

Nov. 28, 1944.

R. WUSSOW ET AL

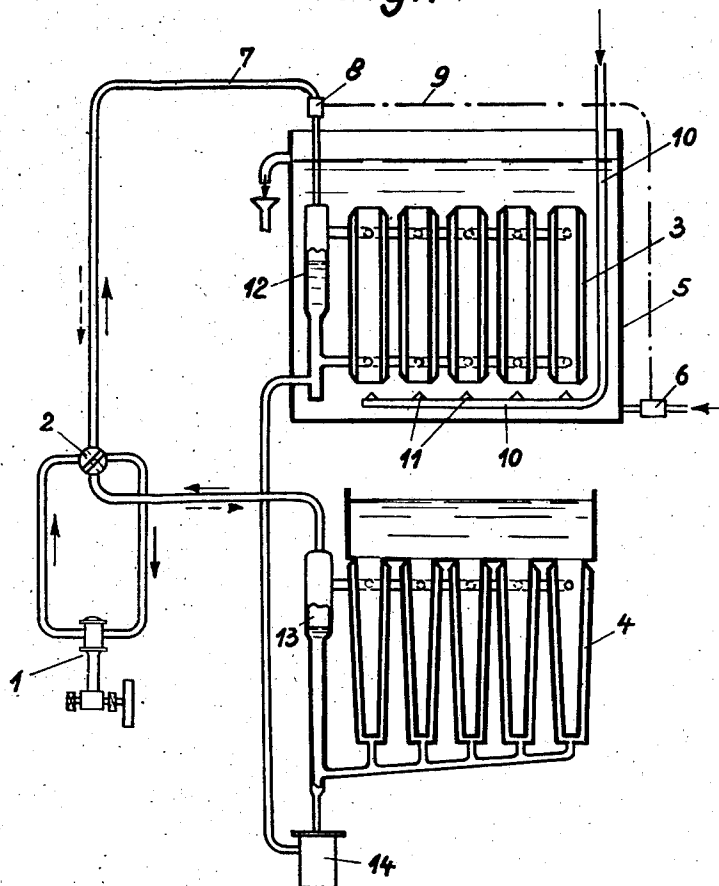
2,364,016

ICE PLANT OPERATING WITH COMPRESSION AND EVAPORATION

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2 Sheets-Sheet 1

Fig. 1.



Inventors

REINHARD WUSSOW
WILHELM FECHNER

Henry J. Kuehl
THEIR ATTORNEY

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Fig. 2

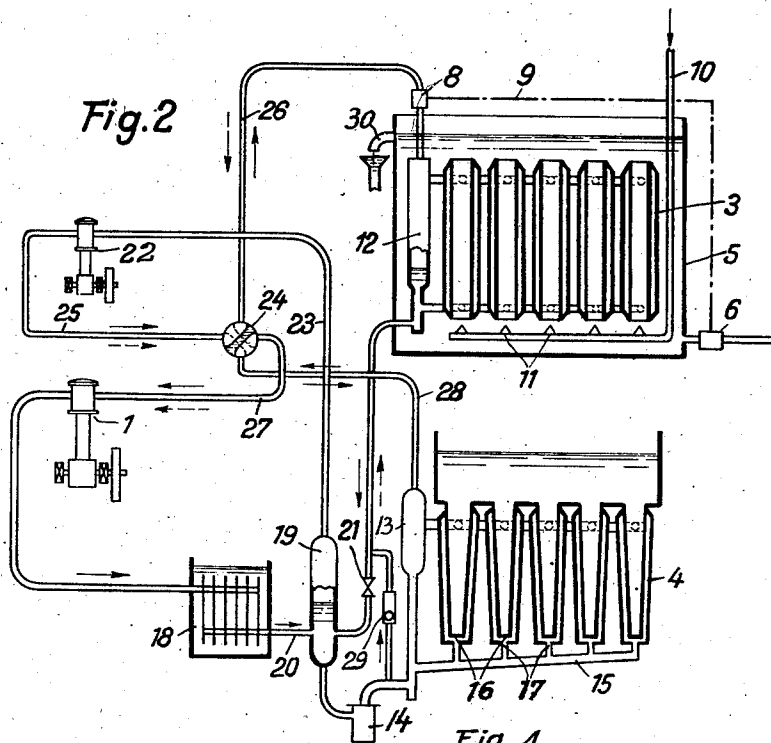


Fig. 4

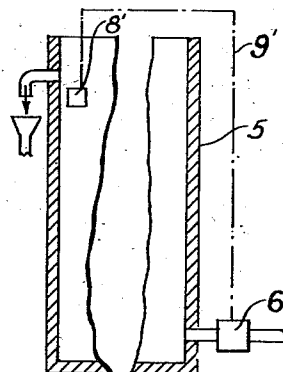
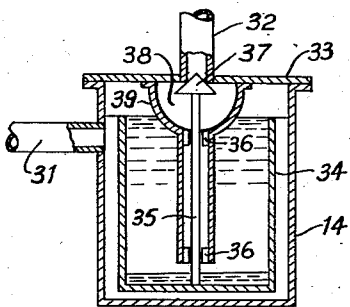


Fig. 3



Inventors
 REINHARD WUSSOW
 WILHELM FECHNER
 BY *Henry J. Locke*
 THEIR ATTORNEY

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ICE PLANT OPERATING WITH COM-
PRESSION AND EVAPORATIONReinhard Wussow, Berlin-Charlottenburg, and
Fritz Wilhelm Fechner, Hamburg, Germany;
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In Germany November 28, 1938

8 Claims. (Cl. 62-105)

This invention relates to an ice plant operating with compression and evaporation, and has for its object to increase the economy of such plants by constructing in a novel manner the part of the plant serving for the condensation of the refrigerant.

The invention is illustrated by way of example in the accompanying drawings, in which

Figure 1 is a diagrammatic view of a single-stage reversible ice-making plant; and

Fig. 2, a diagrammatic view of a two-stage ice-making plant indicative of multi-stage operation.

Figure 3 is a view partly in section of a float valve.

Fig. 4 shows diagrammatically an alternative method for controlling the flow of cooling water in the condenser cooling tank.

In the drawings, 1 designates a compressor; 2, a reversing member; 3, a condenser; and 4, an evaporator or ice generator. In the example shown the condenser 3 is of the submerged type fitted with double vertical pipes and arranged, according to the invention, in a cooling-water tank 5 which is so dimensioned that the heat content of the heated water present therein suffices to meet the necessary heat requirement during the thawing period when the stream of refrigerant is reversed and the condenser operates as evaporator. No cooling-water is therefore consumed during thawing, since the heat of condensation given off to the cooling-water during freezing is now recovered for thawing off the ice blocks. This involves also a saving in working, because the vaporized refrigerant drawn off from the condenser, due to the higher temperature of the cooling-water, flows under higher pressure to the compressor. A further advantage is that the thawing time is reduced owing to larger circulation.

The cooling-water considerably cooled in its tank 5 at the reversal to freezing can, moreover, serve again for cooling the condenser, so that no fresh supply is required until the cooling-water is heated again up to normal temperature. This means a saving in cooling-water also at the beginning of the freezing period as well as in energy, since during this phase of operation the temperature of condensation and thus the pressure thereof are lower due to the cold water in the tank 5. These measures according to the invention insure therefore a considerable increase in the total economic efficiency of the plant.

This mode of operation can be readily attained by installing an automatic regulator 6 in the cooling-water piping, which is controlled by an im-

pulsor member 8 disposed in a pressure piping 7 through a piping 9. The cooling-water regulator may be controlled also by a feeler responsive to the temperature at the discharge end as illustrated diagrammatically at 6', 8' and 9' of Figure 4. The member 6 regulates also the fresh water supply in dependence upon the condensation pressure or the temperature of the cooling-water. When the plant is changed over to thawing, the condensation pressure or the temperature of the cooling-water in the tank 5 is lowered, and further supply of fresh water during the entire thawing period is thus interrupted, and this interruption continues also during reversal to freezing until the temperature of the cooling-water or the condensation pressure is normal again.

To bring about a lively exchange of heat between the cooling-water and the condenser an agitator is provided for keeping the water in constant circulation in the tank 5 or in the heat exchanging surfaces of the condenser. As shown in the drawings, the condenser tubes are of the double vertical type and the annular intermediate space serves as condensing or evaporating space, the circulation of the cooling-water being effected by blowing air into the inner tubes. 10 designates a compressed air piping extending below the condenser 3 and provided with a blast nozzle 11 underneath each tube. The cooling-water is forced up in the inner tubes by the blast air and flows back around the external walls, so that it is continually circulated during the freezing and thawing periods, independently of the supply of fresh water to the tank 5 or through the condenser 3, whereby a particularly lively heat exchange is effected, as confirmed by experiments.

It has now been found that in the case of condensers built along the lines indicated, only very small amounts of cooling-water are consumed. The consumption of cooling-water, especially when the outer air was dry, involved quantities considerably lower than those calculated from the heat of condensation on the one hand and the difference in heat between the inflowing and outflowing water on the other. This phenomenon is probably due to the fact that the strongly moved bubbling surface of the water maintained a lively evaporating exchange with the superposed layer of air, also moved as it were by the boiling surface, so that a large amount of heat came out in the form of steam.

In order to provide for a lively exchange of heat in the condenser 3 operating as evaporator when a change is made to thawing, a liquid separator 12 of the type usual in flooded evaporators

is disposed parallel to the tubes of the condenser 3. This construction insures active circulation of the liquid refrigerant through the heat exchanging chambers during the thawing period and thereby lively evaporation or rapid thawing off of the ice blocks formed in the evaporator.

The condenser space is preferably made so large that the condenser at a change-over to thawing can accommodate the total liquid refrigerant from the evaporator, making allowance also for emulsification during evaporation, so that the thawing action covers all surfaces of the evaporator chambers in contact with ice.

In the construction shown in Fig. 1, 13 designates a liquid separator for the evaporator and 14 a float valve. The float valve comprises an outer casing 33, having an inlet 31 and an outlet 32. Seated in the outlet opening is a valve member 37, the stem of which is attached to a floating cup 34 positioned within the casing 33. A member 39, of generally tubular shape extends downwardly within the floating cup and provides bearing surfaces 36 for the valve stem. Refrigerant from the separator 13 flows into the casing 33 causing the cup 34 to rise, thus closing the outlet 32. Refrigerant continues to rise in 33 and finally spills into the cup 34. When a sufficient quantity has passed into cup 34, it settles opening outlet 32. Refrigerant may thus pass to the evaporator until enough has been withdrawn from cup 34 to permit it to rise and again close outlet 32. It is believed that the purpose and operating possibilities of the other parts shown in the diagram will be understood without further explanation. In the full-line position of the reversing member 2 the refrigerant takes the course indicated by the full-line arrows, the compressed refrigerant in the form of vapor passes therefore in the usual manner into the condenser 3 and after liquefaction through the float valve 14 into the evaporating system where it serves for producing cold or ice. When the member 2 is placed in the position indicated by broken lines, the refrigerant passes through the plant in the direction of the broken-line arrows and condenser and evaporator change their roles.

In the construction shown in Fig. 2 two-stage compression of the vapor of the refrigerant is assumed. 1 designates a low-pressure compressor, 22 a high-pressure compressor, 3 a condenser and 4 an evaporator.

In the example shown the condenser 3 is of the submerged type fitted with double vertical tubes and arranged, according to the invention, in a cooling-water tank 5 which in this instance, too, is so dimensioned that the heat content of the heated water present therein suffices to meet the necessary heat requirements during the thawing period when the stream of refrigerant is reversed and the condenser operates as evaporator. No cooling-water is therefore consumed or passed through the condenser 3 during thawing, since the heat of condensation given off to the cooling-water during freezing is now recovered for thawing off the ice cakes. This involves also a saving in working, because the vaporized refrigerant drawn off from the condenser, due to the higher temperature of the cooling-water, flows under higher pressure to the compressor.

Furthermore, the cooling-water considerably cooled in its tank 5 at the reversal to freezing can be used again for cooling the condenser, so that no fresh supply is required until the cooling-water is heated again to normal temperature.

This means a saving in cooling-water also at the beginning of the freezing period as well as in energy, since during this phase of operation the temperature of condensation and thus the pressure thereof are lower due to the cold water in the tank. These measures according to the invention insure therefore a considerable increase in the total economic efficiency of the plant.

Depending upon prevailing conditions and requirements, it is possible to operate with large reserves of water and slight changes in temperature, for instance in stationary plants to improve the thermal efficiency still more, or with a low water reserve and considerable changes in temperature and also partial freezing of the water reserve, for instance in portable ice plants in the interest of light weights and small dimensions.

This can readily be attained by installing an automatic regulator 6 in the cooling-water supply piping, which is influenced by the condensation pressure or the efflux temperature of the cooling-water, for instance with the aid of an impulsor member 8 disposed in the pressure piping coming from the compressor and controlling the regulator 6 through a piping 9. It is further possible to install within range of the cooling-water discharge 30, instead of the member 8, a feeler responsive to temperature which will then act as temperature regulator for the cooling-water regulator 6. The member 6 regulates also the fresh water supply in dependence upon the condensation pressure or the efflux temperature at 30. When the plant is changed over to thawing, the condensation pressure as well as the temperature of the water in the tank 5 are lowered and further supply of fresh water during the entire thawing period is interrupted, and this interruption continues also during reversal to freezing until the condensation pressure or the temperature of the cooling-water is normal again.

To bring about a lively exchange of heat between the cooling-water in the tank 5 and the condenser an agitator is provided for keeping the water in constant circulation in the tank or in the heat exchanging surfaces of the condenser. As shown in the drawings, the condenser tubes are of the double vertical type and the annular intermediate space serves as condensing or evaporating chamber, the circulation of the water being effected by blowing air into the inner tubes. 10 designates a compressed air piping extending below the condenser 3 and provided with a blast nozzle 11 under each tube. As the cooling-water is forced up in the inner tubes by the blast air and flows back on the outer walls, it is continually circulated during the freezing and thawing periods, independently of the supply of fresh water to the tank 5 or through the condenser 3, whereby a particularly lively heat exchange is effected, as was confirmed by experiments.

It has now been found that in case of condensers built along the lines indicated only very small amounts of cooling-water are consumed. The consumption of cooling-water, especially when the outer air was dry, was found to involve quantities considerably smaller than those calculated from the heat of condensation on the one hand and the difference in heat between the inflowing and outflowing water on the other. This is probably due to the fact that the strongly moved bubbling surface of the water maintains a lively evaporating exchange with the superposed air, also moved by the boiling surface, so

that a large amount of heat comes out in the form of steam.

In order to provide for a lively heat exchange in the condenser 3 operating as evaporator when a change is made to thawing, a liquid separator 12 of the type usual in flooded evaporators is disposed parallel to the tubes of the condenser 3. Owing to this combination of the condenser 3 with a liquid separator 12, lively circulation of the liquid refrigerant through the heat exchanging chambers is insured during the thawing period and thereby good evaporation or rapid thawing off of the ice blocks formed in the evaporator.

The condenser space including the liquid separator 12 is preferably made so large that the condenser at a change-over to thawing can accommodate the total liquid refrigerant from the evaporator, making allowance also for emulsification during evaporation, so that the thawing action covers all the surfaces of the evaporator chambers in contact with ice.

The freezing units of the evaporator are also constructed in the form of double tubes to provide for smooth and rapid detachment of the ice blocks produced, the space between the tubes serving as evaporating chamber. The inner tubes are filled with water and serve as freezing units fitted with a bottom 16 surrounded by the external evaporating jackets 17. The entire bottom of the units is thus enclosed by the evaporating space. The connecting pieces between the evaporating spaces and the distributing pipe 15 arranged below are united with the evaporating chamber in such manner that their cross-sectional area of discharge into the bottom of the units is located at a lower point than the lowest point of the bottom of the inner freezing unit 16. Owing to this arrangement, the entire surface of the freezing units, immediately after reversal to thawing, is surrounded by the hot high-pressure refrigerant vapor, whereby rapid thawing off is insured.

The distributing pipe 15 disposed below the freezing units 4 has a steady inclination to provide for smooth and unrestrained flow of the liquid refrigerant to the condenser 3 or the members interposed between the evaporator and condenser.

It has already been described in connection with the single-stage plant shown in Fig. 1 to reverse the stream of refrigerant with the aid of a suitable member for the purpose of thawing so as to change the condenser to an evaporator and the latter to a condenser. This controlling arrangement is, however, not directly adapted for use in multi-stage plants, and a further object of the invention is therefore to provide a control system which permits a reversal of the stream of refrigerant by means of a simple change-over member also for multi-stage plants. To explain the solution of this problem according to the invention the ice plant shown in diagram in Fig. 2 is of the two-stage type. 18 designates an intermediate cooler and 19 a liquid separator into which opens an intermediate pressure piping 20 coming from the cooler 18 and which receives also the liquid passing from the condenser 3 through a reducing valve 21. The liquid space of the separator 19 is further connected with a float regulator 14 leading to the evaporator 4 and the steam space thereof with a suction piping 23 of the high-pressure compressor 22. The compressor 22, while operating at a higher pressure than com-

pressor 1, obviously has a smaller capacity. This difference in capacity is diagrammatically represented in the drawings by a difference in size of the units. Reference character 24 designates the change-over member which in the construction shown has the form of a simple four-way cock connecting when in full-line position the pressure piping 25 of the high-pressure compressor 22 with the condenser 3 through a piping 26 and, on the other hand, a suction piping 27 of the lower-pressure compressor 1 with the evaporator 4 through a piping 28. In this position the plant operates as follows:

The vaporous refrigerant is drawn by the low-pressure compressor 1 from the evaporator 4 through the piping 28, change-over member 24 and suction piping 27, forced through the intermediate cooler 18 and the piping 20 into the separator 19. The high-pressure compressor 22 draws refrigerant from the separator 19 through the piping 23 and forces it through the piping 25, the change-over member 24 and the conduit 26 into the condenser 3 whence the condensates pass through the reducing valve 21 into the separator 19 and from the latter through the float valve 14 into the evaporator 4, whereby the cycle indicated by the full-line arrows is completed.

On reversal of the member 24 into the broken-line position the pressure piping 25 of the high-pressure compressor 22 is connected with the evaporator 4 and the suction piping 27 of the low-pressure compressor 1 with the condenser 3. In this case, the low-pressure compressor 1 draws the vaporous refrigerant out of the condenser 3, forces it in the manner described above into the high-pressure compressor 22 by which it is forced into the evaporator 4, so that at this connection of the units the condenser 3 and the evaporator 4 change their functions while the compressors remain serially connected as before. The cycle is completed as indicated by the broken-line arrows.

Between the injection pipe leading to the evaporator 4 and the condenser 3 a by-pass piping 29 fitted with a check valve 29 opening toward the condenser 3 is preferably provided. Owing to higher condenser pressure, this valve 29 is closed during a freezing period and, due to higher evaporator pressure, opened on reversal to thawing in consequence whereof the liquid is forced out of the evaporator 4 and into the condenser 3 independently of the reducing float valve 14. It is further possible to arrange the check valve 29 directly in the float valve 14.

What is claimed is:

1. In a plant for making ice by compressing and evaporating a refrigerant, a condenser comprising, a receptacle for a cooling liquid, double walled condenser tubes in said receptacle defining channels for the flow of the cooling liquid, means for producing streams of cooling liquid through said channels, means for supplying a refrigerant to, and discharging it from, said condenser tubes, means for supplying cooling liquid to and discharging it from, said receptacle and for maintaining the surface of the cooling liquid above said cooling tubes, said last named means comprising a supply pipe with built-in regulating valve opening into the receptacle below the condenser tubes, an overflow in the receptacle above the condenser tubes and means for controlling said regulating valve in accordance with the temperature of the cooling water at the overflow.
2. In a device according to claim 1 in which the means for controlling the regulating valve is

responsive to the pressure in the piping supplying refrigerant to the condenser tubes.

3. In a plant for making ice by compressing and evaporating a refrigerant, a condenser comprising, a receptacle for a cooling liquid, condenser tubes in said receptacle, means for supplying cooling liquid to and discharging it from said receptacle, the walls of the said condenser tubes forming channels for the flow of the cooling liquid, the axis of the channels extending in a vertical direction, said condenser tubes forming parallel rows having laterally disposed joint supply and discharge pipes, a supply piping with an in-built regulating valve for controlling the passage of cooling liquid through the receptacle, said supply piping opening into the bottom of the receptacle, an overflow in the receptacle above the condenser tubes and the supply piping for cooling liquid, means for controlling said regulating valve, a compressed air line extending below the condenser tubes at the bottom of the receptacle, and spray nozzles on said air line, each of said nozzles being provided below each channel formed by the condenser tubes, the openings of said nozzles pointing toward said channels.

4. In a plant for making ice by compressing and evaporating a refrigerant, a condenser comprising, a receptacle for a cooling liquid, condenser tubes in said receptacle, means for supplying cooling liquid to and discharging it from said receptacle, the walls of the said condenser tubes forming channels for the flow of the cooling liquid, the axis of the channel extending in a vertical direction, said condenser tubes forming parallel rows having laterally disposed joint supply and discharge pipes, a supply piping with an in-built regulating valve for controlling the passage of cooling liquid through the receptacle, said supply piping opening into the bottom of the receptacle, an overflow in the receptacle above the condenser tubes and the supply piping for cooling liquid, means for controlling said regulating valve, a pressure piping extending below the condenser tubes at the bottom of the receptacle, and a spray nozzle provided on said pressure piping below each channel formed by the condenser tubes, the openings of said nozzles pointing toward said channels, and a liquid separator connected with the joint supply and discharge piping of the condenser tubes parallel to the condenser tubes.

5. A plant according to claim 4, in which the liquid separator is built into the cooling receptacle.

6. A plant for producing ice by compression and evaporation, comprising, a compressor, an open cooling receptacle, a condenser disposed in the open cooling receptacle, said condenser being provided with condenser tubes, means for supplying cooling liquid to said receptacle, means for

maintaining the surface of the cooling liquid in the said receptacle above the condenser tubes, means for controlling the supply of cooling liquid to the receptacle, means for producing circulation of the cooling liquid around the condenser tubes, a liquid separator disposed parallel to the condenser, an evaporator for making ice, a second liquid separator disposed parallel to the said evaporator, pipings for connecting the compressor with the condenser and the evaporator, pipings for connecting the condenser with the evaporator, means for directing the flow of the refrigerant from the compressor to the condenser and then to the evaporator, means for reversing this flow, and a float-valve in the piping between the condenser and the evaporator.

7. A plant for making ice by compressing and evaporating a refrigerant, comprising a high-pressure compressor, a low-pressure compressor, an open cooling receptacle, said condenser being provided with condenser tubes, means for supplying cooling liquid to said receptacle, means for maintaining the surface of the cooling liquid in said receptacle above the condenser tubes, means for controlling the supply of cooling liquid to the said receptacle, means for producing circulation of the cooling liquid around the condenser tubes, a liquid-separator connected parallel to the condenser, an evaporator for making ice, a second liquid separator connected parallel to the evaporator, an intermediate cooler and a liquid separator connected in series in a pressure piping with the low-pressure compressor, a reducing valve being arranged between the said last-mentioned separator and the condenser, the said last-mentioned separator being also connected by piping with the suction side of the high-pressure compressor and also through a float valve with the outlet of the evaporator, a rotary valve movable to two selected positions for connecting when in one of said positions, the output side of the high pressure compressor to the condenser and the suction side of the low pressure compressor to the evaporator, and for connecting, in the other of said positions the output side of the high pressure compressor to the evaporator and the suction side of the low pressure compressor to the condenser, and a check valve interposed between the evaporator and the condenser and opening towards the condenser.

8. A plant according to claim 6, in which the inner space of the condenser tubes occupied by the refrigerant and the inner space of the separator are capable of jointly accommodating the total refrigerant in liquid form during the reversal period.

REINHARD WUSSOW.
FRITZ WILHELM FECHNER.