

Oct. 13, 1936.

C. S. LEOPOLD

2,056,970

COOLING SYSTEM

Filed April 18, 1933

3 Sheets-Sheet 1

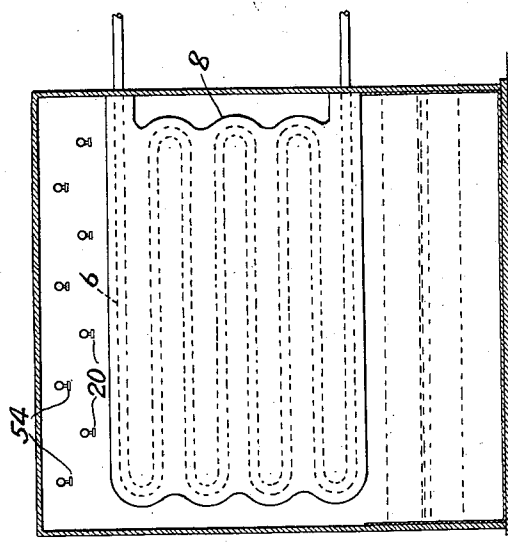


FIG. 2.

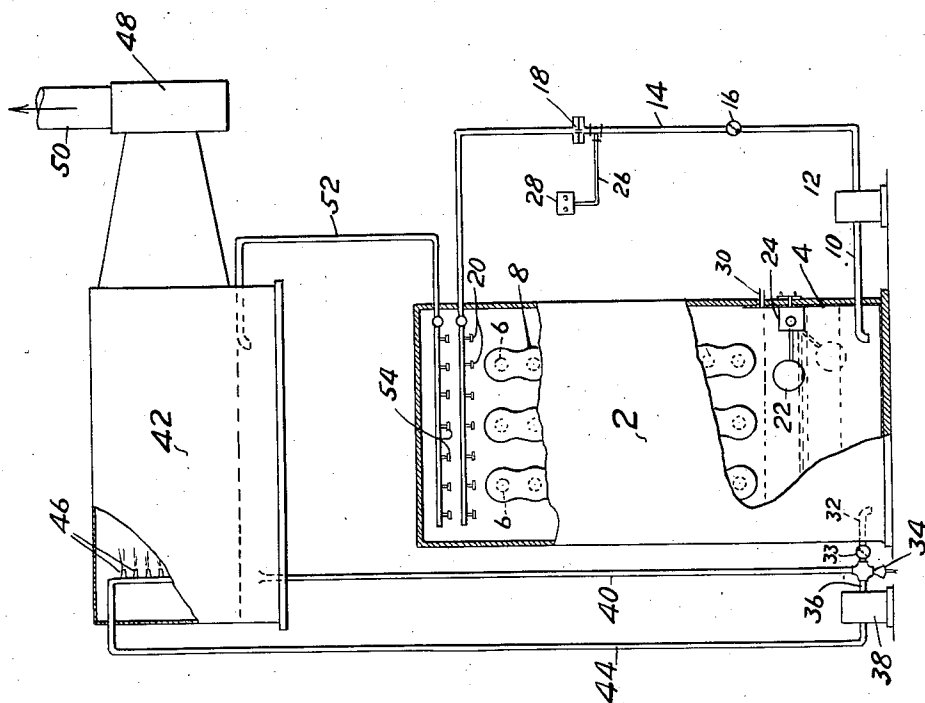


FIG. 1.

WITNESS:

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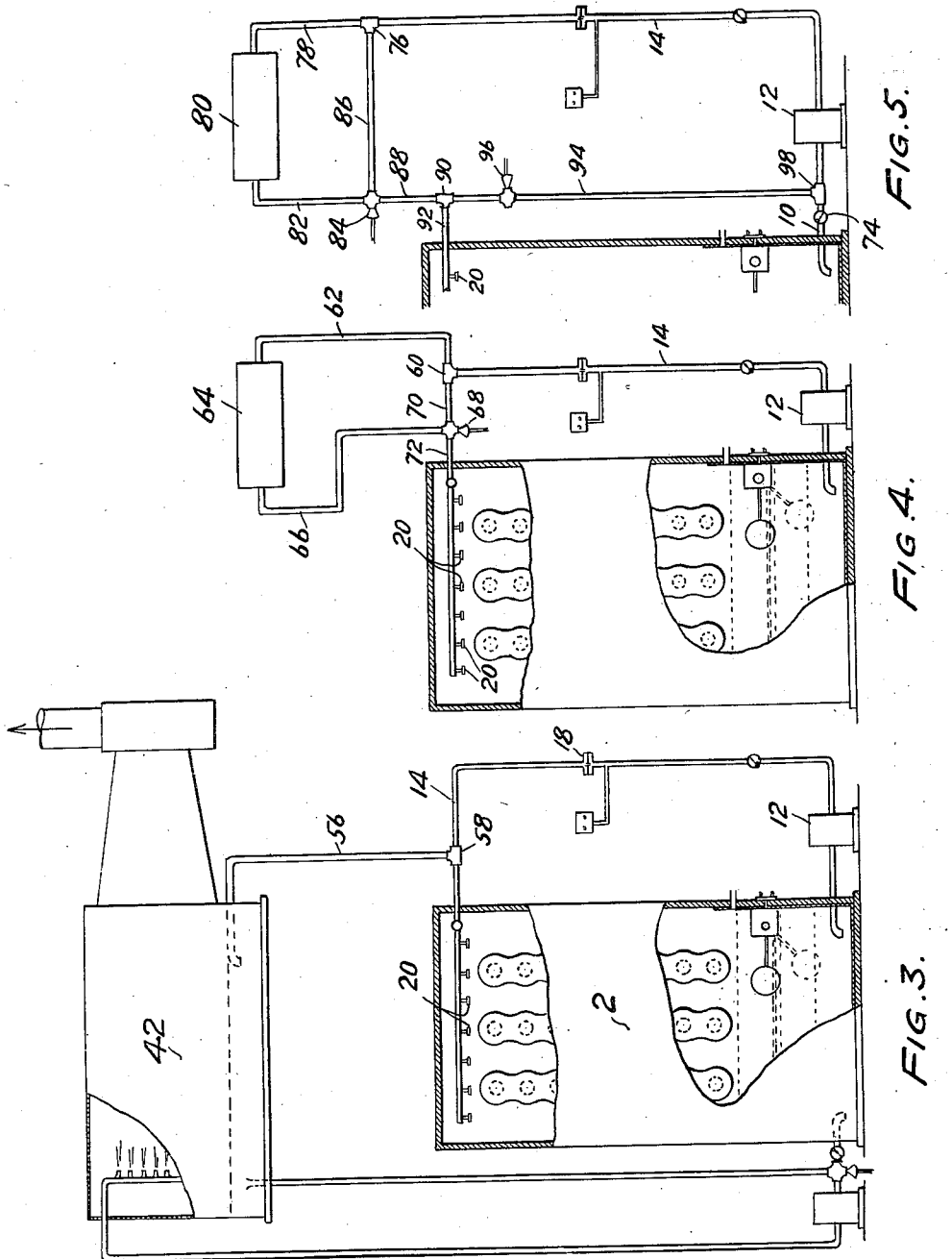
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Filed April 18, 1933

3 Sheets-Sheet 2



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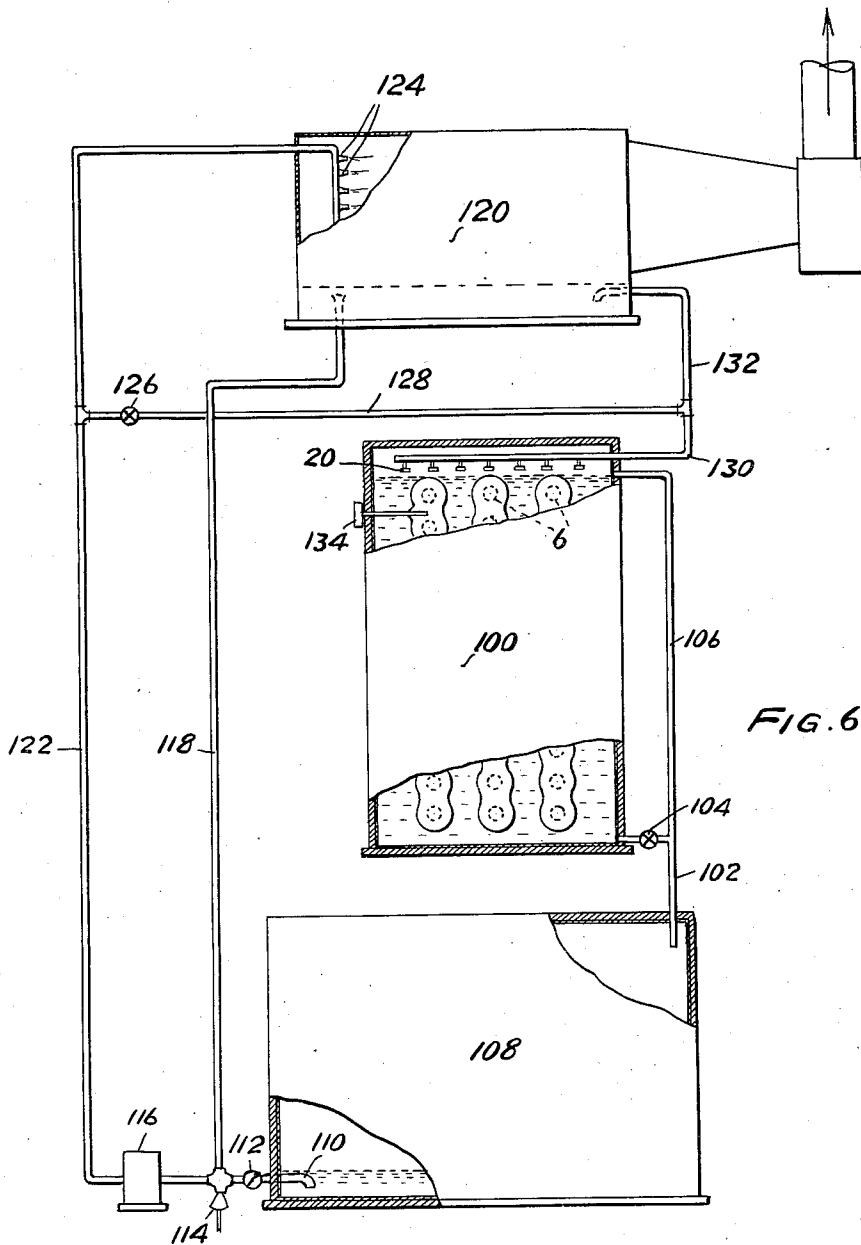
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Filed April 18, 1933

3 Sheets-Sheet 3



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2,056,970

COOLING SYSTEM

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Application April 18, 1933, Serial No. 666,668

11 Claims. (Cl. 62-141)

This invention relates to a cooling system and more particularly to an arrangement of such system whereby an economy of size and capacity of apparatus is effected.

5 In refrigerating systems comprising evaporators, compressors and condensers, it is the usual practice to design the equipment to meet the peak demand with the result that the system is usually operated at much less than full load. 10 This, for example, is particularly true in systems designed for cooling of air in theatres, office buildings, or the like, which are in use only a relatively small part of an entire day and seldom at peak capacity.

15 As a result of this usual type of design there results a decrease in operating efficiency and since the apparatus must be sufficient to meet the simultaneous peaks, the first cost is therefore high. Where refrigeration is applied to air conditioning systems it is customary to design 20 the refrigerating apparatus to meet the simultaneous peaks due to maximum outside temperature and humidity, maximum heat losses from the conditioned space, and maximum heat due to the sensible and latent heat given off by the occupants of the conditioned space. This combined peak is greatly in excess of the average load with the consequent losses just mentioned.

25 Tanks to store cold water during off peak periods have at times been used to carry the high loads of the peak but their use has not proved generally satisfactory due to the excessive size of the containers which are required. More recently evaporator coils have been immersed in a tank of water and ice allowed to accumulate 30 during the off peak periods to be used to take care of the peaks. Due to the high latent heat of fusion of ice this resulted in the use of smaller tanks and partially solved the problem. It offered, however, the serious objection that at certain rates of flow of water through such a tank it is difficult to bring the water to a temperature close to that of the ice. The exchange 35 of heat from ice to water depends upon the velocity of the water and in a system as above described even though the water is caused to pass through a long channel to contact with the ice the velocity is very low as the channels must be wide enough so that the ice will not freeze them shut when there is a maximum amount of ice on 40 the coils.

Furthermore, when the ice is melting from the coils the water channels widen with a consequent decrease in velocity and in heat transmission. 45 There is an additional disadvantage in that the

ice formation is not open to inspection and that if a refrigerating system fully automatic in operation is used it is difficult to use a control to shut off the machine when a satisfactory amount of ice is formed. 5

It is the broad object of this invention to provide a system for the storage, control, and melting of the ice which will eliminate or substantially reduce the aforementioned objections. Specifically the invention is concerned with the formation of ice on cooling surfaces over extended periods followed by the melting of the ice by water flowing in a film thereover during the hours of use of the cooling effect so that the supply of cooling effect can vary to meet the actual demand whereas the evaporation of the refrigerant proceeds at a substantially constant rate, except as indirectly effected by the thickness of ice formation on the coils. Additionally in the preferred embodiment of the invention the ice is 10 formed on surfaces cooled below the freezing point of water by the flow over such surfaces of a film of water during the off peak periods. With this arrangement the film flow serves at certain periods for the building up of ice and at other 15 periods for its melting to cool the flowing water.

Subsidiary objects of the invention particularly relating to the control of ice building upon refrigerating surfaces and other details of construction involving, for example, controls of 20 pumps and the refrigerating apparatus, will be apparent from the following description read in conjunction with the accompanying drawings in which:

Fig. 1 is a diagrammatic view of a preferred 25 embodiment of the invention, certain of the parts being shown broken away to show interior constructions;

Fig. 2 is a vertical section through the ice containing chamber; 30

Fig. 3 is a diagrammatic view similar to Fig. 1 but showing an alternative arrangement; 35

Figs. 4 and 5 are likewise similar diagrammatic showings of further modifications; and 40

Fig. 6 is a diagrammatic view showing a modification in which the ice is formed in a different fashion although cooling by the ice is effected in accordance with the invention. 45

Referring first to Figs. 1 and 2 there is illustrated at 2 a heat insulated chamber in the base 50 of which there is provided an open tank 4 for the reception of water. As will be obvious hereafter this tank 4 need not necessarily form a part of the chamber 2 but may be arranged to receive water therefrom either by gravity flow or by the 55

use of an auxiliary pump. Located in the upper portion of the chamber 2 are refrigerating coils 6 in which refrigerant is evaporated in the usual fashion to reduce their temperature below the freezing point of the liquid used in the system which will be described herein as water although it will be understood that other liquids such as aqueous solutions, or even non-aqueous liquids, may be used in accordance with the invention for various purposes. The coils 6 form a part of a conventional refrigerating system including a suitable compressor and condenser. It is on the outside of these coils that ice is built up as indicated at 8 preferably in the fashion indicated in the drawings so as to completely imbed the coils in off peak periods as will be obvious hereafter.

A conduit 10 joins the lower part of the tank 4 with the inlet of a water pump 12, the outlet of which is connected to a conduit 14 in which there is interposed an upwardly opening check valve 16 and a restricted orifice 18. Water is delivered by the conduit to a system of spray nozzles indicated at 20 located above the coils 6 and designed to spray water thereon so that it will flow over the coils in heat exchange relationship therewith either by direct contact with the metallic coils or, as partial freezing takes place, over the ice built up thereon with the result that either more ice is formed or, if the water is warm, a certain amount is melted.

A float 22 located in the tank 4 controls a switch 24 which is arranged to open the circuit energizing the motor 12 when the float drops to a certain position corresponding to the minimum height of liquid in the tank. An overflow 30 is arranged to prevent the liquid from rising too high, as in a dehumidifying system the moisture taken from the atmosphere is continually added to the total water in the system.

On the pump side of the orifice 18 there communicates with the conduit 14 a tube 26 connected to a pressure controlled switch 28 which controls the circuit of the refrigerant compressor in the refrigerating system. This arrangement is such that as long as the pump 12 is operating, by reason of the restricted orifice there will be a pressure on the pump side thereof sufficient to maintain the switch 28 closed and the compressor running. When the flow through 14 ceases this pressure is no longer maintained and the switch 28 is automatically opened stopping the compressor.

This arrangement provides safety for the compressor since it insures that the compressor will not operate when there is no water passing over the coils from which heat may be absorbed.

Water is drawn from the tank 4 through a pipe 32 and an outwardly opening check valve 33 into one port of a three-way valve 34. This valve is such that, depending upon its operation, the water will be received from the pipe 32 or alternatively from the pipe 40 and delivered through the connection 36 to a pump 38 by which it will be delivered in the form of a spray into a chamber 42 through the pipe 44 and spray nozzles 46. The spray produced in the chamber 42 is traversed by air flowing to a blower 48 and discharged thereby through a conduit 50 to the point of use. While there is illustrated specifically in this modification an air conditioning apparatus it will be obvious that the invention is applicable to cooling systems in general in which cooled water or other liquid is passed in heat exchange relationship with a warmer medium to abstract heat therefrom. It happens that the system is particularly

useful in connection with air conditioning apparatus in view of the fact that this involves the imposition of various loads and consequently utilizes the advantageous features of the system.

The three-way valve 34 which may be of conventional type actuated by fluid, the flow of which under pressure is controlled by a thermostat or other sensitive instrument, is arranged to be operated by a thermostat located, for example, either in the water accumulating from the spray in chamber 42 or the air after passing through the water spray. Its control is such that if the temperature at the thermostat is high it will provide communication between 32 and 36 shutting off the line 40. On the other hand, if the temperature at the thermostat is low it will shut off the connection 32 and open communication between 40 and 36 with the result that a circulation of liquid will be maintained without cooling. In general, it is desirable that the three-way valve be capable of assuming intermediate positions so that the flow may be apportioned, part of the liquid passing to the pump 38 being received from 32 and the remainder from 40, the proportions depending upon the demand indicated by the thermostat.

A pipe 52 whose open end within the chamber 42 is located at a level higher than the open end of the pipe 40 provides for the flow of liquid from chamber 42 to nozzles 54 located adjacent the nozzles 20 and also arranged to discharge water upon the coil 6.

The apparatus so far described will incorporate not only the elements already mentioned but also manually operated valves and switches desirable for use in shutting down and re-starting. The arrangement of these, however, depends on the convenience of the operator of the installation and are not described since they form no essential part of the automatic system. The operation of the system may be described as follows:

Assuming a peak load, in which case the valve 34 would provide communication between 32 and 36 and close off 40, liquid would be drawn from the tank 4 and sprayed into 42, thus cooling the air, and would then return through the pipe 52 and nozzles 54 over the coils 6 by which it would be cooled whence it would drop again into the tank 4. If the conditions were such that dehumidifying was taking place there would be no necessity for adding further water. In fact, eventually the amount might increase so that overflow through 30 would take place. If evaporation occurred water would be added to the tank 4 either automatically or at intervals by manual operation. At the same time during such peak loads further cooling would be effected by the flow of water caused by the pump 12 with the resulting additional spray through the nozzles 20. By reason of the flow through the orifice 18 the pressure in 28 would be maintained and the refrigerating apparatus kept operating. The float 22 would of course be raised with the result that the pump 12 would continue to produce such flow.

If now a decreased demand on the apparatus was made, evidenced by a lowered temperature of the water collecting in the bottom of chamber 42, the valve 34 would be operated to decrease or even cut off the flow through 32 and permit flow through 40. In such case a recirculation of the spray from the nozzles 46 would occur without addition of cool water through 32 until the circulated water temperature would rise. Under very low demands such as might occur, for ex-

ample, in off hours, or if the external temperature was low so that the water spray would be used for air washing alone, no flow through 32 would take place. At the same time, by reason of the free flow through 40 the level in the bottom of 42 would drop so that no water would pass through the nozzles 54. Under these conditions the pump 12 would continue to operate to circulate cold water from the tank 4 through the nozzles 20 and over the refrigerating coils 6. As the temperature would continue to fall ice would build up upon the coils. As the formation of ice continued the amount of liquid in the circulating system would decrease and consequently the liquid level in the tank 4 would drop. Eventually it would drop to such extent that the float 22 would open the switch 24 stopping the pump 12 and, by reason of the occasional drop of pressure at 28, also the refrigerant compressor. The function of the float 22 will now be obvious. It is so arranged that it will interrupt further circulation of water when the liquid level in the tank drops to an extent corresponding to the maximum desired coating of ice upon the coils 6. In this way the thickness of the ice coating is definitely limited and there is definite insurance against the closing off of the passages between the coils by a solid cake of ice.

If the demand on the system is then increased, the valve 34 will again open the passage 32 and warm water will be sprayed from the nozzles 54 upon the ice. This water flowing in a film over the ice will gradually melt the same acquiring a temperature approximately that of the freezing point of the liquid. In this fashion the amount of liquid in the tank 4 again increases with a consequent rise of the float 22 closing the switch 24 and restarting pump 12 and the refrigerant compressor.

In view of the accumulation of the ice upon the coil in off peak periods it will be obvious that the refrigerating apparatus need only be designed for a little more than the average twenty-four hour demand rather than for the large peaks of short duration as might occur, for example, at mid-day in a restaurant or the like. By reason of the high latent heat of fusion of water there will in general, except when long extended peaks occur, be ice upon the coils 6. This by its gradual fusion reinforces the refrigerating action of the coils 6 during peak periods. There is thus, in general, an equilibrium condition reached at any time either resulting in a slow building up or slow melting down of the ice on the coils 6. The refrigerating apparatus of small size may thus run at its maximum efficiency over extended periods and take care not only of peak loads but also of periods of low or no demand during which it will prepare the apparatus for peaks.

Referring now to Fig. 3 there is illustrated therein a modified arrangement resembling rather closely that of Fig. 1. In this case all the parts are the same with the exception of the return to the chamber 2 from the chamber 42 wherein heat exchange takes place. The conduit 56 in this case is connected at 58 to the conduit 14 so that the returned liquid is sprayed through the nozzles 20 as well as the liquid passing from the pump 12. In this case it is only necessary that the head in pipe 56 be sufficient to insure that the flow will be downwardly and through the nozzles 20 rather than in a reverse direction. The orifice 18 of course assures a relatively low pressure at 58 due to the pump 12, so that the desired equilibrium condition is readily attained. The operation is

in all respects substantially identical with that described above with the exception of the specific path of the returned liquid.

In Fig. 4 there is illustrated an arrangement in which the conduit 14 communicates with one branch of a T 60. Another branch of this T communicates with a pipe 62 leading to a heat exchange device indicated conventionally at 64 which may, as before, be an air conditioning arrangement, but may be of any type wherein cooling is to be effected. The liquid from the exchanger 64 returns through pipe 66 to a three-way valve 68, one opening of which has communication through connection 70 with the third branch of the T 60. The other port of the three-way valve communicates through 72 with the nozzles 20.

In this arrangement the valve 68 may be thermostatically controlled, in this case so as to cause a flow through 14, 62, 64, 66 and 72 during peak loads and through 14, 60, 70 and 72 during periods of no demand, the flow through the heat exchanger at the latter time being completely interrupted by closure of the outlet of the conduit 66. For intermediate demands, the flow is apportioned by intermediate conditions of the valve 68. In this apparatus the pump 12 functions not only to provide the recirculation in the refrigerating chamber but also to supply the flow to the heat exchanger. The operation of building up and melting down the ice is substantially that heretofore described.

Fig. 5 represents a further development along the lines of Fig. 4 but embodying a recirculation through the heat exchanger in addition to that through the refrigerating apparatus. In this case the connection 10 between the tank 4 and the pump 12 contains an outwardly opening check valve 74. The conduit 14 connects with one branch of a T 76. Another branch of this T communicates through 78 with the heat exchanger 80 from which discharge takes place through 82 to one branch of a three-way valve 84. Another branch of this valve is connected by 86 to the third branch of the T 76. The third branch of the three-way valve 84 connects through 88 with one branch of the T 90, a second branch of which delivers to the nozzles 20 through pipe 92. The third branch of the T 90 communicates with a T 98 connected in the line 10 between the check valve 74 and the pump 12 through a pipe 94 in which is interposed a thermostatically controlled valve 96. The valve 84 is controlled in the same fashion as the valve 68 of Fig. 4 and corresponds thereto, valves 84 and 96 apportioning the flow by their partial closures of the respective conduits. The valve 96 is then thermostatically controlled by the temperature in the space to be cooled or by a thermostat, say in the pipe 78, with the result that it will permit a circulated flow of partially warmed water so that the water entering the pump is made up of cooled water from the tank 4 as well as a certain amount of this partially warmed water. When heat transfer is not required in 80, valve 84 stops circulation through the heat exchanger 80 and valve 96 is closed so that the building up of ice on the coils takes place until the operation is automatically stopped when sufficient has been built up by the fall of liquid level in the tank 4.

In Fig. 6 there is illustrated another embodiment of the invention in which, however, the building up of ice upon the coils 6 does not take place entirely by the flow of a film thereover. In this modification the coils 6 are immersed in

a tank 100. At the bottom of this tank communication is furnished through 102 to a tank 108, the passage being controlled in the present instance by a hand operated valve 104 which, as will be pointed out later, may be automatic. An overflow 106 extends from the upper end of tank 100 and connects with 102.

At the bottom of the tank 108 an outlet pipe 110 communicates through an outwardly opening check valve 112 with one branch of a thermostatically controlled three-way valve 114 corresponding to the valve 34 of the modification of Fig. 1. Another branch of this valve communicates with a pump 116 which delivers water to the heat exchanger 120 through a pipe 122 connected with nozzles 124. A bypass connection 128 in which is interposed a shut-off valve 126 connects 122 with the pipe 130 which delivers water to the nozzles 20. A pipe 132 connects the chamber 120 with the pipe 130 being equivalent to the pipe 56 of Fig. 3. This pipe 132 opens in the chamber 120 above the level of the pipe 118 which is connected to the third branch of the valve 114.

A thermostat 134 extends through the side wall of the chamber 100 in such position that ice forming on the coils 6 will surround it. It is adjusted so as to interrupt the operation of the refrigerating mechanism providing refrigerant for the coils 6. In this manner the thickness of the ice obtained is limited.

When the apparatus of Fig. 6 is in its idle condition the chamber 100 contains water so that the coils 6 therein are submerged, the valve 104 at this time being closed. The refrigerating apparatus is then operated to bring the coils 6 below the freezing point whereupon ice begins to build up on them until the operation is interrupted by the thermostat 134 which is adjusted so as to stop the refrigerant compressor when it is covered to a predetermined extent by the ice which in its interior will have a temperature below the freezing point. When this condition is attained the valve 104 may be manually opened although it may alternatively be automatically opened also by the operation of thermostat. The remaining liquid in 100 is thus discharged into the chamber 108.

When cooling in 120 is desired the valve 114 will open 118 or 110, or both, as the conditions may warrant and valve 126 may be closed or partly opened so as to apportion the flow and obtain the desired cooling action by the flow of the liquid in the form of a film over the ice within the chamber 100. At the same time the refrigerating unit is put into operation so that a double cooling effect is obtained. It will be seen that the apparatus of Fig. 6 lends itself to the production of ice coatings in the same fashion as those previously described. Its advantage lies in the fact that the circulating pump need not be used during the ice formation, for example, overnight, although ice may be formed during off peak periods at certain times by the flow of liquid over the pipes 6 as heretofore described.

It will be seen that the various arrangements indicated above provide a sufficiently rapid circulation of water to obtain an excellent heat transfer so that the water supply either in the tank 4 of the first modifications or the tank 108 of the modification of Fig. 6 may be maintained very close to the temperature of the ice. This is essential in air conditioning systems where low dewpoints are required.

While more power is required to produce a

given refrigerating effect at 32° than at higher temperatures, and the present system may thus require more power per ton of refrigerating effect this is more than offset by the great decrease in size of the apparatus and the lower cost of electrical energy for the supply of smaller peaks and use over longer periods.

It will be noted that the invention embodied in this application is applicable to the system described and claimed in my application, Serial No. 658,370, filed February 24, 1933.

It will be clear that various changes may be made in the embodiments of the invention without departing from the scope thereof as defined in the following claims.

What I claim and desire to protect by Letters Patent is:

1. In combination, means for holding a supply of liquid, means providing a surface cooled below the freezing point of the liquid, means for producing a flow of liquid from the supply in heat interchange with said surface in the form of a film, and back to the supply, whereby there is built up on said surface a coating of frozen liquid over which the liquid film flows, and means for interrupting said flow when the liquid in the supply decreases below a predetermined amount, whereby the thickness of coating is limited.

2. In combination, means for holding a supply of liquid, means providing a surface cooled below the freezing point of the liquid, means for producing a flow of liquid from the supply in heat interchange with said surface in the form of a film, and back to the supply, whereby there is built up on said surface a coating of frozen liquid over which the liquid film flows, means for interrupting said flow when the liquid in the supply decreases below a predetermined amount, whereby the thickness of coating is limited, and means for restarting said flow when the liquid in the supply again increases.

3. In combination, means providing a surface cooled below the freezing point of a liquid, means for recirculating the liquid in the form of a film in heat interchange with said surface whereby there is built up on said surface a coating of frozen liquid over which the liquid film flows, means for interrupting said recirculation when the thickness of the coating attains a predetermined amount, and means for interrupting at the same time further cooling of said surface.

4. In combination, means providing a surface cooled below the freezing point of a liquid, means for recirculating the liquid in the form of a film in heat interchange with said surface whereby there is built up on said surface a coating of frozen liquid over which the liquid film flows, means for interrupting said recirculation when the thickness of the coating attains a predetermined amount, means for interrupting at the same time further cooling of said surface, and means for simultaneously resuming the recirculation and further cooling of the surface when the thickness of the coating decreases.

5. In combination, a circulatory system including means providing a surface cooled below the freezing point of a liquid and means for recirculating the liquid in the form of a film in heat interchange with said surface whereby there is built up on said surface a coating of frozen liquid over which the liquid film flows, and means for abstracting cooled liquid from said system, passing it in heat interchange with another warmer medium, and returning it to the system.

6. In combination, a circulatory system including means providing a surface cooled below the freezing point of a liquid and means for recirculating the liquid in the form of a film in heat interchange with said surface whereby there is built up on said surface a coating of frozen liquid over which the liquid film flows, a second circulatory system including means for producing a flow of liquid and means whereby the liquid is brought into heat interchange with another warmer medium, and means whereby cooled liquid may pass from the first system to the second and warmer liquid may return from the second to the first.
7. In combination, a circulatory system including means providing a surface cooled below the freezing point of a liquid and means for recirculating the liquid in the form of a film in heat interchange with said surface whereby there is built up on said surface a coating of frozen liquid over which the liquid film flows, a second circulatory system including means for producing a flow of liquid and means whereby the liquid is brought into heat interchange with another warmer medium, and automatically controlled means whereby cooled liquid may pass from the first system to the second and warmer liquid may return from the second to the first.
8. In combination in a water cooling device, a conduit, a pump for producing a flow of water through the conduit, fixed flow restricting means in the conduit, and a pressure controlled device communicating with the conduit on the pump

side of the flow restricting means whereby the pressure on said pressure-controlled device depends upon the rate of flow of water through the conduit.

9. In combination, means providing a series of surfaces cooled below the freezing point of a liquid, means for recirculating the liquid in the form of a film in heat interchange with and between said surfaces whereby there are built up on said surfaces spaced coatings of frozen liquid between and over which the liquid flows in the form of a film, and means whereby the thicknesses of the coatings are limited to avoid closing of the passages between the coatings.

10. In combination, means providing a series of surfaces cooled below the freezing point of a liquid, means for contacting liquid with said surfaces whereby there are built up on said surfaces spaced coatings of frozen liquid, and for recirculating liquid in the form of a film between and over said coatings, and means for limiting the thicknesses of the coatings to avoid closing of the passages between the coatings.

11. In combination, means providing a series of surfaces cooled below the freezing point of a liquid, means for contacting liquid with said surfaces whereby there are built up on said surfaces spaced coatings of frozen liquid, and means for limiting the thicknesses of the coatings to avoid closing of the passages between the coatings, whereby the passages are open for the passage of fluid between and over said coatings.

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