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Kuehner

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[54] **REFRIGERATION SYSTEM UTILIZING ICE SLURRIES**

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[73] Assignee: **Borg-Warner Corporation**, Chicago, Ill.

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[52] **U.S. Cl.**........................ **62/114**, 62/333, 62/502, 165/104

[51] **Int. Cl.**.. **F25b 23/00**

[58] **Field of Search**............. 62/114, 333, 334, 502; 165/104

[56] **References Cited**

UNITED STATES PATENTS

3,247,678	4/1966	Mohlman	62/199
3,564,727	2/1971	Fraser	62/332 X
3,603,379	9/1971	Leonard, Jr.	62/333 X

FOREIGN PATENTS OR APPLICATIONS

1,011,104	1965	Great Britain	165/104

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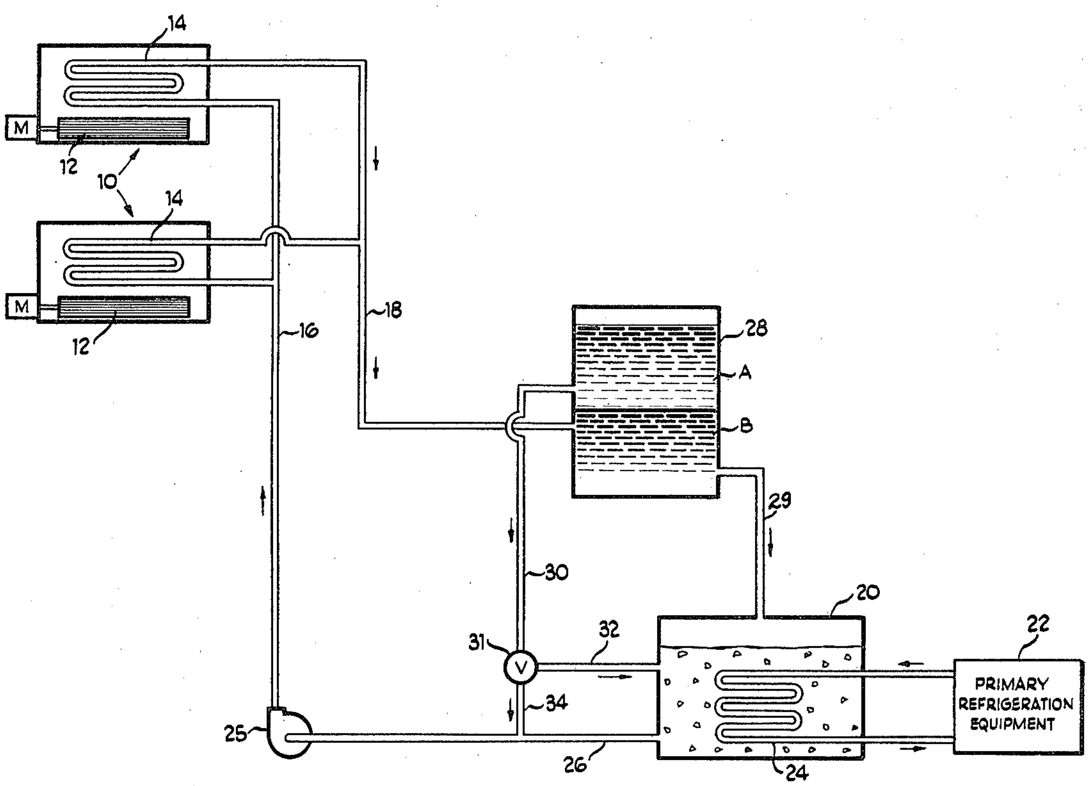
[57] **ABSTRACT**

A slurry of ice crystals in a water immiscible carrier fluid, for example, toluene, is produced and circulated to a heat exchanger for absorbing heat from a load, principally by means of the melting ice. The two liquids are then forwarded to a receiver where they separate into two phases. The liquid water from the melted ice is returned separately to the ice forming unit and at least a part of the carrier fluid is re-chilled prior to re-circulating the slurry through the system.

9 Claims, 3 Drawing Figures



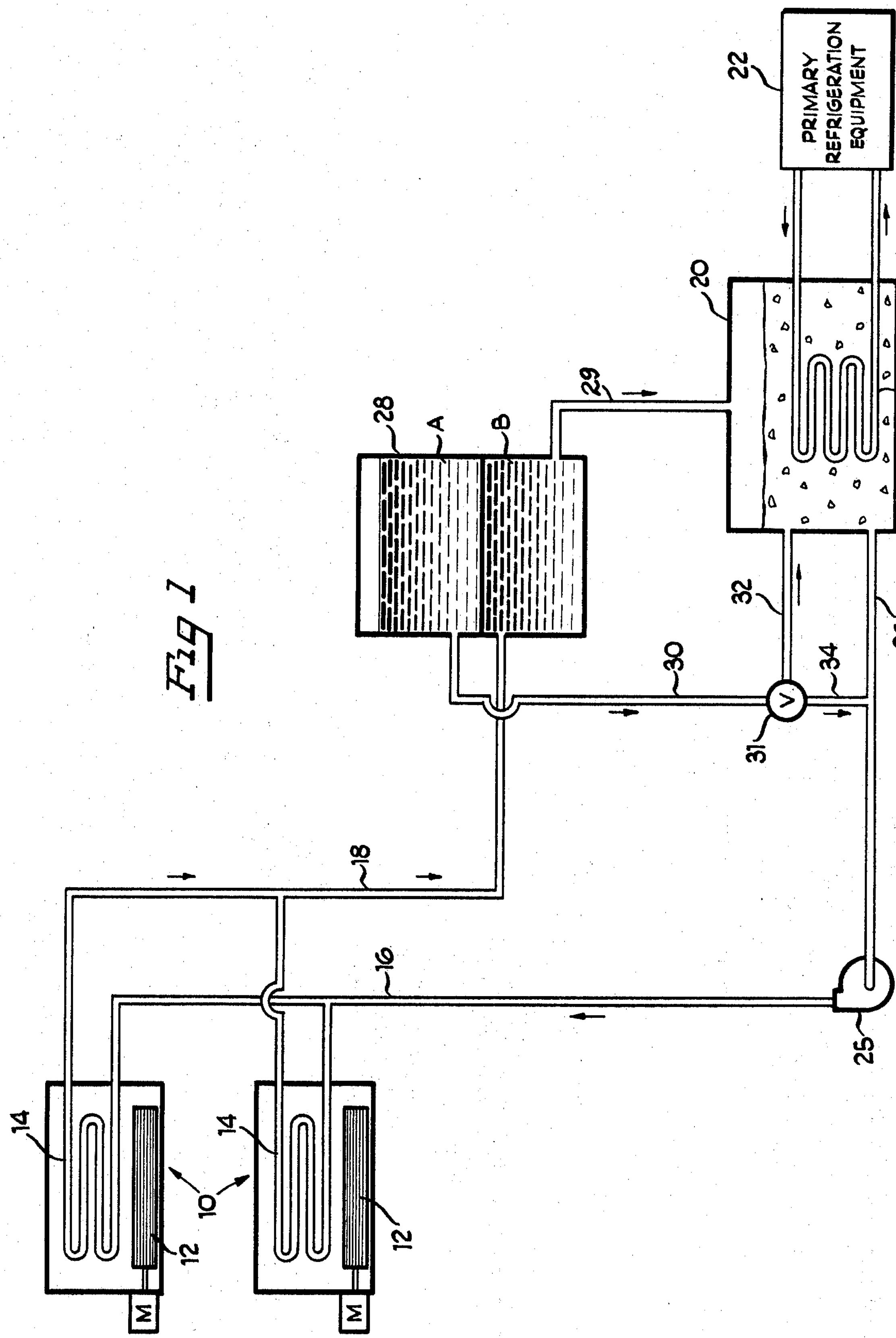

PRIMARY
REFRIGERATION
EQUIPMENT
22
20
24
29
28
A
B
32
30
34
26
31
18
16
25
14
14
10
12
12
M
M

Fig 1

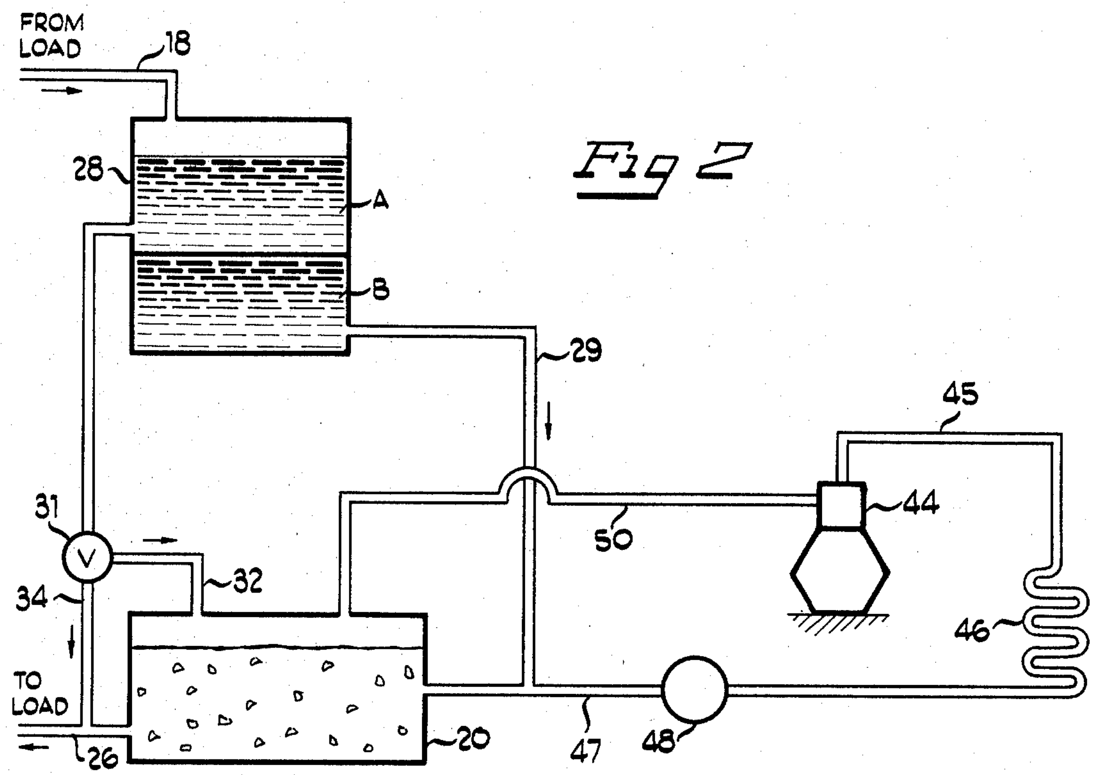

FROM LOAD
18
28
A
B
29
45
31
V
44
50
32
34
46
TO LOAD
26
20
47
48

Fig 2

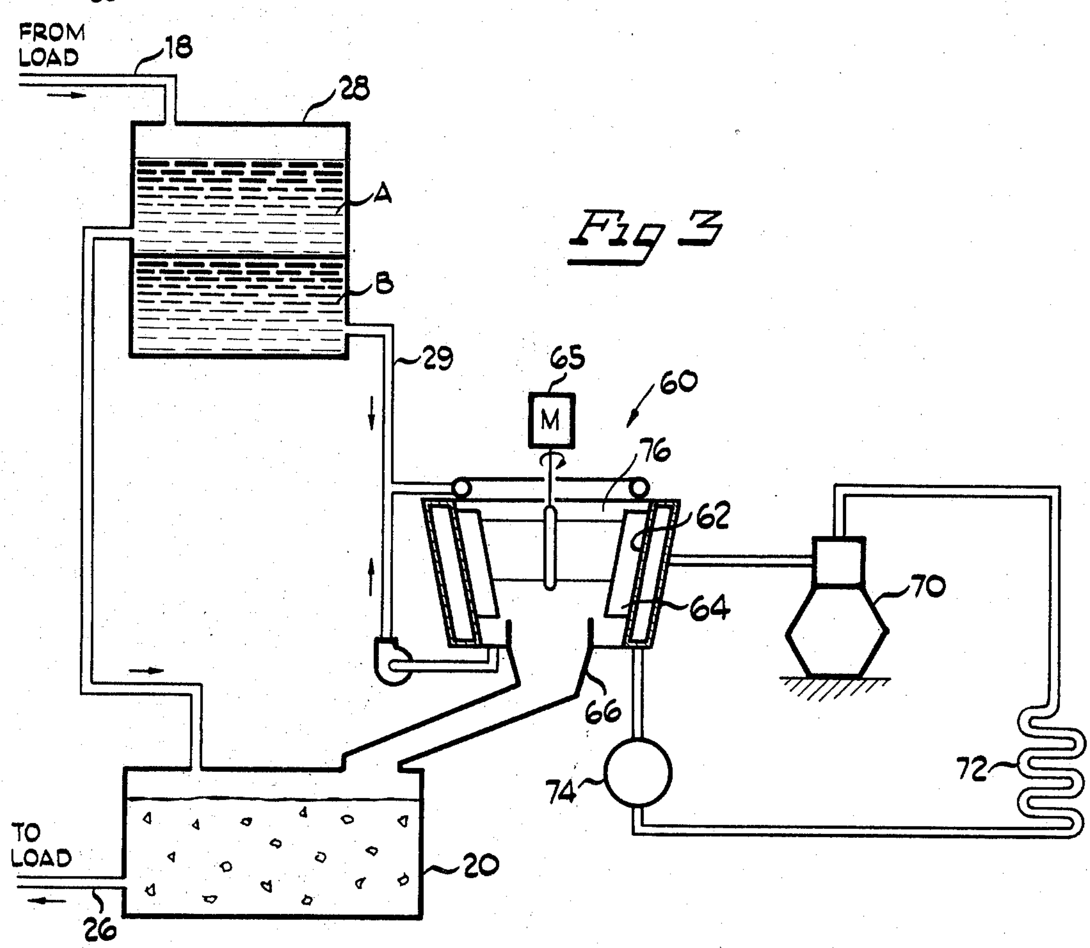

FROM LOAD
18
28
A
B
29
65
M
60
76
62
70
64
66
74
72
TO LOAD
26
20

Fig 3

REFRIGERATION SYSTEM UTILIZING ICE SLURRIES

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates generally to an improved refrigeration system using a slurry consisting of ice particles in a water immiscible carrier. This invention is particularly useful in air conditioning systems employing a plurality of heat exchangers located in the various zones requiring air conditioning.

Various systems have been proposed in the prior art for supplying a refrigerated liquid, usually chilled water, from a central refrigeration station. More recently, there has been described a system in which an ice-brine slurry is circulated to the various heat exchangers through supply risers and returned to the central station for reforming of the ice-brine slurry. For example, in U.S. Pat. No. 3,247,678 issued to J. W. Mohlman on Apr. 26, 1966, an air conditioning system of the previously mentioned type utilizes a direct expansion of butane into a brine solution which is adapted to freeze ice crystals therein; and means for circulating the ice brine slurry to the heat exchange units located throughout the building.

The advantages of using an ice slurry are also recognized. A pound of ice in melting will absorb approximately 80 BTUs, whereas if the system has to rely solely on sensible heat of the chilled fluid, 1 pound of water would only be able to absorb 1 BTU for each degree rise in temperature of the fluid. For example, in a typical system with a 10°F. water-temperature rise, 1 pound of recirculated water will absorb 10 BTUs of heat. On the other hand, it is possible to absorb the same 10 BTUs by melting only one-eighth of a pound of ice. Since it is possible to produce and pump a slurry containing up to 40 percent ice, the system would only be required to circulate about 0.3 lbs of slurry to achieve the same effect.

From the foregoing, it is clear that the amount of piping, which represents a major cost in any air conditioning installation, can be materially reduced. Moreover, it is possible to utilize smaller heat exchangers and/or the recirculation of less air. If the latter, this would permit the use of smaller ducts and fans.

In the Mohlman system referred to above there is a rather serious problem since the presence of salt reduces the freezing point of water. The ice-brine slurry in equilibrium inherently has a temperature less than the freezing point of pure water, 32°F. As the brine circulates through the heat exchanger, it is almost impossible to prevent a substantial build up of frost or ice exchanger coil. In addition, brine solutions are also very corrosive so that expensive metal alloys for the piping are required to handle a brine solution without serious problems.

Still another disadvantage of an aqueous system is the fact that ice particles will tend to agglomerate into larger particles which can plug the passages through which the slurry is pumped. For example, if the size of the particles is large enough two or more of the particles may, attempting to move through a restricted passage, be forced into contact with one another and, in effect, form an impassable bridge. Moreover, it is extremely difficult to maintain a uniform suspension of the ice particles in the aqueous fluid without continuous agitation. For example, in a brine system the ice has a lower specific gravity and the particles will tend to float. In the present invention, the specific gravity of the water immiscible carrier can ccan be selected to be equal to the specific gravity of ice to maintain the ice particles in suspension. If required, the carrier fluid can be made either more or less dense than ice so that one can predict to what extent the particles will float or settle as the particular application requires. Also, the carrier fluid may be selected on the basis of its lubricating properties which protect the surface with a lubricating layer or film to prevent agglomeration and maintain the particles at the proper size and the correct degree of suspension.

In a preferred embodiment of the invention, a slush is produced by discharging water into a water immiscible liquid which has been chilled substantially below 32°F. The resultant slurry is pumped through the cooling coils where the heat is absorbed from the air by the heat of fusion of the ice. As the ice melts, of course, it produces liquid water; and when all the ice is melted a two phase liquid system results. This is discharged into a separator where the two liquids, being immiscible, separate into two phases. The water is returned to the freezer for refreezing and the non-aqueous liquid used as the carrier is returned separately for rechilling and/or to raise the slurry to a temperature to prevent coil frost.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram illustrating a preferred embodiment of the apparatus used to carry out the present invention;

FIG. **2** is a modification of the apparatus shown in FIG. **1**; and

FIG. **3** is still another modification of the apparatus shown in FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. **1**, there is depicted a typical air conditioning system for use in a multi-room office, apartment or residential building which includes a plurality of terminal units **10** through which air is circulated to be cooled. Although shown as a fan coil unit wherein fan **12** blows air over the heat exchange coil **14**, it is obvious that induction units or other terminal units may be used. The source for the ice slurry is connected to the various heat exchangers **14** by means of supply risers **16** and return risers **18**. Slush ice is formed in a freezing tank **20** which is cooled by any conventional form of refrigeration equipment **22** wherein refrigerant is circulated through a coil **24** to cool the liquid introduced into the freezing tank. The slurry, as indicated above comprises ice and a liquid which is immiscible with water, such as for example, toluene, chlorobenzene or similar fluids. Such water immiscible liquid is sometimes referred to herein as the "carrier fluid".

From the freezing tank **20** the ice containing slurry is circulated by means of a pump **25** through line **26** to the supply riser **16**. In accordance with the demand for cooling existing at any given time, the slurry is diverted through heat exchange coil **14** in terminal units **10** and the air is circulated thereover by fan **12**. Suitable thermostatic controls (not shown) are included to control the flow of slurry and/or the operation of blower **12**. The returning slurry directed through return riser **18** consists essentially of liquid water and the carrier fluid.

This mixture is delivered to separation tank **28** wherein the two liquids separate by gravity into two homogeneous liquid phases. It will be assumed that the carrier fluid A, toluene for example, in this case would have a specific gravity lower than that of water. In this case, the upper body of liquid A would comprise substantially 100 percent carrier fluid while the lower body B consists of essentially 100 percent water which is usually liquid, but may include some unmelted ice. Water is delivered to freezing tank **20** through line **29.** Carrier fluid is drawn off through line **30** and may be divided into two streams under the control of mixing valve **31** which may be manually or automatically controlled. The one stream **32** is returned to the freezing tank **20** and the other stream is passed through line **34** to control the percentage of carrier fluid in the slurry stream going to the supply riser **16.** In this way the temperature of the slurry can be controlled at about 32°F.

Various modifications may be made to the system just described to achieve substantially the same results. For example, a direct contact system may be utilized in which a refrigerant is introduced directly into the receiver containing the mixture of water and the carrier fluid. Also, it is possible to manufacture a slurry of ice and introduce it directly into a body of carrier fluid for circulation to the load.

FIG. **2** illustrates a first modification showing that portion of the system which is designed to make up the slurry for distribution to the risers **16** and **18.** Where this system employs features of construction in common with FIG. **1,** the same reference numerals are used to designate corresponding elements.

The mixture of carrier fluid and essentially liquid water is returned from the load via return riser **18** and delivered to tank **28** where the water and carrier fluid separate into two distinct liquid phases. The water B is withdrawn through line **29** while the carrier fluid (which is the upper layer of liquid within the tank **28**) is conducted to vessel **20** through line **32.** A separate branch line **34** for the carrier fluid connects with conduit **26** leading to the suction side of the pump for distribution to the load, and is under the control of mixing valve **31** in the same manner as the FIG. **1** embodiment.

The foregoing system is commonly referred to as a direct contact system and utilizes a refrigerant which may be a halocarbon refrigerant or a hydrocarbon such as butane. Compressor **44** compresses the refrigerant and directs it through line **45** to a condenser **46** to liquefy the hot gas by heat exchange with air or water. The high pressure liquid refrigerant then passes through expansion device **48** in line **47** where it is mixed with water flowing through line **29** and enters chamber **20.** The refrigerant evaporates in chamber **20** and by abstracting the heat from the water causes a slurry of ice to form. The suction gas is then returned through line **50** to the suction side of compressor **44.**

In FIG. **3** there is shown a system which utilizes suitable means for manufacturing finely divided ice particles and is adapted to introduce such ice particles directly into a body of carrier fluid for circulation to the system. As in the other embodiments the water and carrier fluid separate into two phases in receiver **28** and the water B is conducted via line **29** to an ice maker unit designated at **60.** This unit which may be of any conventional design is illustrated as being of the type described in U.S. Pat. No. 2,575,374 issued to E. C. Walsh on Nov. 20, 1951 which is intended to be incorporated by reference herein. Water is frozen on the walls of a drum **62** and removed therefrom by scraper elements **64** driven by motor **65** for discharge through a chute **66** into the mixing vessel **20.** The ice maker is refrigerated by a vapor cycle circuit including a compressor **70,** condenser **72,** expansion device **74** and an evaporator chamber **76** which is in direct communication with the walls of the drum **62.** In this system the temperature of the fluid in chamber **20** is never below 32° F., so it is not necessary to use a mixing control from the separation chamber **28.** All of the carrier fluid may be conducted to mixing chamber **20** to receive the ice discharged from the ice maker.

It is, of course, not necessary to use the ice-water change of state in the present invention. All that is required is that two substances be provided which are capable of existing both in liquid and solid phases and provided further that the two substances in liquid phase be immiscible. Naturally, one substance should have a freezing point low enough to abstract heat efficiently from air used in human comfort air conditioning applications, i.e., at least as low as about 60°F., and the other substances must have a freezing point substantially below that of the first substance.

In selecting the carrier fluid, various criteria should be considered. First of all the fluid must be a liquid over the entire operating range, including shut down conditions. The specific gravity of the cooling liquid should also be preferably the same as ice at the temperatures at which the ice is frozen and circulated but different when both exist as liquids. The immiscibility of the carrier fluid in water has previously been discussed and it should be mentioned further that this property must be maintained throughout the entire temperature range at which the system is operable. Other considerations include non-toxicity, low viscosity, stability and reasonable cost. In addition to the materials mentioned earlier, satisfactory fluid would include kerosene and light fuel oil.

While this invention has been described in connection with a certain specific embodiment thereof, this is by way of illustration and not by way of limitation; and the scope of the appended claims should be construed as broadly as the prior art will permit.

What is claimed is:

1. A system comprising a first substance capable of existing in both liquid and solid phases and having a freezing point below about 60°F.; a second substance capable of existing in both liquid and solid phases and having a freezing point substantially below the freezing point of said first substance and being immiscible with said first substance when both are in the liquid phase; means for chilling said first substance to a temperature below its freezing point to effect a change of state from liquid to solid; means for mixing the resulting solid first substance with said second substance in liquid phase; means for circulating the resulting mixture to a refrigeration load to abstract heat therefrom by the change of state from solid to liquid of said first substance; and means for separating said first and second substances.

2. A system as defined in claim **1** including a primary refrigeration system for chilling said second substance to a temperature below the freezing point of said first substance, but above its own freezing point; and means for introducing said first substance, in liquid phase, into said chilled second substance.

3. A system as defined in claim **1** including a direct contact refrigeration system; and means for introducing a refrigerant from said direct contact refrigeration system into intimate contact with a non-homogeneous mixture of said first and second substances.

4. A system as defined in claim **1** including a refrigeration system for chilling said first substance per se below its freezing point to effect a change of state from liquid to solid; and means for mixing the resulting solid first substance with said second substance in the liquid state.

5. A system as defined in claim **1** wherein said first substance is water.

6. A method of refrigerating a thermal load comprising the steps of forming a slurry consisting essentially of ice in a water immiscible carrier fluid; circulating the slurry to said load and bringing said slurry into heat exchange relation therewith whereby heat is abstracted by the melting of the ice in the slurry; returning the two

phase stream to a separator for separating the two phases consisting essentially of water and the water immiscible carrier fluid; separating the water and said carrier fluid; re-freezing the water; and re-forming the slurry for recirculation to said thermal load.

7. A method as defined in claim **6** wherein said liquid water and water immiscible carrier fluid are mixed together and then brought into direct contact with a refrigerant to freeze the ice into a slurry.

8. A method as defined in claim **6** wherein liquid water per se is frozen and then mixed with said water immiscible carrier fluid.

9. A method as defined in claim **6** wherein said water immiscible carrier fluid is chilled to a temperature below the freezing point of water but above its own freezing point by indirect contact with a refrigerant; and liquid water is introduced into the resulting chilled carrier fluid to form a slurry.

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