July 6, 1948. B. F. KUBAUGH 2,444,514

TUBE-ICE MACHINE USING COMPRESSOR TO REVERSE PRESSURE

Filed Jan. 28, 1944 2 Sheets-Sheet 1

Fig. 1.

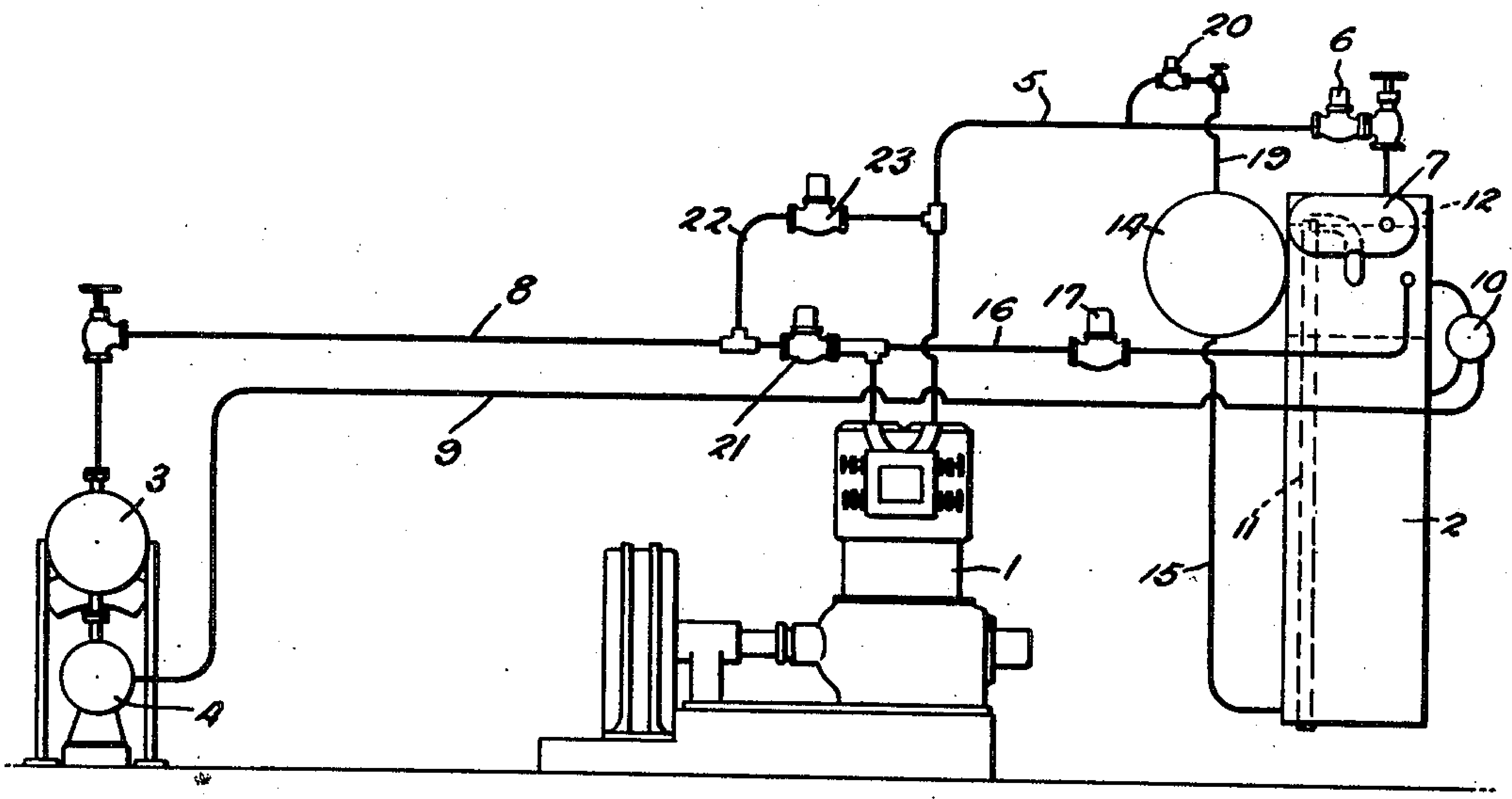
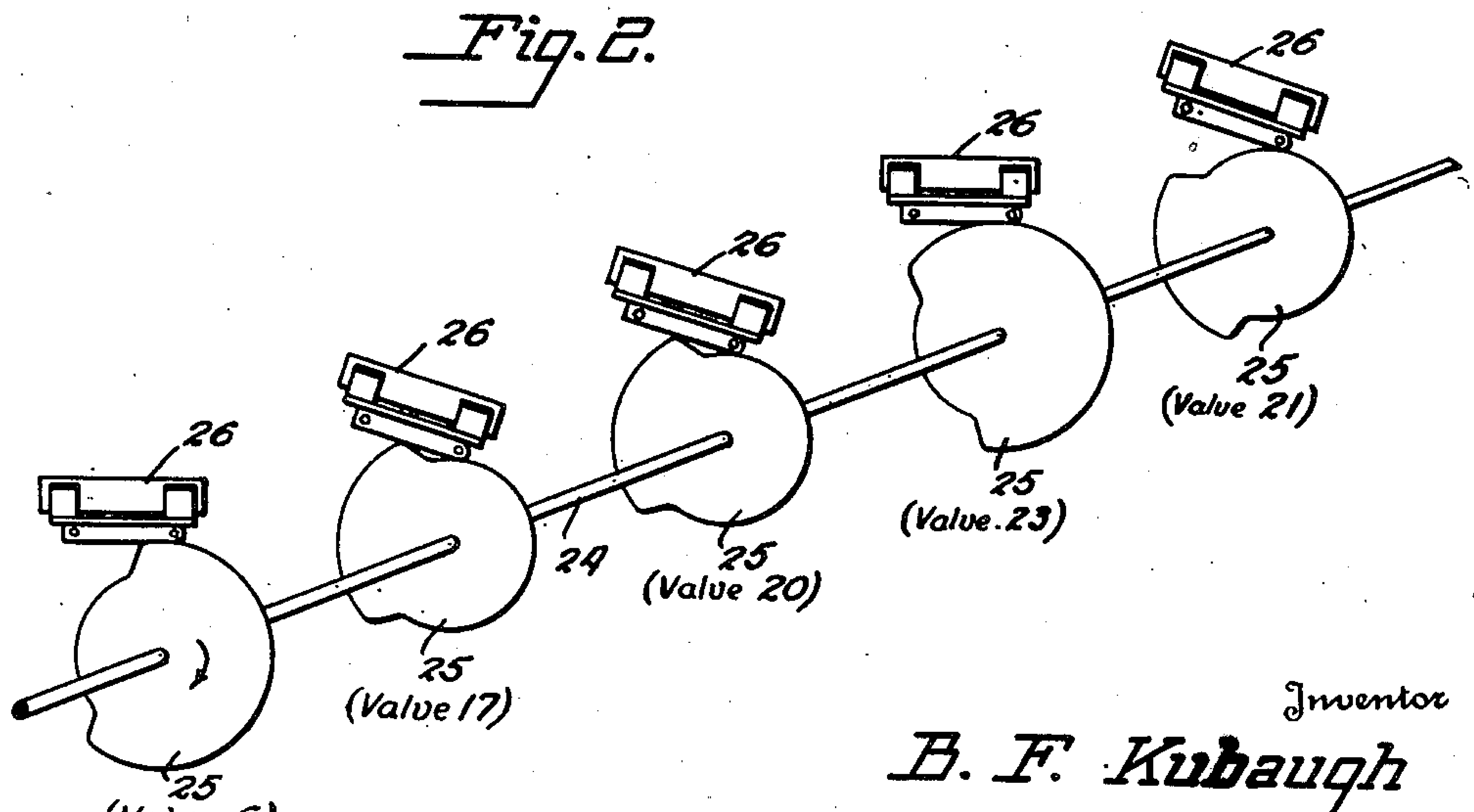


Fig. 2.



Inventor

B. F. Kubaugh

By Mason Fenwick & Lawrence

Attorneys

July 6, 1948.

B. F. KUBAUGH

TUBE-ICE MACHINE USING COMPRESSOR TO REVERSE PRESSURE

2,444,514

Filed Jan. 28, 1944

2 Sheets-Sheet 2

Fig. 3.

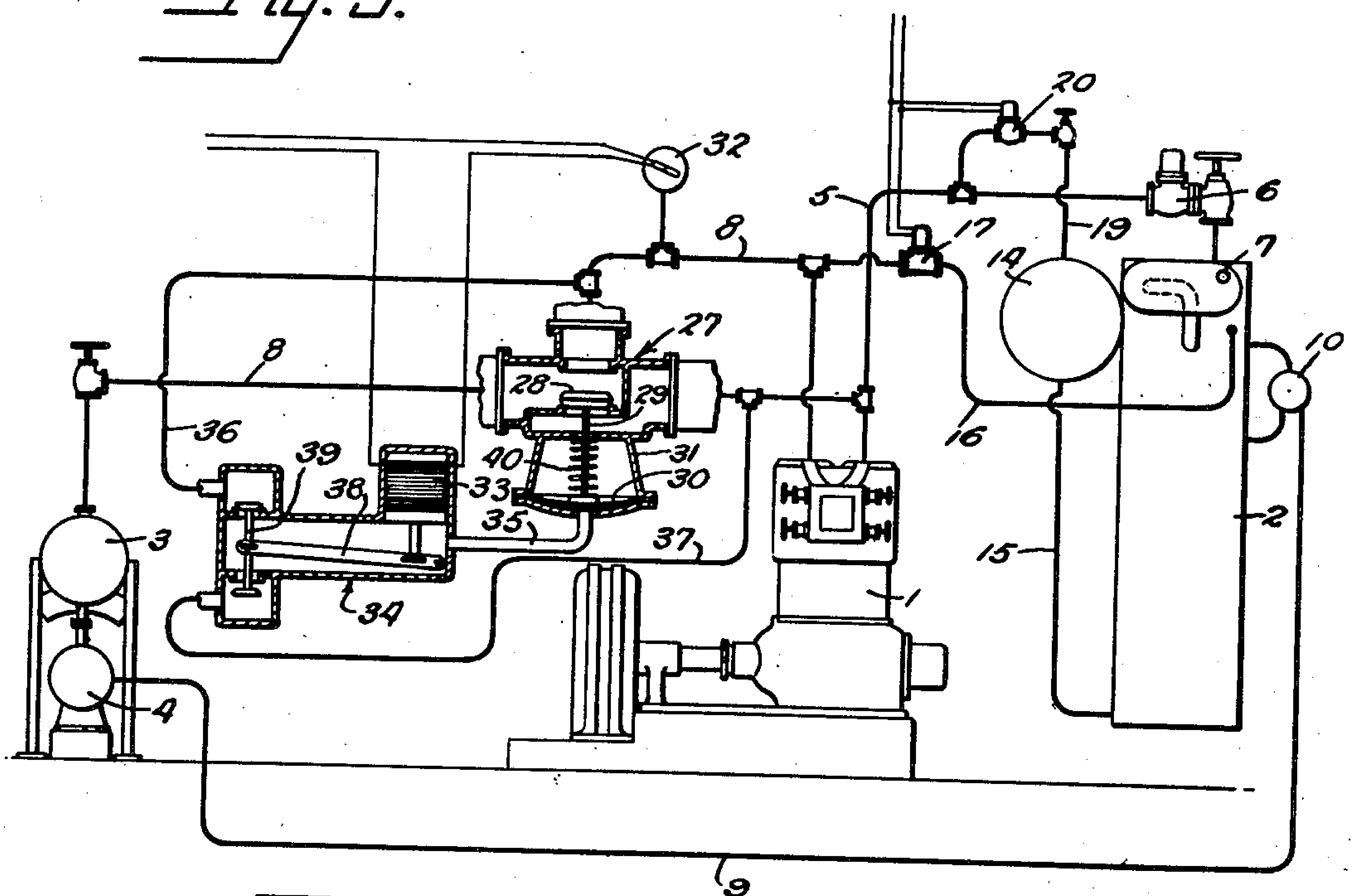
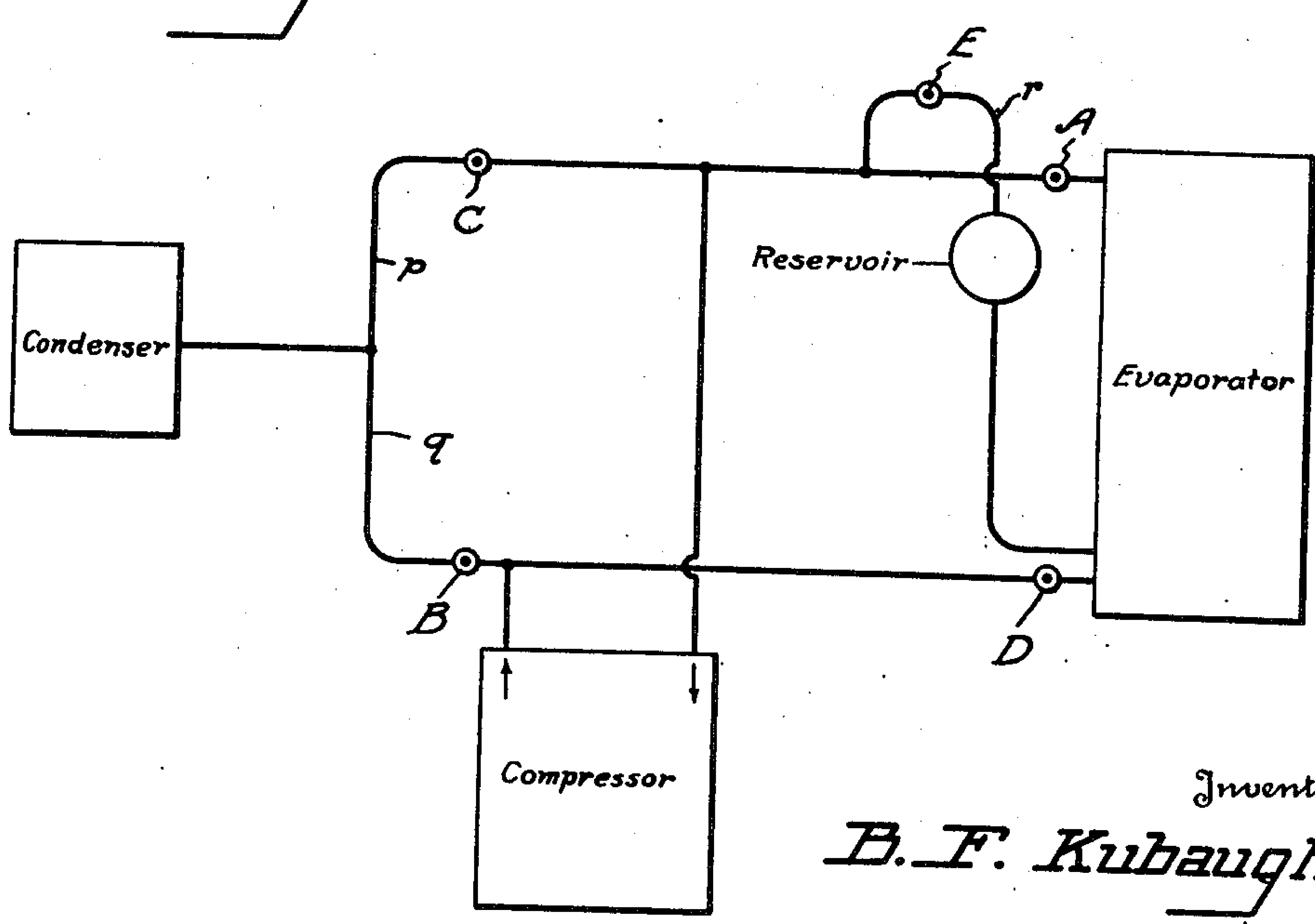


Fig. 4.



Inventor

B. F. Kubaugh

By Mason Fenwick & Lawrence

Attorneys

Patented July 6, 1948

2,444,514

UNITED STATES PATENT OFFICE

2,444,514

TUBE-ICE MACHINE USING COMPRESSOR TO REVERSE PRESSURE

Benjamin F. Kubaugh, Louisville, Ky., assignor to Henry Vogt Machine Co. Inc., Louisville, Ky., a corporation of Kentucky

Application January 28, 1944, Serial No. 520,086

9 Claims. (Cl. 62—3)

This invention relates to the manufacture of ice by freezing water in a vessel in the evaporator chamber of a Carnot type refrigeration system, in which the ice is thawed from adherence to the walls of the vessel by the substitution of hot gaseous refrigerant in the evaporator chamber for the liquid refrigerant which has effected the freezing.

This method of thawing has been practiced in the tube ice machine forming the subject of Kubaugh Patent No. 2,200,424, granted May 14, 1940, and Kubaugh Patent No. 2,239,234, granted April 22, 1941, in which ice is periodically frozen in an upright bundle of open ended tubes extending through the shell of the evaporator, the ice being thawed from the inner walls of the tubes following the freezing period. Since the liquid refrigerant in the evaporator chamber is at relatively low pressure while hot gaseous refrigerant is available in the condenser at relatively high pressure, the system described in said patents employs the hot gas from the condenser to displace the liquid refrigerant from the evaporator temporarily, it being collected in a displacement reservoir and re-admitted to the evaporator at the end of the evacuation cycle for the next freezing period.

In practice it was found that the volume of gas in the condenser was so small that when its pressure became equalized with that in the evaporator, the resulting pressure was insufficient to completely displace the liquid refrigerant so that it was necessary during the freezing period to divert a part of the hot compressed gas from the high side of the compressor to an auxiliary storage reservoir to supplement the volume of hot gas from the condenser. This expedient resulted in less than the maximum of refrigerant re-liquefied in the condenser.

Then too, the mixing of the relatively small volume of condenser gas with the cold gas in the evaporator unduly lowered the thawing temperature of the mixture, while the gas in the storage reservoir had an opportunity to cool somewhat, so that the thawing effect was slower than it might have been under optimum conditions.

Since it was, of course, necessary to cut off the low side of the compressor from the evaporator at the end of the freezing phase and prior to the evacuation phase, the compressor during the evacuation period was drawing in nothing, therefore compressing nothing, but operating at a high vacuum and constituting a useless load upon the system.

The present invention has for its principal object to provide an ice making system of the type described, in which at the end of the freezing period, the suction side of the compressor is switched from the evaporator to the condenser and the pressure side of the compressor switched from the condenser to the evaporator. By this reversal of the objective functioning of the compressor, it on the one hand, delivers hot compressed gas to the evaporator in sufficient volume and under adequate pressure to displace the liquid refrigerant therefrom, thus avoiding the need for any auxiliary storage reservoir, and on the other hand, it does useful refrigeration work upon the condenser and associated receiver, lowering the temperature of the liquid refrigerant supplied to the evaporator.

Other objects of the invention will appear as the following description of preferred and practical embodiments thereof proceeds.

In the drawings which accompany and form a part of the following specification, and throughout the several figures of which the same reference characters have been used to denote identical parts:

Figure 1 is a view in side elevation, largely diagrammatic, showing a simple form of ice making system embodying the principle of the subject invention;

Figure 2 is a diagrammatic view showing the controller which operates the valves;

Figure 3 is a view similar to Figure 1, showing a system in which reversal of the objective compressor functions is automatically responsive to pressure changes in the system;

Figure 4 is a conventionalized diagram illustrating the broad principles of the invention.

Referring first to that form of the invention shown in Figure 1, the refrigeration system is of the Carnot type, including the compressor 1 which normally sucks from the upper part of the evaporator shell 2 and delivers hot compressed gaseous refrigerant to a condenser unit comprising the condenser 3, in which it is liquefied and a receiver 4 in which the condensed refrigerant is collected and from which the liquid refrigerant is supplied to the evaporator according to refrigeration needs.

The reference character 5 represents the low pressure conduit from the evaporator to the low side of the compressor, having a cut-off valve 6, and communicating with the evaporator by way of a liquid trap 7. The reference character 8 represents a conduit from the high pressure side of the compressor to the condenser, and 9, a conduit from the receiver to the evaporator communicating with the latter through a liquid level maintaining device 10.

In the illustrated embodiment of the invention, the evaporator shell 2 contains a plurality of vertical tubes 11 open at both ends, the upper ends communicating with a water chamber 12, the lower ends extending through the bottom of the shell. Water from the chamber 12 flows through the tubes 5 and congeals upon the inner walls of said tubes, forming cylinders of ice the thickness of walls of which depends upon the length of the freezing period. In order to thaw the ice cylinders from their adherence to the walls of the tubes 11, the liquid refrigerant in the shell is displaced by hot gaseous refrigerant derived from the system. A displacement reservoir 14 is therefore provided, to which the liquid refrigerant is temporarily transferred through a conduit 15 communicating with the lower part of the shell. A branch conduit 16 for hot gas connects the upper part of the shell with the conduit 8, and has the cut-off valve 17.

It will be understood that the subject invention is not necessarily concerned with the specific tube ice freezing machine above described, but that any water containing vessel within the evaporator in which ice is frozen and from adherence to the walls of which it is thawed by hot refrigerant gas to effect its discharge from said vessel, is within the purview of the invention.

The system as described thus far, is old, and in order to distinguish the new from the old, a brief description of the operation of the known system will now be given. At the end of the freezing period the valve 6 is closed, cutting off the low side of the compressor from the evaporator. The compressor continues to operate, drawing a high vacuum but compressing nothing, and constituting a useless load on the power by which the compressor is driven. The valve 17 is also opened at the end of the freezing period, putting the condenser into communication with the shell. Since the suction gas in the evaporator is at a much lower pressure than the hot compressed gas in the condenser, an equalization of pressure occurs, but the volume of compressed gas in the condenser is so inconsiderable that the resulting equalized pressure is generally insufficient to completely evacuate the liquid refrigerant from the shell, so that resort was had to the provision of an auxiliary storage reservoir, not shown into which some of the compressed gas from the high side of the compressor was diverted during the freezing period and admitted to the shell for evacuation purposes concurrently with the admission of the gas from the condenser.

The disadvantages of this arrangement are not only that the compressor is a useless load on the system during the evacuation period, but that the auxiliary storage reservoir is objectionable as occupying unnecessary space, and the storage of some of the gas delivered by the high side of the compressor robs the condenser and results in less refrigerant being liquefied in the condenser. Furthermore, the gas stored in the auxiliary reservoir cools somewhat, and the gas from both the condenser and storage reservoir cools considerably in expanding, so that while the gas employed for evacuation is still warm enough to melt ice, its thawing effect is more sluggish than if it did not suffer these heat losses.

The subject invention adds to the known system the following instrumentalities: a relief conduit 19 from the top of the displacement reservoir 14 to the suction conduit 5, having a cut-off valve

20; a valve 21 in the conduit 8 for cutting off the high side of the compressor from the condenser, and a conduit 22 between the condenser conduit 8 and the suction conduit 5, by-passing the valve 21 for placing the condenser in communication with the low side of the compressor and provided with a cut-off valve 23. The operation of the system during the evacuation phase may be regarded as two stages, first a pressure equalizing stage which takes place immediately at the end of the freezing period, and second, the evacuation stage.

At the end of the freezing period the valve 6 is closed; the valves 17 and 20 are opened, the valve 21 remaining open, and the valve 23 remaining closed. Closing of the valve 6 terminates the freezing period. Opening of the valve 20 causes the compressor to draw on the displacement reservoir 14, to make room for the liquid refrigerant to be displaced from the shell 2. Opening of the valve 17 places the condenser into communication with the evaporator and equalizes the gas pressure in the condenser and evaporator.

After a few seconds, which may be termed the pressure equalization period, the valve 21 is closed and the valve 23 opened. The compressor now draws gas from the condenser and receiver by way of the conduits 8 and 22, and delivers it compressed and heated to the evaporator 2 by way of the conduit 16.

There is an unlimited volume of gas available in the condenser, for as the pressure on the surface of the liquid diminishes, the rate of evaporation of the liquid accelerates. This also cools the liquid refrigerant in the receiver so that the liquid refrigerant is supplied to the evaporator during the freezing period at a lower temperature than in the old system. The gas from the condenser compressed in the compressor is admitted to the shell 2 with ample pressure to evacuate the liquid refrigerant from said shell, and at comparatively high temperature to effect rapid thawing of the adherent ice surfaces.

At the conclusion of the evacuation period the positions of the several valves are restored to those proper for the functioning of the succeeding freezing phase of the refrigeration cycle.

By the above operation, the evaporator pressure is raised to effect the liquid evacuation and release of the ice; a high vacuum on the compressor is avoided; and the compressor does useful refrigerating work in cooling the liquid in the condenser and receiver.

In Figure 1 the valves 6, 17, 20, 21 and 23 are each shown as solenoid operated, and may be actuated through a motor driven controller 24 having cams 25, which at proper intervals trip mercoid switches 26 in circuit with the respective solenoid valves.

In that form of the invention shown in Figure 3, the valves 21 and 23 of Figure 1 are substituted by a three-way diaphragm valve 27 operating remotely respective to pressure variation in the conduit between the condenser and evaporator inherent to the equalization of pressure between these vessels at one time, and the restoral of compressor pressure at another. Pressure control of the three-way valve 27 is effected through the intermediary of a pressure actuated switch and a three-way magnetic valve operated through said switch, and it alternately applies pressure to the diaphragm of the valve 27 and releases pressure from said diaphragm.

The three-way valve 27 has a valve member 28 with stem 29 connected to a diaphragm 30 within a casing 31 forming a diaphragm chamber. The valve member 28 has alternate seating positions determined by the position of the diaphragm. In its lower seating position it opens the avenue of communication between the high side of the compressor and the condenser, functioning as valve 21 in Figure 1. In its upper seating position it opens a passage between the condenser and suction side of the compressor, therefore functioning as valve 23 in Figure 1. The valve member 28 moves all the way from one seating position to the other, so that when one passage is open, the other is closed. It is normally biased to its lower seat by a spring 40, so that the upper valve passage is normally open. The valve 27 is actuated by a pressure responsive switch 32, the motor element of which is in communication with the conduit 8, in which the pressure falls when the valve 17 is opened, to equalize the pressure between the condenser and evaporator, and in which the pressure rises when the valve 17 is closed. The switch 32 closes when pressure in conduit 16 falls, engaging the solenoid 33 of the three-way magnetic valve 34. This valve has a pipe 35 communicating with the diaphragm chamber of the valve 27, which pipe is alternately connected to the high pressure conduit 36 or to a relief conduit 37 communicating with the suction conduit 5. The solenoid, when energized, rocks a lever 38, moving the valve member 39 upward to admit high pressure to the diaphragm chamber.

Figure 4 represents a conventionalized diagram of the salient features of the system illustrating the broad concept of the invention. In this view the condenser and evaporator are connected by a low pressure conduit *p* and a high pressure conduit *q*. The low side of the compressor is connected at an intermediate point to the low pressure conduit, and the high side of the compressor at an intermediate point to the high pressure conduit. The low pressure conduit *p* is provided with the evaporator low pressure valve A and the condenser low pressure valve C on opposite sides of the point of connection of said conduit with the compressor, the valve A serving the evaporator and the valve C, the condenser. The evaporator high pressure valve D and the condenser high pressure valve B are intercalated in the pressure conduit on opposite sides of the point of connection of the compressor with said conduit, the valve D serving the evaporator and the valve B, the condenser. The displacement reservoir is connected by a relief conduit *r* with the suction conduit at a point between the valve A and a compressor connection. A relief valve E is in the relief conduit. Normally, for performing a freezing cycle in the evaporator, the valves of the system are so set that the valve A is open, the valve C closed, the valve D closed, and the valve B open. When it is desired to reverse the functions of the compressor so as to perform a suction cycle in the condenser and to deliver hot compressed gas to the evaporator, the positions of the valves are reversed. The valve A is closed and the valve C is opened. The valve D is opened and the valve B closed. However, in practice, it is found desirable to have the individual valves open and close in a certain sequence. The valves A and D are first operated, being simultaneously respectively closed and opened. The relief valve E may be opened at the same time as the valve D. The valve B is then closed a few seconds after the opening of the valve D, while the valve C may be opened simultaneously with the closing of valve B. This sequence of operation permits the compressor to evacuate the displacement chamber immediately following the closing of the valve A and prior to the opening of the valve C. It also permits the condenser pressure to equalize with the evaporator pressure while the valves B and D are open. This lowers the pressure in the condenser and prevents the compressor from having to compress the already highly compressed gas from the condenser and which might produce an excessive compression pressure.

While I have in the above disclosure described what I believe to be preferred and practical embodiments of the invention, it will be understood to those skilled in the art that the specific arrangement of parts and sequence in the operation of the valves as well as the specific means by which the valves are operated are by way of illustration and not to be construed as restricting the scope of the invention which is defined in the appended claims.

What I claim as my invention is:

1. In a system for freezing ice, a condenser, an evaporator, a vessel in said evaporator in which ice is frozen and from the surface of which it is thawed following freezing by replacement of liquid refrigerant in said evaporator by hot gaseous refrigerant under pressure, a displacement vessel connected to said evaporator into which the liquid refrigerant is evacuated, a compressor, conduits between said compressor and said condenser and evaporator, a conduit between said displacement vessel and the suction side of said compressor, valve means controlling said conduits, means for periodically operating said valve means to cause said compressor alternately to pump from said evaporator to said condenser and from said condenser to said evaporator, defining successive freezing and evacuation phases, and to open said displacement chamber conduit to the suction side of the compressor at the beginning of the evacuation phase and close it at the beginning of the freezing phase.

2. In a system for freezing ice, a condenser, an evaporator and a compressor operatively connected to said condenser and evaporator, a vessel in said evaporator in which ice is frozen and from the surface of which it is thawed following freezing by replacement of liquid refrigerant by hot gaseous refrigerant under pressure, means for periodically reversing the external functions of the compressor whereby it alternately pumps from the evaporator into the condenser and from the condenser into the evaporator, and means for equalizing the pressure between the condenser and evaporator immediately prior to the pumping from the condenser to the evaporator.

3. In a system for freezing ice, an evaporator and a condenser unit, there being a liquid refrigerant conduit from said condenser unit to said evaporator, a vessel in said evaporator in which ice is frozen and from the surface of which the ice is thawed following freezing, a gaseous refrigerant conduit communicating with said condenser unit, low and high pressure branch conduits communicating with said gaseous refrigerant conduit and with said evaporator, a compressor having its induction side connected to said low pressure branch at an intermediate point and having its eduction side connected at an intermediate point to said high pressure branch, an evaporator suction valve in said low pressure branch and an evaporator pressure valve in said high pressure branch, both of said valves being between the evaporator and the compressor, means for substantially simultaneously operating said valves to close one and

open the other, a fluid pressure responsive three-way valve intercalated in said system between said compressor and condenser having a port communicating with said low pressure branch, a port communicating with said high pressure branch and a port communicating with said gaseous refrigerant conduit, including valve means for placing said low and high pressure ports alternately in communication with said gaseous refrigerant conduit port, a diaphragm for actuating said valve means, a magnetic valve for alternately subjecting said diaphragm to differential pressures derived from the respective low and high pressure branches, a pressure actuated switch for operating said magnetic valve having a pressure element communicating with said low pressure branch, responsive to pressure valves therein incident to the opening and closing of the evaporator pressure valve, the high and low pressure ports of said three-way valve being normally respectively open and closed when the evaporator suction and pressure valves are respectively open and closed.

4. In a system for freezing ice, an evaporator and a condenser unit, there being a liquid refrigerant conduit from said condenser unit to said evaporator, a vessel in said evaporator in which ice is frozen and from the surface of which ice is thawed following freezing, a displacement reservoir for liquid refrigerant connected to the lower part of said evaporator, a gaseous refrigerant conduit communicating with said condenser unit, high and low pressure branch conduits communicating with said gaseous refrigerant conduit and with said evaporator, a compressor having its induction side connected to said low pressure branch and its eduction side connected to said high pressure branch, valves in said high pressure branch on opposite sides of the point of connection of said compressor with said branch, respectively alternately opened and closed to selectively direct compressed gaseous refrigerant to said condenser unit or to said evaporator, valves in said low pressure branch on opposite sides of the point of connection of said compressor with said branch, respectively alternately opened and closed to selectively draw gaseous refrigerant from said evaporator or condenser, and means for opening and closing the said valves in each branch conduit in alternation, and with respect to both branch conduits, operating said valves which are on corresponding sides of the compressor connections, in opposite phase.

5. In a system for freezing ice, an evaporator and a condenser unit, there being a liquid refrigerant conduit from said condenser unit to said evaporator, a vessel in said evaporator in which ice is frozen and from the surface of which the ice is thawed following freezing, a gaseous refrigerant conduit communicating with said condenser unit, high and low pressure branch conduits communicating with said gaseous refrigerant conduit and with said evaporator, a compressor having its induction side connected to said low pressure branch and its eduction side connected to said high pressure branch, valves in said high pressure branch on opposite sides of the point of connection of said compressor with said branch, respectively alternately opened and closed to selectively direct compressed gaseous refrigerant to said condenser unit or to said evaporator, valves in said low pressure branch on opposite sides of the point of connection of said compressor with said branch, respectively alternately opened and closed to selectively draw gaseous refrigerant from said evaporator or condenser, one of said last named valves being adjacent said evaporator, a displacement reservoir for liquid refrigerant connected to the lower part of said evaporator, a relief conduit establishing communication between the upper part of said reservoir and said low pressure branch at a point between the compressor connection with said branch and said adjacent valve, a valve in said relief conduit, and means for opening and closing the said valves in each branch conduit in alternation, and with respect to both branch conduits, operating said valves which are on opposite sides of the compressor connections, in opposite phase, and means for opening and closing the valve in said relief conduit in phase with said adjacent valve.

6. In a system for freezing ice which includes a compressor, condenser, evaporator and a vessel in which ice is frozen, in heat exchanging relation to said evaporator, a liquid refrigerant displacement chamber connected to the lower part of said evaporator, a liquid refrigerant conduit and a gaseous refrigerant conduit between said condenser and evaporator, said compressor being intercalated in said gaseous refrigerant conduit, said evaporator and displacement chamber being connected in parallel to said gaseous refrigerant conduit on the same side of said compressor, the latter functioning normally to suck from said evaporator and deliver under pressure to said condenser producing refrigeration in said evaporator, the method of operating such a system to change the freezing phase to a thawing phase in said evaporator, comprising substantially simultaneously cutting off the suction of said compressor from said evaporator and putting said displacement chamber into communication with the suction side of said compressor to exhaust said displacement chamber, then reversing the functions of the compressor by causing it to suck from said condenser and deliver hot gaseous refrigerant under pressure to said evaporator, thereby displacing the liquid refrigerant therein into the exhausted displacement chamber, and bringing said hot gaseous refrigerant into heat exchanging relation to said vessel.

7. In a system for freezing ice which includes a compressor, condenser, evaporator and a vessel in which ice is frozen, in heat exchanging relation to said evaporator, a liquid refrigerant displacement chamber connected to the lower part of said evaporator, a liquid refrigerant conduit and a gaseous refrigerant conduit between said condenser and evaporator, said compressor being intercalated in said gaseous refrigerant conduit, said evaporator and displacement chamber being connected in parallel to said gaseous refrigerant conduit on the same side of said compressor, the latter functioning normally to suck from said evaporator and deliver under pressure to said condenser producing refrigeration in said evaporator, the method of operating such a system to change the freezing phase to a thawing phase in said evaporator, comprising substantially simultaneously cutting off the suction of said compressor from said evaporator, putting said condenser into direct communication with said evaporator by-passing said compressor, and putting said displacement chamber into communication with the suction side of said compressor to exhaust said displacement chamber, then reversing the functions of the compressor by causing it to suck from said condenser and to deliver hot gaseous refrigerant under pressure to said evaporator, thereby displacing the liquid refrigerant therein

into the exhausted displacement chamber, and bringing hot gaseous refrigerant into heat exchanging relation to said vessel.

8. In a system for freezing ice in which the normal freezing phase is followed by a thawing phase, a compressor, condenser, evaporator, and a vessel in which ice is frozen in heat exchanging relation to said evaporator, a liquid refrigerant displacement chamber connected to the lower part of said evaporator, a liquid refrigerant conduit and a gaseous refrigerant conduit between said condenser and evaporator, said compressor being intercalated in said gaseous refrigerant conduit, said gaseous refrigerant conduit including a branch conduit to said evaporator by-passing said compressor, said evaporator and displacement chamber being connected in parallel to said gaseous refrigerant conduit on the same side of said compressor, the latter functioning normally to suck from said evaporator and deliver under pressure to said condenser producing refrigeration in said evaporator, means operating following the freezing phase for substantially simultaneously cutting off the suction of said compressor from said evaporator and putting said displacement chamber into communication with the suction side of said compressor to exhaust said displacement chamber, and means operating sequentially to said first named means for reversing the functions of said compressor causing it to suck gaseous refrigerant from the condenser and to deliver hot gaseous refrigerant under pressure to said evaporator, thereby displacing the liquid refrigerant therein into the exhausted displacement chamber and bringing said hot gaseous refrigerant into heat exchanging relation to said vessel.

9. In a system for freezing ice in which the normal freezing phase is followed by a thawing phase, a compressor, condenser, evaporator, and a vessel in which ice is frozen in heat exchanging relation to said evaporator, a liquid refrigerant displacement chamber connected to the lower part of said evaporator, a liquid refrigerant conduit and a gaseous refrigerant conduit between said condenser and evaporator, said compressor being intercalated in said gaseous refrigerant conduit, said gaseous refrigerant conduit including a branch conduit to said evaporator by-passing said compressor, said evaporator and displacement chamber being connected in parallel to said gaseous refrigerant conduit on the same side of said compressor, the latter functioning normally to suck from said evaporator and to deliver under pressure to said condenser producing refrigeration in said evaporator, means operating following the freezing phase for substantially simultaneously cutting off the suction of said compressor from said evaporator, putting said displacement chamber into communication with the suction side of said compressor to exhaust said displacement chamber, and putting said condenser into direct communication with said evaporator, and means operating sequential to said first named means for reversing the functions of said compressor to cause it to suck gaseous refrigerant from said condenser and to deliver hot gaseous refrigerant under pressure to said evaporator, thereby displacing the liquid refrigerant therein into the exhausted displacement chamber and bringing said hot gaseous refrigerant into heat exchanging relation to said vessel.

BENJAMIN F. KUBAUGH.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,135,285	Gibson	Nov. 1, 1938
2,182,691	Crago	Dec. 5, 1939
2,221,212	Wussow et al.	Nov. 12, 1940
2,364,016	Wussow et al.	Nov. 28, 1944