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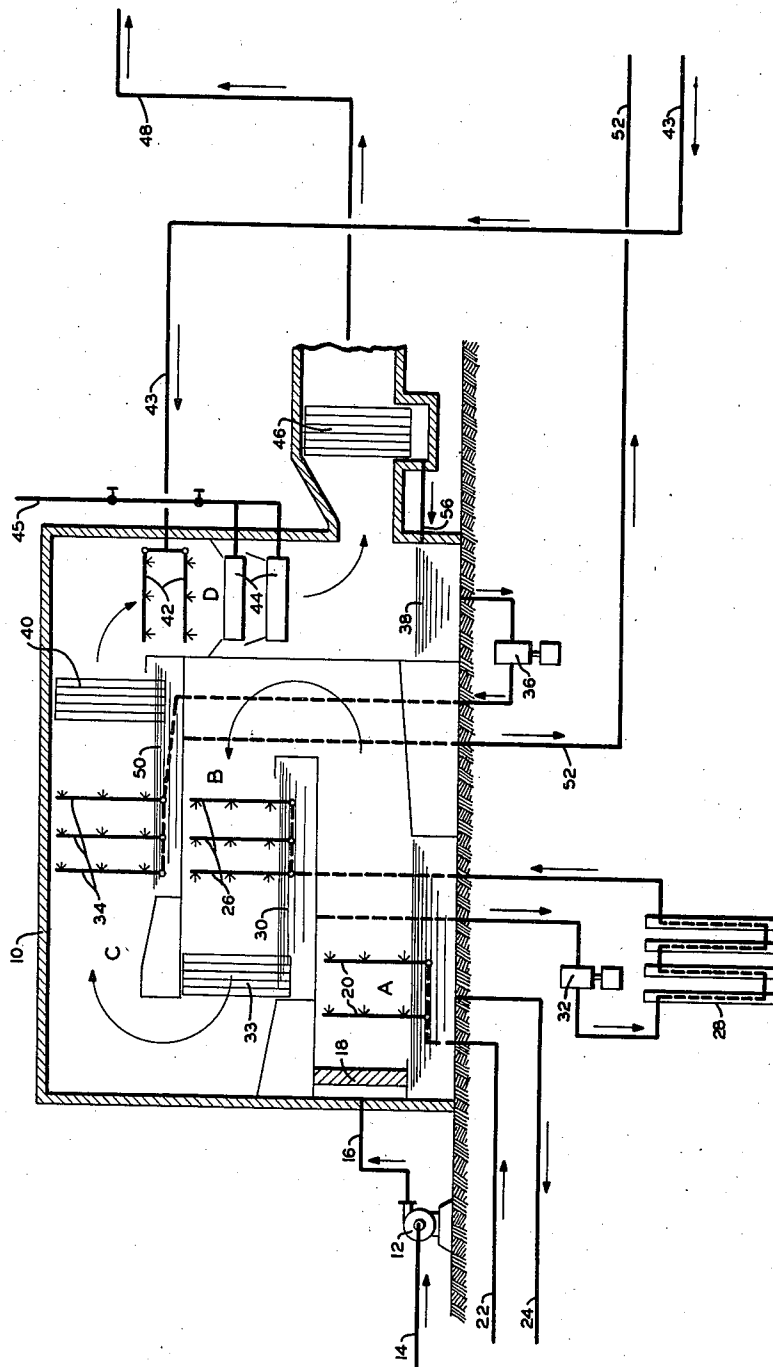
N. H. HILLER, JR
REFRIGERATING PROCESS

2,286,618

Filed Nov. 3, 1939

3 Sheets-Sheet 1

FIG. 1



NICOLAI H. HILLER JR.
INVENTOR

BY *R. J. Dearborn*
Daniel Stuyker
ATTORNEYS

June 16, 1942.

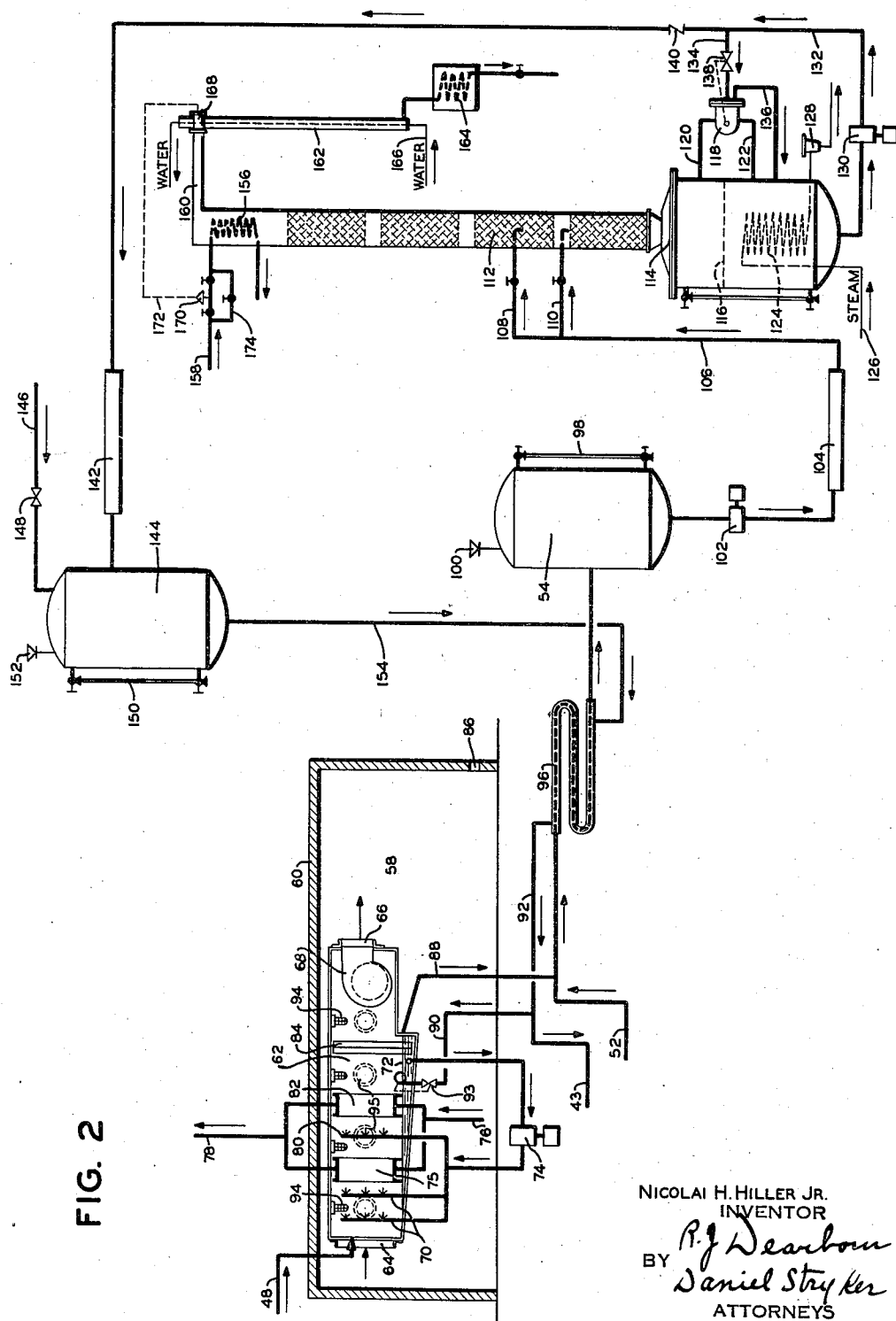
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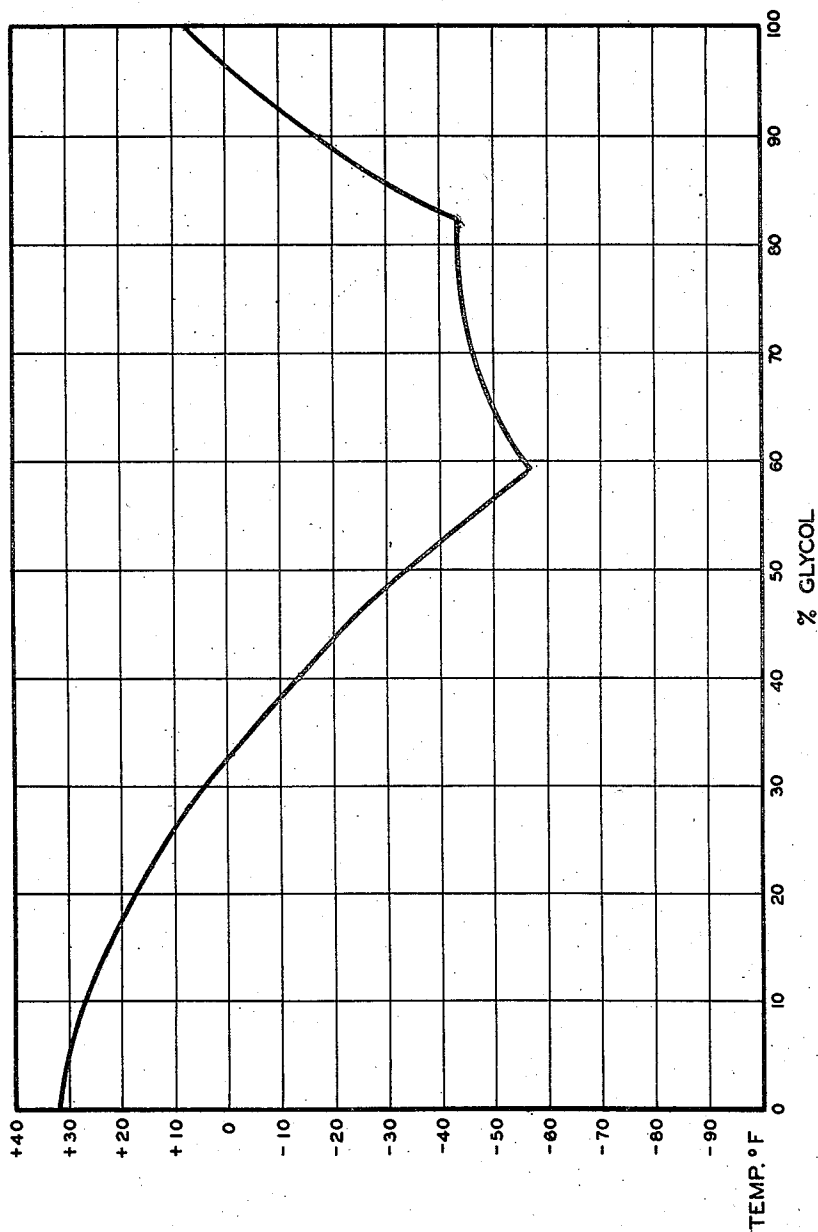


FIG. 3

NICOLAI H. HILLER JR.
INVENTOR

BY

R. J. Dearborn
Daniel Stryker
ATTORNEYS

UNITED STATES PATENT OFFICE

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REFRIGERATING PROCESS

Nicolai H. Hiller, Jr., Bronxville, N. Y., assignor,
by mesne assignments, to The Texas Company,
a corporation of Delaware

Application November 3, 1939, Serial No. 302,660

1 Claim. (Cl. 183—120)

This invention relates to refrigerating systems and more particularly to a method and apparatus for continuously cooling and dehumidifying a gas or air. The principal object of the invention is to produce continuously a cold, neutral gas or air which is clean and which has a minimum moisture content. Another object is to provide chemical means for continuously defrosting the equipment used in cooling the gas, and a still further object is to provide means for regenerating or concentrating the chemical used in defrosting so as to eliminate waste thereof.

This is a continuation in part of my co-pending application Serial No. 160,942 filed August 26, 1937.

Several methods of defrosting cooling equipment have been used in the past but most of these are unsatisfactory for various reasons. When using hot ammonia vapor, such procedure requires the use of two sets of cooling coils or other equipment so that one set can remain in use while the other is being defrosted in order to produce a continuous supply of cold gas or air. This involves a double investment for cooling equipment and also presents a problem of disposing of the melted frost in an atmosphere likely to be below freezing, without affecting the operation of the companion cooling unit.

It has also been proposed to defrost the equipment by heat supplied, for instance, by electric heating elements disposed in the stream of gas to be cooled. It is thus necessary to cut off the circulation of brine or other cooling medium and to defrost the unit by means of the warmed gas or air blowing against the frosted elements. This requires considerable time and consequently causes an abrupt rise in temperature of the space being cooled, or else the investment necessary for double or twin cooling units, as was mentioned in regard to the use of hot ammonia vapor. Other methods of supplying heat for defrosting, such as the use of steam coils, also involve additional expensive equipment and many operating difficulties.

In accordance with the present invention, the cooling coils and equipment are prevented from becoming frosted by means of a spray of a hygroscopic aqueous solution of a neutral inherently hygroscopic compound, said solution to be of a predetermined concentration. Suitable hygroscopic compounds include ethylene glycol, diethylene glycol, propylene glycol or diethylene glycol monoethyl ether having a low freezing point. This solution which will be hereinafter

termed the defrosting solution is regenerated or concentrated to permit continuous use.

In carrying out the invention in connection with the cooling of a room or space, such as may be used for observing the reaction of various substances to low temperatures or in treating processes such as the solvent dewaxing of hydrocarbon oils, the room is refrigerated by the provision of internal circulation of air over suitable cooling or chilling units, the cooled air being returned to the room and a portion of the foul air being displaced continuously by fresh air, chilled and dehumidified and introduced into the main chilling unit. The cooling coils and other equipment are continuously submitted to a cold spray of a defrosting solution such, for example, as a mixture of water and ethylene glycol in proper proportions serving to prevent the formation of frost on the equipment and also to absorb moisture from the air passing therethrough. In the course of use the defrosting solution, because of its hygroscopic character, absorbs moisture and this continues until the spray solution has become so dilute that it is no longer hygroscopic at the working temperature. Such a solution is denoted as being spent. A spray solution which contains an undesirably high proportion of water but which still displays some hygroscopicity will be denoted as being partly spent. Although usually the defrosting solution after having been sprayed once is partly spent, such conditions may obtain as to cause the defrosting solution to be completely spent. In order to maintain the defrosting solution at its optimum efficiency it is desirable that the partly spent solution be continuously regenerated by removing therefrom sufficient water to maintain the solution within a particular range of concentrations. This may be effected by subjecting the partly spent defrosting solution in whole or in part to distillation or to any other suitable operation for the removal of water. By this system a continuous supply of cold, dehumidified air or other gas is thus made available either for cooling a room or for other purposes. Furthermore, since the defrosting solution is continuously regenerated without appreciable loss of the contained hygroscopic compound the process is relatively inexpensive in operation.

The method of regenerating or concentrating the solution is an important feature of the invention. In accordance with the invention a system of control is provided so that the used solution can be concentrated between predetermined definite limits, depending upon the temperature

to which it is desired to cool the air, and other requirements.

For a better understanding of the invention, reference may be had to the accompanying drawing in which—

Figure 1 is a somewhat diagrammatic representation of a vertical elevation of a unit for cooling and dehumidifying the make-up air or gas;

Figure 2 is a sectional elevation through a "cold room" and also an elevation and flow diagram of the apparatus for concentrating the defrosting solution; and

Figure 3 is a freezing point curve for an aqueous solution of ethylene glycol.

Fresh air dehumidifier and chiller

As shown in Figure 1, the equipment for dehumidifying and cooling the make-up air, i. e., the fresh air necessary for continuously displacing a predetermined amount of foul air from the room or space to be cooled, is preferably mounted in a box or container 10 the walls of which are suitably heat insulated. A pump or blower 12 draws fresh air at the desired rate through the inlet pipe 14 and exhausts this air through the conduit 16 into the space A which may be termed the first stage of the make-up air cooler. It is to be understood that instead of the blower 12 at the inlet of space A, a suction fan or pump may be located at the outlet of space D to be described hereinafter. A suitable filter 18 is preferably mounted in the path of the air issued from the conduit 16 and serves also to straighten out the currents of air so that they will flow uniformly through the space A. The air passing through space A is washed by means of cooling water sprays 20 which are fed through the conduit 22, the water being withdrawn by means of conduit 24. This cooling water need not be at a particularly low temperature, 60° F. having been found suitable. The cooling water may be supplied from the cooling system of the plant where the apparatus is to be used or it may be supplied from any suitable separate pump, not shown. These sprays will remove approximately 99% of any dust, dirt, lint, absorbable gas or other impurities and the cooled air should then approximate 65° F. and 100% relative humidity.

The cooled air having been washed by the sprays 20 will then enter section B where it will be further cooled by means of the cold water sprays 26. The cold water for the sprays 26 is shown as supplied from a cooler such as a direct expansion ammonia cooler 28, the ammonia temperature being held to approximately 33° F. and the cooling water entering the sprays 26 at from 33° to 37° F. The cooling water collects in the tray 30 and is recirculated by means of the pump 32. Although the water cooler 28 is shown as being arranged externally of the housing 10, it is to be understood that this unit may be mounted entirely within the housing at any convenient location. An "eliminator" 33 at the outlet of section B removes all of the entrained moisture from the air, thus permitting air of approximately 39° F. and 100% relative humidity to enter the section or third stage C. It is to be understood that the "eliminator" may be any suitable device through which the air must pass and which will collect and remove the moisture entrained therein. The moisture content of the air entering space C will have been reduced from approximately 100 grains per pound to 35 grains

per pound, the condensed moisture having been picked up in the A and B sections.

In space C the air passes through sprays 34 of the defrosting solution which for the purpose of this example is a solution containing 60% ethylene glycol and 40% water. Since ethylene glycol has the ability to absorb large quantities of water or water vapor, the incoming air to section C will be reduced in temperature to approximately -15° F. The defrosting solution for the sprays 34 is supplied by means of a suitable pump 36 from a sump tank or reservoir 38 under the ammonia chillers to be described later. An eliminator section 40 at the outlet of the C section removes any entrained partly spent defrosting solution and the chilled air enters the final stage or section D where final chilling brings its temperature down to approximately -30° F. or lower. As the air enters the D section it passes through sprays 42 of defrosting solution supplied from conduit 43 and located at the up-stream side of the direct expansion chilling units 44 receiving a suitable refrigerant such as ammonia through the conduit 45. The continuous wash of defrosting solution over the chilling units 44 maintains the latter in a frost-free condition while at the same time some moisture will be absorbed from the air by the defrosting solution from the sprays 42. The cold air then passes through another eliminator section 46 and then outwardly through a duct 48 to the point of use, which in this case is shown as the main room cooling unit in Figure 2.

The partly spent defrosting solution from section C will collect in the reservoir 50 and will run by gravity through the conduit 52 to the solution tank 54 in the concentrator shown in Figure 2. Liquid collecting below the eliminator 46 will pass through a conduit 56 into the reservoir 38.

Main chilling unit

In Figure 2 the room or space 58 to be cooled is shown as having suitably heat-insulated walls 60 and as containing in its upper portion the main chilling unit indicated generally as 62. This unit which may either be horizontally disposed, as shown, or arranged vertically, comprises a series of chambers connected together and having an inlet opening 64 at one end and an outlet opening 66 in which an exhaust fan 68 is positioned. The fan or blower 68 in drawing air through the unit causes air from the room to enter at 64 together with a predetermined amount of fresh dehumidified and cooled air from the conduit 48 connected to the unit shown in Figure 1. The air from the room, together with the fresh make-up air, first passes through sprays 70 of defrosting solution supplied from a sump or reservoir 72 by means of a suitable pump 74, these sprays being disposed at the upstream side of the direct expansion chilling unit 75, this unit being supplied with a suitable refrigerant such as ammonia through conduit 76 and the ammonia being exhausted through conduit 78. The air then passes through another defrosting solution spray 80 and then through the second ammonia chilling unit 82.

As was brought out in connection with the apparatus disclosed in Figure 1, the defrosting solution spray in passing continuously over the chilling units 75 and 82 prevents the formation of any frost or ice on these units while at the same time the chemical absorbs a considerable amount of moisture from the air. The cold air then passes through an eliminator section 84

which draws off entrained defrosting solution, and the cold dry air is then picked up by the blower 68 and forced outwardly into the room through the opening 66. A predetermined amount of foul air from the room 58 will be removed from the room through a suitable opening 86, and the operation is such that the make-up air supplied through conduit 48 will balance the amount of foul air so withdrawn.

A predetermined amount of the partly spent defrosting solution is continuously withdrawn from the reservoir 72 through the conduit 88, this conduit leading into the previously described conduit 52 from the unit shown in Figure 1. Defrosting solution is supplied to the reservoir 72 from a branch 90 of a conduit 92 to which latter conduit the conduit 43 shown in Figure 1 is connected. A suitable float-controlled valve 93 at the outlet of the branch conduit 90 maintains the level of the defrosting solution at the desired height in the reservoir 72. The various chambers of the unit are shown as provided with electric lights 94 and with sight openings or port holes 95 through which the operation of the unit may be observed.

Defrosting solution concentrator

Aqueous solutions of the inherently hygroscopic compounds, the use of which is contemplated in the practice of this invention, yield curves of the general shape of the eutectic curve such as the example shown in Figure 3 which is a freezing point curve of ethylene glycol water solutions. In general the curve shows that the freezing point of the pure solvent alone is at a higher temperature than a certain mixture of the solvent and water. For instance, as shown in Figure 3, pure ethylene glycol freezes at approximately plus 8° F. whereas a mixture of 60% ethylene glycol and 40% water freezes at approximately minus 56° F. At any temperature above minus 56° F. there is a certain range of ethylene glycol concentration at which a solution will remain in its fluid state. Thus at minus 30° F. any solution ranging from 46 to 86% ethylene glycol will be fluid and any concentrations below 46% or over 86% will be slushy or solid at this temperature. In order to maintain a frost free chilling coil at minus 30° F. it would be necessary to hold the defrosting solution in the range just given by means of a suitable concentrator or regenerator which would remove the excess water absorbed in the chilling unit and maintain the proper concentration.

To this end a suitable method and an apparatus have been devised which will automatically maintain a proper concentration as demanded by the process, and at the same time eliminate entirely the loss of defrosting material such as ethylene glycol which would normally accompany concentration in an open receptacle. The apparatus consists of a refluxed fractionation column and a reboiler, the temperatures of both of which are maintained at a predetermined level by means of suitable control, preferably automatic. Because of the small amount of cooling required to hold the temperature at the top of the tower at the boiling point of water, a closed reflux cooling coil is employed, the amount of cooling fluid being controlled by a temperature controller in the vapor line. Since the concentration of the ethylene glycol in the reboiler at the bottom of the tower is determined by the temperature therein, a second means of control is incorporated in the reboiler structure.

Such second control means may suitably comprise a valve in the steam line 126, controlled by a thermostatic actuating device having its heat-responsive element in contact with the liquid in the tank 114.

The partly spent defrosting solution returning from the fresh air chiller shown in Figure 1 through conduit 52 and from the main chilling unit 62 through conduit 88 passes through a heat exchanger 96 and thence to the partly spent solution tank 54, previously mentioned, this tank being equipped with a suitable liquid level gauge 98 and safety valve 100. The partly spent defrosting solution is drawn from the reservoir 54 by means of a suitable pump 102 and passes through a heater 104 and thence through a conduit 106, having valve-controlled branches 108 and 110, to an extraction tower 112 which may be of the bubble tray or rock type. The tower 112 is mounted on top of a heating tank 114, the solution passing downwardly through the tower and into the tank 114 where it is maintained substantially at the level 116 by means of a float control 118, the latter being connected to the heating tank by means of conduits 120 and 122. A heating coil 124 in the tank 114 is supplied preferably by steam entering at 126, the condensate leaving the coil through trap 128. The float control 118 is arranged so that when there is insufficient solution in the heating tank 114 to reach the level 116, the solution which is continuously withdrawn from the tank by means of the pump 130 is by-passed from conduit 132 through the connection 134 and back to the tank through conduit 136. When the liquid reaches the level 116, the float control 118 closes a valve 138 in the connection 134, and the concentrated solution is then forced by pump 130 past a check valve 140 and through a suitable cooler 142 into a defrosting solution storage tank 144.

The defrosting solution in the storage tank 144 is maintained under a positive pressure by means of compressed air supplied from a conduit 146 containing a suitable reducing valve 148. The tank 144 is provided with a liquid level gauge 150 and a safety valve 152. The defrosting solution passes from the tank 144 through conduit 154 and then through the previously mentioned heat exchanger 96 to the conduit 92 from which, as has been previously described, part passes through conduit 90 into the reservoir 72 while the remaining portion passes through conduit 43 to the sprays 42 shown in Figure 1.

Referring again to the tower 112, a cooling coil 156 serves to control the temperature in the upper end of the tower, this coil being supplied preferably by cold water from a conduit 158. By means of the cooling coil 156 the temperature at the top of the tower is maintained substantially at the boiling point of water. The water vapors leave the upper end of the tower 112 through duct 160 and then pass downwardly through a cooler 162 from which they are led to a suitable condenser 164, the cold water for which is supplied from a conduit 166. A thermostat 168 in the duct 160 actuates a valve 170 in the cold water line 158, as is shown diagrammatically by dotted line 172, for controlling the temperature in the upper portion of the tower 112. A valved by-pass 172 is preferably connected around the valve 170 so that the cold water entering the cooling coil 156 may be manually controlled if desired. It is to be understood that the tower 112 may be of the bubble tray type or it may be

in the form of a rock tower packed with suitable material such as Raschig rings.

It is believed that the operation will be clear from the foregoing description. However, in summarizing, the main cooling unit 62 continuously draws in air from the room 58, cooling this air and forcing it back into the room through the outlet 66. A supply of fresh air which has been partially cooled and dehumidified by means of the apparatus shown in Figure 1 also enters the main cooling unit 62 through conduit 48 in order to make up for the portion of foul air which is continuously discharged at 86. The defrosting solution which is supplied to the main cooling unit 62 and also to the fresh air cooler and dehumidifier is withdrawn and part of the water removed by means of the heating tank 114 and the tower 112 and is then recirculated without substantial loss.

Although certain more or less definite temperatures and volumes have been mentioned, it is to be understood that this is a specific adaptation of the invention and that these figures may vary greatly from those given without departing from the scope of the invention.

The invention has been described in one adaptation as applied to the cooling of air for a room which may be used for testing or other purposes, but it is to be understood that the air which is cooled and dehumidified in accordance with the invention may be used for other purposes such, for instance, as the refrigeration or freezing of foods.

Obviously many modifications and variations

of the invention as before set forth may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated by the appended claim.

I claim:

A cyclic process for cooling and dehumidifying a gas adapted to produce a cold dehumidified gas for direct contact frost-free refrigeration at temperatures at least as low as -30° F., which comprises contacting said gas with a spray of aqueous ethylene glycol solution, and with cooling surfaces maintained at a temperature below -30° F. and covered with a film of said aqueous ethylene glycol solution resulting from the action of said spray, causing the aqueous ethylene glycol solution flowing from said cooling surfaces to be recycled to said spray, maintaining the concentration of said aqueous ethylene glycol solution at said spray within the range of 46% to 86% by volume, and sufficiently above 46% and below 86% concentration to maintain said solution as a sprayable liquid free from a solid phase, by subjecting to rectification at least a portion of the recycle aqueous ethylene glycol solution flowing from said cooling surfaces, while controlling the temperature of the vapor removed by said rectifying operation to cause substantially complete reflux of said ethylene glycol, and recycling to said spray the resulting rectification residue of reduced water content.

NICOLAI H. HILLER, JR.