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Newton

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[54] **AIR CONDITIONING SYSTEM UTILIZING ICE SLURRIES**

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

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 312,172, Dec. 4, 1972, abandoned.

[52] **U.S. Cl.** **62/332**; 62/114

[51] **Int. Cl.²** **F25B 5/00**

[58] **Field of Search** 62/114, 76, 502, 332, 435, 62/330, 59

[56] **References Cited**

UNITED STATES PATENTS

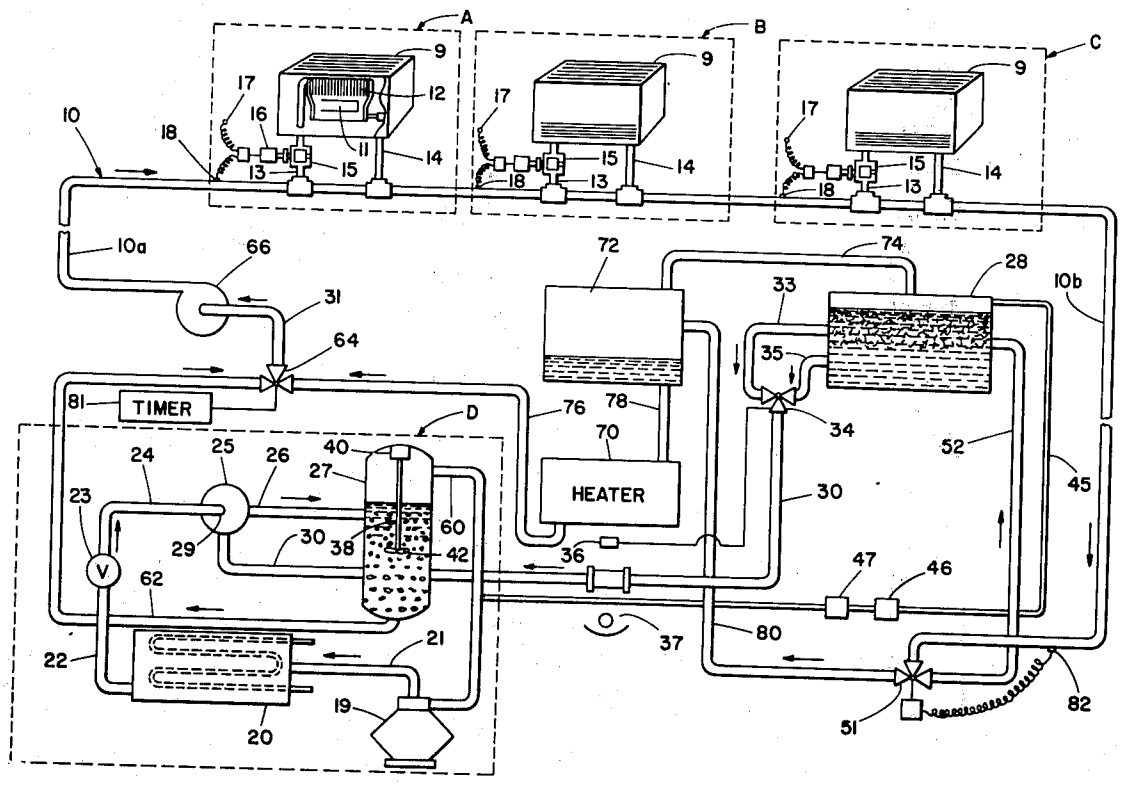
3,247,678	4/1966	Mohlman	62/199
3,384,155	5/1968	Newton	165/2
3,416,977	12/1968	Rein	62/64 X

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[57] **ABSTRACT**

An improved single pipe air conditioning system utilizing a slurry of ice crystals in a water-immiscible liquid phase as the heat exchange medium during the cooling cycle. In the system described in U.S. patent 3,384,155, a heated medium and a chilled medium are alternatively circulated in a closed loop, single pipe system to a plurality of individual room units in heat exchange relation with the zones to be air conditioned. In this improvement, a slurry of ice crystals is circulated to the room units during the cooling cycle and since the heat of fusion has significantly greater cooling capacity than the sensible heat available in chilled water, the amount of liquid circulated through the cooling cycle can be greatly reduced. The percentage of ice crystals in the slurry may be controlled by varying the mixing ratio of the streams of water and refrigerant which is brought to direct contact with the water to form the ice slurry.

4 Claims, 1 Drawing Figure



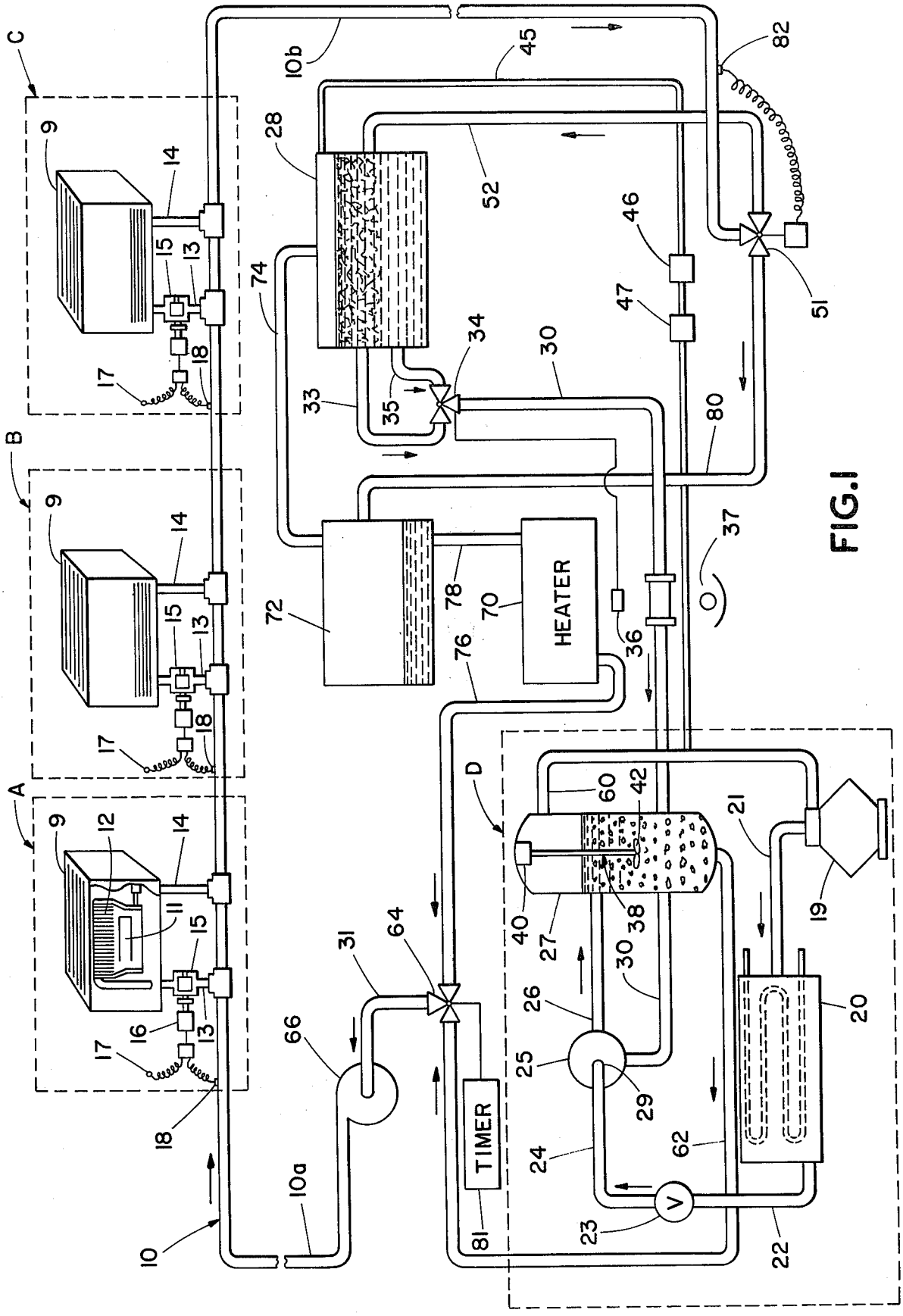

HEATER
TIMER
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FIG.1

AIR CONDITIONING SYSTEM UTILIZING ICE SLURRIES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 312,172 filed Dec. 4, 1972 now abandoned.

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates to an improved single pipe air conditioning system of the type described in U.S. Pat. 3,384,155 using a slurry of circulating ice crystals in a water-immiscible liquid refrigerant to be circulated to the load when on the cooling cycle.

It is conventional to provide means for supplying chilled water from a single refrigeration station, as a common source, to multi-room buildings, such as hotels, office buildings, and similar structures for air conditioning purposes. Numerous advantages are realized by employing a common refrigeration source, resulting in increased efficiency of operation. However, since the heat absorbing capacity of water as a refrigerant is relatively low, circulation of relatively large quantities of water in such system is necessary to insure required minimal cooling.

Attempts to provide more efficient and economical refrigeration systems have resulted in proposals to utilize an ice-brine slurry from a central refrigeration station to air handling units in a multi-room building, the air to be cooled being passed in heat exchange relation with the slurry. Such a system is described, for example in Mohlman, U.S. Pat. 3,247,678 issued Apr. 26, 1966. Since the heat abstracted by ice melting (heat of fusion) is about 80 BTU/lb., a predetermined volume of ice-brine slurry provides the same refrigeration as a much larger volume of cold water. The use of brine also makes it practicable to control the temperature at which ice crystals are formed for the slurry, thereby to effect control of the ice content in the slurry. In one of these systems, the ice crystals are circulated in brine but not the refrigerant, and also the crystals are stored in brine.

The present invention is directed to, and has for its primary object, the provision of an improved single pipe air conditioning system utilizing a fluid such as water for direct mixing with a water-immiscible liquid refrigerant. Preferably the refrigerant is one which will not form a hydrate when mixed with water. One example of such a refrigerant is refrigerant R-114 which investigators have found will not form hydrates under practical operating conditions. See "New Agents For Use In The Hydrate Process For Demineralizing Sea WAter", Office of Saline Water, Research and Development Progress Report No. 59, page 27.

As the mixture of ice crystals in the refrigerant circulates through the system, the premature release of refrigerant vapor, which could conceivably cause vapor lock in the room heat exchangers, or their associated lines, is prevented (in the case of R-114) by maintaining the system under a pressure of about one atmosphere (gauge). The ice crystals are formed by directly mixing the refrigerant with liquid water (and residual ice crystals) under such conditions that the refrigerant will immediately evaporate and thereby flash cool the

mixture below the freezing point of water. The mixture of ice crystals and refrigerant, hereinafter referred to as the slurry, is circulated to the individual air handling units which in a preferred embodiment may be connected in a closed loop or single pipe system. The slurry may also be stored at high concentration ready for circulation when needed.

The concept of using circulating ice crystals in a liquid phase which is not miscible with water is described in the co-pending application of Richard L. Kuehner, Ser. No. 375,991, filed July 2, 1973.

DESCRIPTION OF THE DRAWING

The single FIGURE is a schematic or diagrammatic view of a single pipe air conditioning system embodying the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, the FIGURE illustrates a single pipe air conditioning system comprising a closed circuit conduit arrangement including a plurality of room air handling units 9 respectively located in zones A, B and C to be conditioned. The single loop supply and return conduit 10 constitutes the major portion of the piping arrangement including a supply riser 10a and a return riser 10b supplying the heat exchange medium to units 9 and returning it to its source. The room air handling units 9 each include fan 11 or other suitable air circulating means (such as an induction unit) and a heat exchanger 12 connected by individual inlet lines 13 and outlet lines 14 to the conduit 10. Each of the inlet lines 13 includes a pump 15 actuated by a control 16 responsive to air temperature in the zone as sensed by bulb 17 and to the temperature of the heat exchange medium flowing in conduit 10 as sensed by bulb 18.

As more particularly described in U.S. Pat. 3,384,155 issued to A. B. Newton on May 21, 1968, and in U.S. Pat. 3,425,485 issued to A. B. Newton on Feb. 4, 1969, the "single pipe system" uses the alternate circulation of a heated and a chilled heat exchange medium to be made available to the air handling units. If there is a demand for cooling, the controls will permit circulation of the heat exchange medium to the air handling units only if a chilled medium is being circulated through conduit 10. If a heated medium is available, it is simply bypassed. When there is a demand for heating in a particular zone, the controls will permit circulation of such medium through the heat exchanger only if the heated medium is available and will bypass the same if it is chilled.

In the present invention, the means for supplying chilled heat exchange medium is designed to produce a mixture of ice crystals in a water-immiscible liquid refrigerant for circulation through the system. In effect, the means for producing and circulating the ice-refrigerant mixture generally replaces the more conventional liquid chilling units which were intended for use in the system described in U.S. Pat. Nos. 3,384,155 and 3,425,485.

The chiller section, shown generally within the area bounded by dotted lines indicated at D, comprises a compressor 19 and a condenser 20 connected by conduit 21. The compressor delivers refrigerant through conduit 21 to the condenser where it is condensed and flows through conduit 22 to an expansion device 23

and then through conduit 24 to a mixing chamber 25, tube 26, and separator 27.

The system utilizes a fluid, such as water, and a water-immiscible, refrigerant, such as refrigerant R-114, the water being brought into direct contact with the refrigerant to provide an ice crystal slurry in the mixing chamber 25 and separator 27. Refrigerant vapor is returned to the suction side of compressor 19 through line 60; and the slurry is circulated, during the cooling cycle, through conduit 62, three-way valve 64, pump 66 and then through conduits 10, 10*a* and 10*b* to and from the air conditioning units 9. As described in more detail below, the slurry may be stored in a container 28 at high concentration ready for circulation when desired.

When the refrigerant flows from the condenser 20 and expansion valve 23, it enters the mixing chamber 25. There it is mixed with water, which may contain some ice crystals, and refrigerant from conduit 30 to form an ice slurry. More particularly, the conduit 24 extends into the chamber 25 and provides a nozzle forming an eductor 29 in the chamber for supplying a jet of the expanding water-immiscible liquid refrigerant to freeze the water which enters the chamber 25 via conduit 30 from container 28. In this regard, the water and/or ice crystals (which will also contain a controlled amount of refrigerant) flows from container 28 and is aspirated into the liquid refrigerant by the eductor, the water freezing to form an ice slurry. The eductor 29, in effect, operates as a pump driven by the refrigerant flowing through conduit 24.

The ice crystals and liquid refrigerant mixture passes from the mixing chamber 25 and conduit 26 into the vapor-liquid separator 27, where a portion of the refrigerant separates from the mixture by evaporation, returning via line 60, as vapor, to the suction side of compressor 19.

When chilled medium is being circulated through the system, the ice crystal and liquid refrigerant mixture passes from the separator 27 and flows through conduit 62, three-way valve 64, and conduit 31 to the pump 66 for circulation through supply riser 10*a* to the air conditioning units 9 and then to return riser 10*b* to three-way valve 51, conduit 52 to storage container 28. It will be noted that the liquid refrigerant itself is circulated as the principal carrier of the ice cyrstals. Excess ice crystals and/or refrigerant returns for storage in container 28 to provide a cooling reserve.

Pump 66, as well as pumps 15 on the room units, are of the type capable of efficiently handling slurries without jamming the impellers. Such pumps are commonly used to pump sewage.

The liquid refrigerant and ice crystals (and melted ice) separate in the storage container 28, the water and ice crystals floating on top of the liquid refrigerant. The water and ice crystals flow from container 28 through conduit 33 to a three-way valve 34 connected to conduit 30. The liquid refrigerant flows from container 28 through conduit 35 to the valve 34. The valve 34 effectively controls the amount of water and ice flowing to mixing chamber 25 to provide a desired percentage of crystals to level the load on the compressor. Slurry concentration, flowing through conduit 30 to the mixing chamber 28, may be controlled by a photoelectric sensor 36 receiving varying light from source 37 through a transparent section 38 of the pipe 30. Sensor 36 may be used to control the mixing of ice (water) and refrigerant in valve 34.

For the supply of heated medium to air handling units 9, a water heater 70 and storage chamber 72 are provided. The latter is connected to the ice slurry storage chamber 28 by equalizer line 74. The outlet of heater 70 is connected to three-way valve 64 by conduit 76; and the chamber 72 and heater 70 are connected by conduit 78. Returning hot water in return riser 10*b* is directed to valve 51 and then to chamber 72 via line 80.

Since the ice crystals will tend to float on top of the body of refrigerant in vapor-liquid separator tank 27, it is desirable to provide means for continuously stirring the ice and liquid phase to maintain uniform distribution of the ice particles. Means for this purpose are indicated by numeral 38 which comprises a motor 40 and an impeller 42 which may be operated continuously, or at least while the cooling system is functioning.

When using refrigerant R-114, (dichlorotetrafluoroethane) the formation of vapor may be prevented by maintaining the pressure within the system of about one atmosphere (gauge). The boiling point of R-114 under a pressure of one atmosphere is about 96°F. During cooling operation, it is extremely unlikely that the returning mixture of water and refrigerant will rise to this level. Obviously, if there are any ice crystals remaining in the circulating stream, the temperature will be approximately 32°F. Under high load conditions, it is possible that all of the ice will be converted to liquid phase and that the temperature may rise to a higher level. However, the maintenance of one atmosphere (14.7 psi gauge) will be adequate to prevent vapor formation and possible consequent vapor locking of the lines and heat exchangers. In the event some vapor is formed, it may be bled back to compressor suction. The most likely place for vapor formation is in holding tank 28. Accordingly, line 45 provides a vapor flow passage between the upper portion of holding tank 28 (above the normal liquid level) and compressor suction line 60. Such a line may also be provided with a filter 46 to prevent liquid carryover and a pressure regulator 47 so that the pressure in storage tank 28 is not pulled down to any appreciable extent.

OPERATION

Cycling of the single pipe system is controlled by a timer 81 which is adapted to actuate three-way valve 64 having a first inlet receiving hot water from heater 70 from line 76 and a second inlet adapted to receive the mixture of ice crystals and refrigerant from line 62. Assuming that the operation begins with hot water being circulated through the system, heater 70 is adapted to deliver water to the inlet side of pump 66 through line 31 and three-way valve 64. As the water circulates through the system from supply riser 10*a* and return riser 10*b*, the individual air handling units draw off fluid as required depending on the demand for heat in the individual zones. Returning water is delivered to the inlet side of three-way valve 51 and delivered through line 80 to the storage chamber 72 and then to inlet side of heater 70 through line 78.

Upon a changeover, the mixture of ice crystals and refrigerant is delivered from separator 27 through line 62 to three-way valve 64 which is switched over to permit flow between lines 62 and 31 to supply pump 66. The returning water at the same time is delivered to storage tank 72 for holding the hot water as it is drawn

out of the system. When the chilled medium begins to flow through the return riser **10***b*, the temperature is sensed by thermostat **82** upstream from three-way valve **51** which then changes the position of such valve to permit the returning fluid to pass through line **52** to the storage receptacle **28** containing the mixture of ice crystals and refrigerant. Upon switching back from cooling to heating again, three-way valve **64** is repositioned to permit flow between the outlet of heater **70** and inlet of pump **66**; and the returning mixture of chilled medium is stored in receptacle **28** until the heated medium begins to flow through return riser **10***b*.

Various modifications of the system described herein will be apparent from further reading of the aforementioned U.S. Pat. No. **3,384,155.** For example, the air handling units may be induction units or, for that matter, any air handling unit containing a heat exchanger to be supplied with a heat exchange medium and means for circulating room air over the heat exchanger.

While this invention has been described in connection with a certain specific embodiment thereof, it is to be understood that 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 multi-room air conditioning system comprising a plurality of room air conditioning units located in a plurality of zones subject to varying thermal loads, each said conditioning unit including a liquid-to-air heat exchanger; means for producing a chilled heat exchange medium including means for bringing water and a water-immiscible liquid refrigerant, which is incapable of forming a hydrate, into direct contact with each other and evaporating said refrigerant to provide a slurry containing ice crystals; and means for circulating said heat exchange medium to said heat exchangers, said liquid refrigerant providing the carrier for said ice crystals.

2. A system as defined in claim **1** including a mixing chamber, and an eductor in said chamber for providing a jet of expanding refrigerant to freeze water in said chamber, thereby forming said ice crystals.

3. A system as defined in claim **1** wherein said refrigerant is **R-114.**

4. A system as defined in claim **2** including a storage container having an ice crystal containing section and a liquid refrigerant containing section; a first conduit connected to the ice crystal-containing section; a second conduit connected to the liquid refrigerant-containing section; a third conduit; a three-way valve connecting said first and second conduits to said third conduit; and means connecting said third conduit to said mixing chamber, whereby the ratio of ice crystals to liquid refrigerant, in the stream entering said mixing chamber, may be controlled.

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