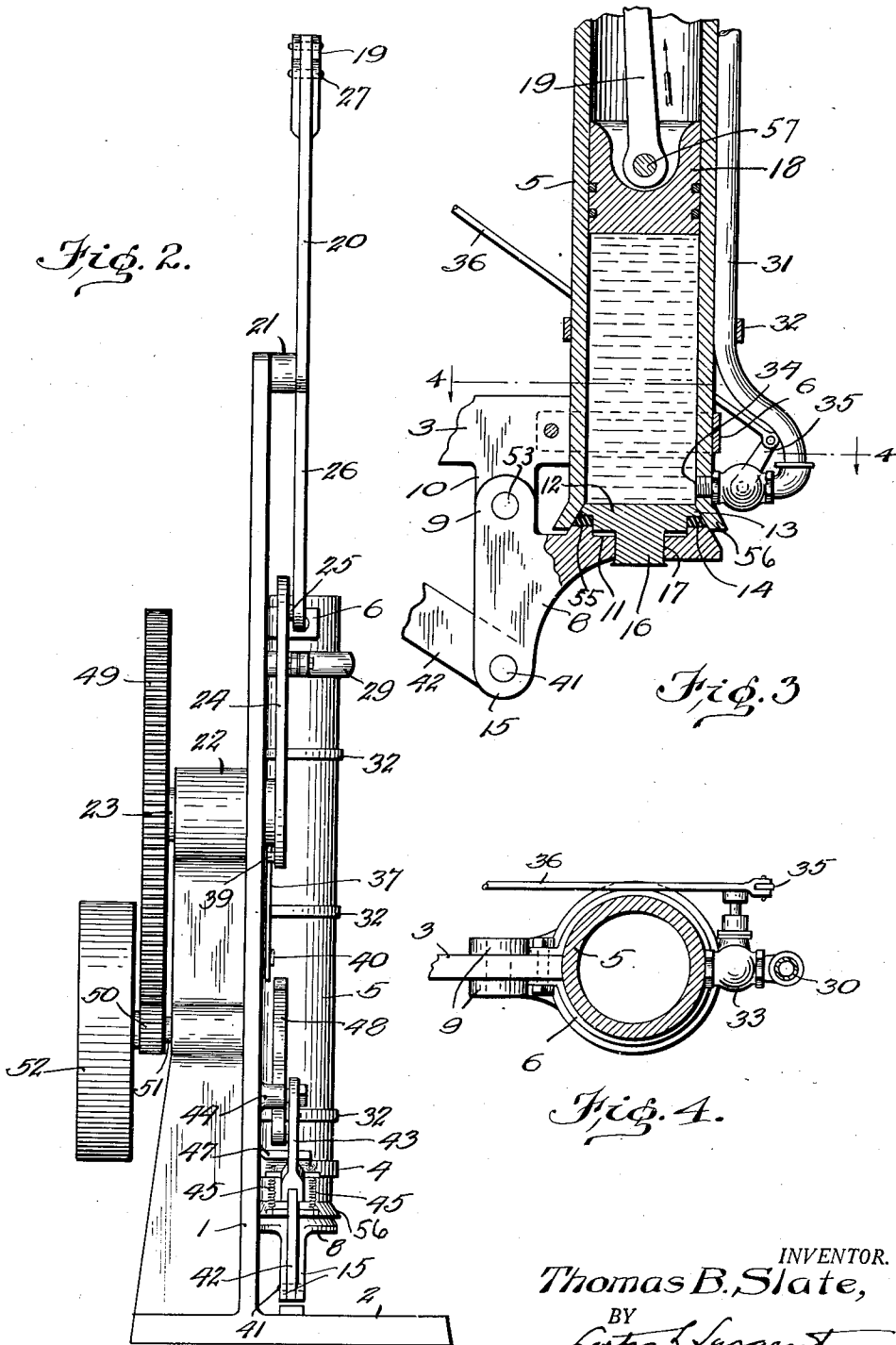
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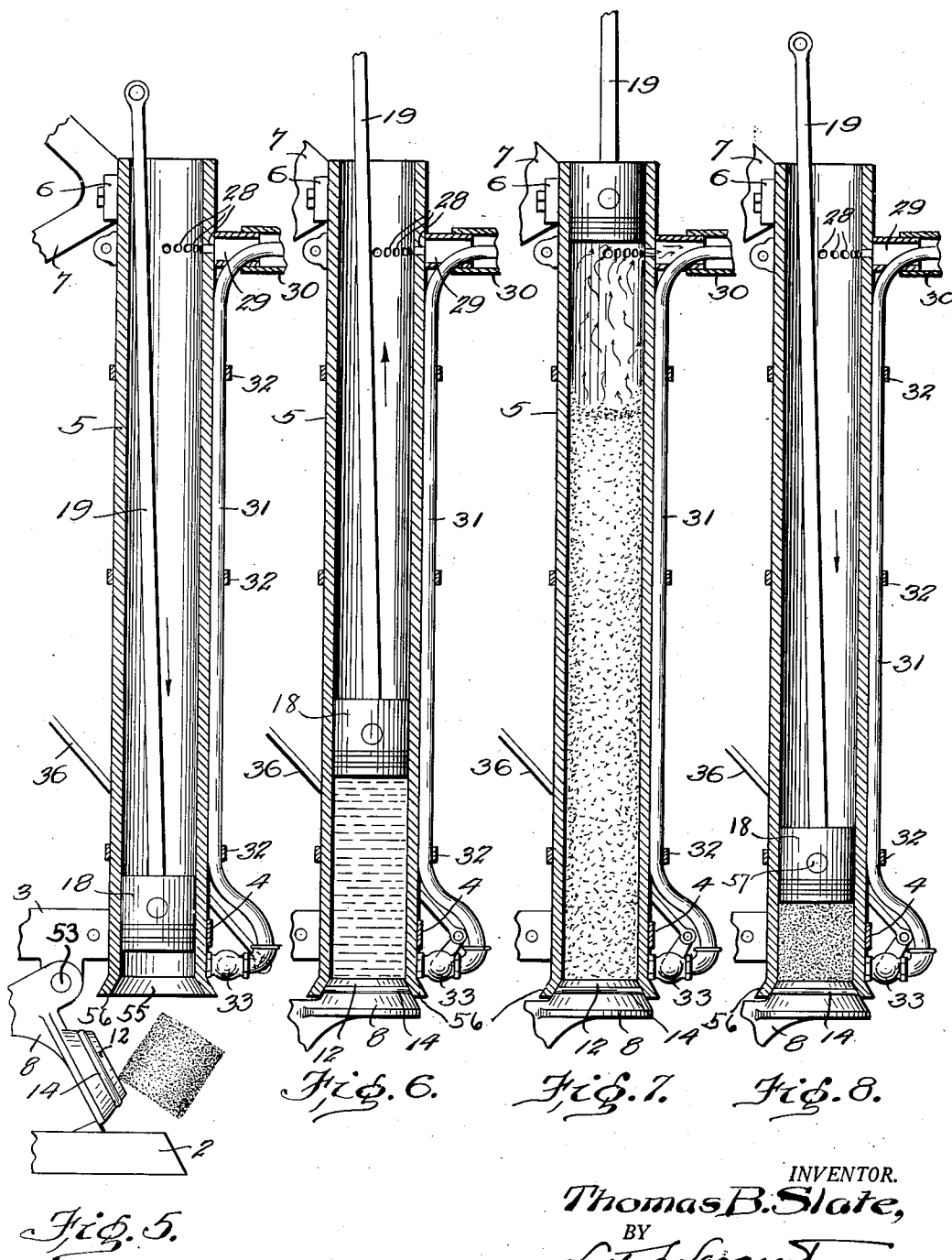
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METHOD AND MACHINE FOR CONVERTING CARBON DIOXIDE TO A SOLID

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3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE.

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METHOD AND MACHINE FOR CONVERTING CARBON DIOXIDE TO A SOLID.

Application filed June 10, 1924. Serial No. 719,198.

The object of my invention is to provide an improved method or process for expanding liquid carbon dioxide or other suitable gas such as highly compressed nitrogen, air, etc. for refrigeration and other purposes and particularly for converting liquid carbon dioxide into a solid; to provide an improved and highly efficient machine for carrying out the process; to provide a novel process and apparatus adapted to utilize both the latent heat of evaporation and the reduction of heat produced by the expansion of the carbon dioxide gas to produce refrigeration; to utilize energy obtained from the carbon dioxide to operate the machine; to provide novel means for automatic operation of my preferred form of apparatus; to provide means for returning surplus carbon dioxide to the source of supply both utilizing its lowered temperature to facilitate the refrigeration process and using it over again for refrigeration, whereby to increase the efficiency of the machine. It is an important object of my invention to include in the machine efficient apparatus for compressing the carbon dioxide snow produced into a compact dense mass which can be conveniently handled. It is also my object to provide the novel combination and arrangement of mechanism in my preferred form of apparatus disclosed in the accompanying drawings, in which—

Figure 1 is a side elevation of my preferred form of apparatus;

Fig. 2 is an edge or end view of same;

Fig. 3 is a detail vertical section of the lower part of the converting or refrigeration chamber;

Fig. 4 is a section on line 4—4 of Fig. 3; and

Figs. 5 to 8 inclusive are vertical sections of converting chamber 5, diagrammatically illustrating successive stages in the process.

Referring to the accompanying drawings, I provide a standard 1 and a base 2. The standard 1, which is in the form of a vertical plate, carries the bearings for the operating parts of the machine and also supports the converting chamber 5. Standard 1 is provided with an offset or horizontal arm 3, to which is secured the strap 4, which engages the lower end of the converting chamber 5. Chamber 5 preferably is in the form of a

cylinder. The upper end of converting chamber 5 is secured to a lug 6 provided on the triangular bracket 7, which is formed preferably integral with the standard 1. Converting chamber 5 is open at each end. Its lower end is provided with an outwardly beveled flange 56, as shown in Fig. 3, to provide a seat 55 for the quick sealing cap 12. Cap 12 is suitably mounted on the pivotal cap-applying device 8. My preferred method of mounting cap 12 on cap-applying device 8 consists in providing on cap 12 a reduced stem 16 which passes through the opening 17 in cap-applying device 8 and is loosely held in place on that casting in suitable manner as by riveting it over.

The upper face of the cap-applying device 8 is in the form of a disc and is provided with a circular recess 11 to receive the pressure cap 12, as shown in Fig. 3. The cap 12 is provided with a beveled flange 13 which seats on the face 55 of flange 56. I also provide a suitable resilient pressure ring 14, disposed under flange 13 which, when cap 12 is seated and further pressure is applied to member 8, provides a tight seal for the lower end of the converting chamber 5. Cap-applying device 8 is provided with upper spaced lugs 9 by means of which it is swingably mounted by pivot 53 and lug 10 of offset arm 3. The lower end of cap-applying device 8 is also provided with spaced lugs 15 to receive the operating arm 42, these parts being operatively connected by pivot 41.

Referring to Figs. 3, 5, 6, 7 and 8, I provide a suitable piston 18, pivotally connected to the end of a suitable piston rod 19, the upper end of this rod 19 in turn being pivotally connected to the oscillating lever 20, mounted in a bearing 21, carried by the upper end of standard 1, as shown in Figs. 1, 2 and 3. I provide a suitable bearing 22 in the standard 1, and also provide a crank shaft 23 in said bearing. Keyed to crank shaft 23 is a rotating arm or crank 24, to the outer end of which a link 26 is operatively connected by the crank pin 25. Link 26 is bifurcated near its outer end and its bifurcated end is connected by pivot 27 to oscillating lever 20 close to the pivot connection of rod 19 with lever 20, as shown in Fig. 1.

Near the upper end of chamber 5 and in a plane just below that of the bottom of

piston 18 when at the uppermost end of its stroke, as shown in Fig. 7, I provide a series of apertures 28 constituting exhaust ports. Ports 28 open into a manifold 29 secured around the converting chamber 5, as shown in Fig. 1, and opening into pipe 30 which extends to a suitable carbon dioxide plant or source of supply of liquid carbon dioxide (not shown). I provide a supply pipe 31 of substantially smaller diameter than pipe 30 and arranged within that pipe. Pipe 31 follows down the length of the chamber 5 to the exterior of which it may be secured by suitable means such as bands 32. Pipe 31 is connected to a throttle valve 3 at the lower end of converting chamber 5. This arrangement of the pipes and the chamber 5 has an advantage in that it functions to absorb the heat from the liquid or gas inflowing through pipe 31 so that it is chilled before entering converting chamber 5. The valve 33 controls the inlet port 34 which is located at the bottom of converting chamber 5, just below the plane of the piston when at the lowermost end of its stroke. Valve 33 is operated at predetermined intervals by means of a suitable lever 35 to which is connected a link or push rod 36, which in turn is connected to and operated by a suitable cam lever 37. Cam lever 37, as shown in Fig. 1, is mounted on the face of the standard 1, and is operated by a suitable cam roller 39 which is carried by the crank 24 on the rear face thereof. Valve 33 is normally held closed by means of a suitable retaining spring 38, preferably arranged as shown in Fig. 1, attached to cam lever 37 and to the bracket 7. I provide suitable means, such as a plurality of apertures 40 in cam lever 37 any one of which may engage a suitable pin, for adjusting cam lever 37, permitting regulating the operation of the cam lever for proper timing of the operation of valve 33.

Referring to Figs. 1 and 2, I provide a toggle joint device having its lower member 42 pivotally connected by pivot 41 to the depending lugs 15 of the cap-applying bracket 8; while the upper toggle member 43 is suitably and pivotally mounted, as by stud 44, on the standard 1. The toggle members 42 and 43 are held under a predetermined and adjustable tension by a suitable spring 45, whereby the pressure from within chamber 1 against cap 12 and cap-applying device 8 necessary to open the cap 12 may be regulated. This adjustment or regulation is controlled by a suitable set screw 46 passing through a stud 47 on the standard 1. I provide a suitable arm 48, which preferably is flexible, suitably affixed to the upper toggle member 43 and resting on the stud 44. Flexible arm 48 extends upward into the path of the rotating arm 24 and when operated by that arm functions to reset the

toggle members to the positions shown in Fig. 1.

Referring to Fig. 2, I provide a gear 49 mounted on crank shaft 23 at the opposite end thereof from crank 24, I also provide on standard 1 a stub shaft 51 carrying the pinion 50 which meshes with gear 49. I also provide a suitable fly wheel 52 which also is mounted on stub shaft 51 and rotates with that shaft and with pinion 50.

The principal steps of my process and the cycle of operation of my machine are illustrated in Figs. 5, 6, 7 and 8. In Fig. 5 the piston 18 is shown almost at the downward limit of its movement. The sealing cap 12 has been released by the extreme pressure exerted by the piston on the compressed brick or cake of solid carbon dioxide which in turn presses on sealing cap 12 until it moves the cap-applying member 8 downwardly far enough to open the toggle joint 54 between members 42 and 43 against the tension of spring 45, whereupon the cap 12 swings out of the way and releases the cake of carbon dioxide. The tension of spring 45 is suitably adjusted to prevent opening of the toggle joint until the cake of solid carbon dioxide has been compressed to a desired and predetermined density. Just at the stage of the operation illustrated in Fig. 5 when the brick of compressed frozen carbon dioxide is falling clear of sealing cap 12, the crank 24 strikes the toggle-joint-resetting arm 48 and causes the toggle joint members 43 and 42 to swing upwardly thus also swinging the cap-applying device 8 upwardly and reseating the sealing cap 12, as shown in Figs. 6, 7 and 8. Cam roller 39 is illustrated in two different positions in Fig. 1, the one corresponding with the dotted line position of other parts being indicated by a dotted lead line.

At the instant that the sealing cap returns to position the cam roller 39 operates cam lever 37 and link 36 to open valve 33 and allow liquid carbon dioxide to flow freely into chamber 5, forcing piston 18 upwardly by the pressure of the liquid carbon dioxide to about the position shown in Fig. 6, at which position valve 33 is closed, the cam roller 39 having passed cam lever 37. The spring 38 acting on members 37, 36 and 35 functions to shift valve 33 to closed position, shutting off further inflow of liquid carbon dioxide. Momentum has been stored in the fly wheel 52; and piston 18, upon which there is still pressure from the vaporized carbon dioxide, continues on its upward path. When piston 18 travels upward from the approximate position shown in Fig. 6 it reduces the pressure on the liquid carbon dioxide in chamber 5. The liquid carbon dioxide thereupon immediately boils, the liquid receding as it evaporates to supply gas which is expanding and following the

piston 18 to the end of its path. The pressure on the piston will rapidly reduce in consequence of the resultant refrigeration. Refrigeration is obtained both from the latent heat of the evaporation of the liquid carbon dioxide and from expansion of the resultant carbon dioxide gas as the piston travels on its way upward. The above described step of the process continues until the piston 18 passes above openings 28. At that time all remaining pressure caused by the evaporating carbon dioxide is quickly released by the escape of gas flowing out through manifold 29 into heat exchange conduit 30 which conducts the gas back to the source of supply of carbon dioxide, such as a manufacturing plant (not shown), to be converted again to a liquid state for a repetition of the process. In the process of refrigeration above described a considerable portion of the liquid carbon dioxide is converted into a mass of light porous carbon dioxide snow, as illustrated in Fig. 7, while the remaining portion (about one-third) reverts to a gaseous state and is released as described through openings 28.

A valuable result obtained by this improved carbon dioxide snow or ice making process and apparatus is that the first part of the process of evaporation and expansion of gases takes place in a completely enclosed chamber, allowing no part of the frozen liquid carbon dioxide to escape from chamber 5.

Another valuable result of the novel method and machine disclosed is that all of the power obtained by the energy exerted on the piston 18 and applied or transmitted through connecting rods and gearing operatively connecting the piston 18 to fly wheel 52 represents just so many heat units removed from the converting chamber 5, thereby converting a portion of the liquid carbon dioxide to snow and lowering the temperature of the escaping carbon dioxide gas to be passed through the heat exchanger conduit 30, which will in turn lower the temperature of the incoming liquid carbon dioxide in conduit 31, and make it possible to run the machine at a lower liquid pressure of the carbon dioxide without danger of evaporation in the conduits leading to the machine and of a resultant freezing of ice in these conduits by such conversion. A greater percentage of snow from a given quantity of liquid carbon dioxide is obtained by the process and apparatus disclosed than by other methods.

The piston 18 when in the position shown in Fig. 7 is ready to start on its return or downward stroke and continue downward driven by the force of the energy stored in fly wheel 52, to about the position shown in Fig. 8. At this stage of the operation of the machine the pressure of the compressed

cake of solid carbon dioxide on sealing cap 12 and cap applying member 8 will throw the toggle joint 54 of members 42 and 43 off center and discharge the compressed cake of carbon dioxide as shown in Fig. 5. The process and cycle of operation above described will then be repeated, with a resultant compression of carbon dioxide snow into a compact solid mass which is ejected from the converting chamber at the end of each cycle.

It is within the contemplation of my invention to modify the timing of the cam lever 37 to actuate the intake valve 33 after the piston 18 has traveled a considerable distance on its way upward in chamber 5 so as to admit the liquid carbon dioxide into a partial vacuum caused by such travel of the piston. The liquid thus being admitted into a vacuum will turn a greater portion of its volume to snow because it does not have to displace atmospheric pressure. The heat of displacing atmospheric pressure is the item saved by this arrangement of the mechanism.

The term "carbon dioxide snow" or "snow" is to be construed as applying to the light porous product produced by the refrigeration before it is compressed into a dense mass, as used in this specification.

The phrase "reducing pressure in the chamber" as used in the succeeding claims is to be construed broadly as applying to any operative method and means for relieving or reducing the pressure on liquid carbon dioxide supplied to a chamber under pressure, whether by utilizing the energy of the expansion of gas from the liquid in a pressure chamber to drive or to continue to drive a movable element such as a piston and thus increase the capacity of such a chamber or whether by other means (not illustrated) for releasing or reducing pressure in the chamber into which the liquid carbon dioxide is conducted under pressure, such as a valve controlled passage adapted to be opened to allow the portion of the liquid carbon dioxide which vaporizes to escape rapidly from the chamber while the remaining portion is refrigerated to snow.

It is of course within the contemplation of my invention to use any suitable apparatus for carrying out the steps of the refrigeration process which I have invented as defined generally in the following claims.

What I claim is:

1. A process for converting liquid carbon dioxide into a solid for refrigeration and other purposes, consisting in conducting liquid carbon dioxide into a chamber under sufficient pressure to cause it to remain a liquid while being admitted; reducing the pressure inside the chamber and thereby converting a portion of the liquid carbon dioxide into a snow-like condition; withdraw-

ing the carbon dioxide which has reverted to a gas; and compressing the carbon dioxide snow into a compact dense mass.

2. A process for converting liquid carbon dioxide into carbon dioxide snow for refrigeration and other purposes; consisting in conducting liquid carbon dioxide into a chamber under sufficient pressure to cause it to remain a liquid while being admitted; and reducing the pressure inside the chamber and thereby converting a portion of the liquid carbon dioxide into a snow-like condition.

3. A process for converting liquid carbon dioxide into a solid for refrigeration and other purposes, consisting in conducting the liquid carbon dioxide into a chamber under sufficient pressure and at sufficiently low temperature to cause solidification of part of it when the pressure is rapidly reduced; rapidly reducing the pressure in said chamber and thereby converting a portion of the liquid carbon dioxide into carbon dioxide snow; withdrawing the portion of the carbon dioxide which has reverted to a gaseous state; and utilizing the cold gaseous carbon dioxide to absorb heat from the liquid carbon dioxide which is being conducted into the chamber under pressure to permit the above described step of converting liquid carbon dioxide into snow being accomplished at a lower pressure than would otherwise be possible.

4. A process for converting liquid carbon dioxide into a solid for refrigeration and other purposes, consisting in conducting the liquid carbon dioxide into a chamber at such pressure and temperature as to cause it to remain a liquid to fill a predetermined portion of the chamber; extending the volume of the chamber to lower the pressure exerted by the liquid; permitting the liquid carbon dioxide to evaporate and expand to cause refrigeration both by the latent heat of evaporation and by the expanding gas simultaneously and thereby producing carbon dioxide snow; transferring energy from within the chamber to machinery outside the chamber; removing heat represented by such energy and thereby increasing the amount of refrigeration possible; and periodically returning energy from the machinery outside the chamber and utilizing it to compress the carbon dioxide snow in the chamber to a compact and dense mass.

5. A process for converting liquid carbon dioxide into a solid for refrigeration and other purposes, consisting in conducting liquid carbon dioxide into a chamber under pressure; rapidly reducing the pressure and thereby converting a portion of the liquid carbon dioxide into a snow-like condition; withdrawing the portion of the carbon dioxide which has reverted to a gaseous state; conducting said gaseous carbon dioxide

around the conduit through which the inflowing carbon dioxide is conducted to the chamber under pressure in the step of the process first mentioned to absorb heat from the inflowing liquid carbon dioxide to permit of carrying out the process under a lower pressure than would otherwise be required; and mechanically compressing the snow-like carbon dioxide into a dense solid cake.

6. A process for continuously converting liquid carbon dioxide into a solid for refrigeration and other purposes, consisting in conducting the liquid carbon dioxide into a chamber under pressure; rapidly extending the volume of the chamber and thereby reducing the pressure and temperature to convert a portion of the liquid carbon dioxide into snow; withdrawing a portion of the carbon dioxide which has reverted to a gas; utilizing the lowered temperature of the carbon dioxide which has passed through the above steps to absorb heat from the liquid carbon dioxide which is being intermittently conducted into the chamber under pressure; mechanically transferring the energy exerted by the expanding liquid carbon dioxide to a rotating mechanical element; and utilizing the energy of the momentum acquired by said rotating element to automatically control a predetermined intermittent admission of the liquid carbon dioxide into the chamber under pressure for continuously carrying out successive cycles of the above described refrigeration process.

7. In an apparatus for converting liquid carbon dioxide to a solid for refrigeration and other purposes, the combination of a converting chamber, a valve controlled conduit for conducting liquid carbon dioxide into said converting chamber under pressure, a tight-sealing cap removably seated on one end of the converting chamber, a piston slidably mounted in the converting chamber arranged to permit of expansion of the liquid carbon dioxide in said chamber and rapid reduction of pressure upon same to convert a portion of it to a snow-like condition, a fly wheel, means operatively connecting the piston with the fly wheel and converting the force applied by the piston on said means into power converted to momentum of the driven fly wheel, means normally holding the sealing cap in sealing position, means for adjusting and supporting said sealing cap to withstand a predetermined pressure from within the converting chamber and adapted to release the sealing cap and discharge the contents of the chamber when said pressure is exceeded, and a controlling member arranged to intermittently operate the sealing cap at predetermined intervals to reseal same, said controlling member being operatively connected with and actuated by the above mentioned

means actuated by said piston, and means actuated by the said controlling member to open and close the valve in the valve-controlled conduit through which liquid carbon dioxide is admitted into the converting chamber at predetermined intervals.

8. In an apparatus for converting liquid carbon dioxide to a solid for refrigeration and other purposes, the combination of a converting chamber, a conduit for conducting liquid carbon dioxide into said converting chamber under pressure, a valve in said conduit, a tight sealing cap removably seated on and adapted to tightly seal one end of the converting chamber, a piston slidably mounted in and sealing the other end of the converting chamber, said piston permitting of expansion of the liquid carbon dioxide in the chamber and permitting rapid reduction of pressure on the liquid carbon dioxide to convert a portion of it to a snow-like condition, a fly wheel, a series of members operatively connecting the piston with the fly wheel and converting the force applied by the piston on the said series of members into power converted to momentum of the driven fly wheel, means for the discharge from the converting chamber of carbon dioxide which has reverted to a gaseous state after each refrigeration operation, a spring-controlled toggle joint device normally holding the sealing cap in sealing position, means for adjusting said toggle joint device to withstand a predetermined pressure applied from within the converting chamber on the sealing cap and to release the sealing cap when said pressure is exceeded to discharge the cake of solid carbon dioxide formed in the converting chamber, and a rotating arm operatively connected with and actuated by the series of members connected with the piston, said rotating arm being suitably arranged to reset the toggle joint device and reseal the sealing cap on the converting chamber at predetermined intervals, and means actuated by the aforesaid mechanism at predetermined intervals to open and close the valve in the conduit through which liquid carbon dioxide is conducted into the converting chamber.

9. In combination with the apparatus described in claim 6, the conduit through which the liquid carbon dioxide is conducted into the converting chamber being arranged in contact with the exterior wall of the converting chamber, whereby the reduction of temperature by the refrigeration in the converting chamber will absorb heat from the liquid carbon dioxide flowing to said chamber through the adjacently positioned conduit and thereby permit of performing the refrigeration with a lower pressure of the liquid carbon dioxide within the converting chamber than would otherwise be possible.

10. In combination with the apparatus described in claim 8, means for adjusting the mechanism actuated by the rotating arm to open and close the valve in the conduit through which liquid carbon dioxide is admitted into the converting chamber to permit of adjusting the timing of the operation of said valve relatively to the operation of the mechanism which reseats the sealing cap.

11. A process for converting liquid carbon dioxide into a solid for refrigeration and other purposes, consisting in conducting liquid carbon dioxide into a variable-capacity chamber under pressure; applying the energy of the inflowing liquid carbon dioxide on a movable element; stopping the inflow of liquid carbon dioxide into said chamber at a predetermined time; utilizing the pressure produced by the expansion of the gas evaporating from the liquid carbon dioxide to operate the movable element to the end of its stroke or path; utilizing both the latent heat of vaporization and the reduction of heat by expansion of the gas simultaneously to convert a considerable portion of the liquid carbon dioxide in the chamber to carbon dioxide snow; withdrawing from the chamber the carbon dioxide which has reverted to a gaseous state; and applying the energy stored in the movable element to mechanically operate and control the intake at predetermined intervals of fresh charges of liquid carbon dioxide in the variable capacity chamber.

12. A process for converting liquid carbon dioxide into a solid for refrigeration and other purposes, consisting in conducting liquid carbon dioxide into a chamber under pressure, extending the capacity of said chamber under the pressure of the inflowing liquid carbon dioxide and applying the energy of the inflowing liquid carbon dioxide on a movable element; stopping the inflow of liquid carbon dioxide into the chamber at a predetermined time; utilizing the pressure produced by the expansion of the gas evaporating from the liquid carbon dioxide to operate the movable element to the end of its stroke or path; utilizing both the latent heat of vaporization and the reduction of heat by expansion of the gas simultaneously to convert a large portion of the liquid carbon dioxide in the chamber to snow; withdrawing from the chamber the portion of the liquid carbon dioxide which has vaporized; applying the energy stored in the movable element to mechanically control the intake of fresh charges of liquid carbon dioxide in the above described chamber; and alternately transferring energy from the piston to a rotating element and from said rotating element back to the piston at predetermined times to compress the refrigerated carbon dioxide to a dense solid mass.

13. Apparatus for converting carbon dioxide from liquid into solid form, comprising an expansible chamber, means for admitting a charge of liquid carbon dioxide
5 under pressure thereto whereby the liquid will evaporate and the gas expand with resultant refrigerating effect and the formation of snow, means for absorbing the work done by the pressure of the admitted liquid
10 and expanding gas in expanding the chamber and storing said energy, and means for applying said energy to compress the said snow into solid form.
14. Apparatus for converting carbon dioxide from liquid into solid form, comprising
15 an expansible chamber, means for admitting a charge of liquid carbon dioxide under pressure thereto whereby the liquid will evaporate and the gas expand with resultant refrigerating effect and the formation of snow, means for absorbing the work done by the pressure of the admitted liquid and expanding gas in expanding the chamber and storing said energy, and means for applying said energy to compress the said snow into solid form and valve means operated thereby to control the admission of the liquid and means operated by said energy to open the chamber and cause the ejection of the solid carbon dioxide.

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