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(71) Applicant: **FRIGESCO LIMITED** [GB/GB]; c/o Sideways Limited, 5 Providence Court, Pynes Hill, Exeter Devon EX2 5JL (GB).

(72) Inventors: **CAMPBELL, Robin**; Frigescio Limited, c/o Sideways Limited, 5 Providence Court, Pynes Hill Exeter EX2 5JL (GB). **DAVIES, Thomas**; Frigescio Limited, c/o Sideways Limited, 5 Providence Court, Pynes Hill Exeter EX2 5JL (GB). **THANGAMANI, Varun**; Frigescio Limited, c/o Sideways Limited, 5 Providence Court, Pynes Hill Exeter EX2 5JL (GB).

(74) Agent: **NOVAGRAAF UK**; 2nd Floor, Renown House, 33-34 Bury Street, London EC3A 5AR (GB).

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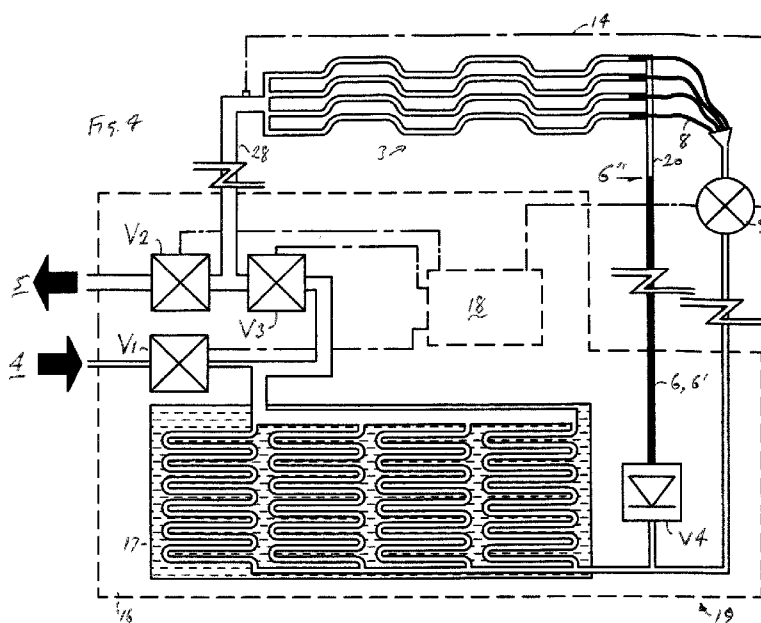
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(54) Title: COOL GAS DEFROST CIRCUIT USING HEAT STORAGE MATERIAL



(57) Abstract: A condensate valve is arranged at the lower end of a condensate conduit forming part of a cool gas gravity circuit for recirculating refrigerant between a heat store and an evaporator during a defrost cycle. A valve assembly is arranged to maintain a column of liquid refrigerant condensate in the condensate conduit above the condensate valve, sufficient to apply a positive pressure gradient in the condensate return flow direction across the condensate valve, by regulating the flow of refrigerant to the evaporator defrost inlet during the defrost cycle. In other aspects, more even and rapid cool gas defrosting is achieved by arranging the cool gas defrost connection at an upper end of the defrost inlet manifold of the evaporator.

Cool gas defrost circuit using heat storage material

This invention relates principally to vapour compression refrigeration circuits in which a heat store (typically a body of phase change material such as paraffin wax) is arranged to store low
5 grade (typically ambient temperature) residual heat from the pressurised refrigerant during the refrigeration cycle and to transfer the stored energy to defrost the evaporator by boiling and recondensation of the refrigerant during a periodic defrost cycle.

In this specification, the term "refrigeration system" is construed to mean any system for
10 transferring heat, whether for cooling or heating or for any other purpose, and thus embraces systems for cooling enclosures for chilled or frozen commodities, ice making systems, freeze desalination systems, heat pumps, air conditioning or dehumidification systems, and other systems in which heat is transferred from a cold side to a hot side. The term "refrigeration" is construed accordingly.

15 In a typical vapour compression refrigeration system, which may be arranged for example for cooling a cold store or a refrigerated display cabinet, or as a heat pump for heating a building, the refrigerant passes during the refrigeration cycle through the condenser in which the heat extracted from the evaporator is rejected to atmosphere. The condensed refrigerant leaves the
20 condenser at a little above ambient temperature and is supplied at approximately ambient temperature to the evaporator.

It is necessary to periodically defrost the evaporator (perhaps once or a few times per day) so as to remove ice which accumulates on the outside of the evaporator in normal operation and
25 which blocks the cooling fins and reduces the rate of heat transfer.

In a cool gas defrost cycle, residual heat from the refrigerant downstream of the condenser is transferred periodically to defrost the evaporator. To avoid the need for an increased refrigerant charge to store this heat during the refrigeration cycle, it is known to provide a heat
30 store comprising a body of phase change material to accumulate this residual heat during the refrigeration cycle and release it during the defrost cycle. When the refrigeration cycle is resumed, the cooled heat store absorbs residual heat from the refrigerant and in doing so cools the refrigerant before it passes to the evaporator, so that a lower evaporator temperature is

initially obtained. In this way defrosting is accomplished using only residual heat which cannot be rejected from the system, and moreover is accomplished without raising the temperature of the evaporator to a level which would cause significant temperature excursions in the food or other contents of the refrigerated compartment, while any small temperature excursion is
5 rapidly reversed by the reduced evaporator temperature at the beginning of the next refrigeration cycle. Cool gas defrost therefore is very energy efficient and also is good for the refrigerated commodity.

Cool gas defrost is significantly more energy efficient than hot gas defrost, which is the term
10 given to systems in which the compressed refrigerant leaving the compressor is diverted directly to the evaporator during the defrost cycle. Hot gas defrost disadvantageously uses energy from the compressor to put back into the system heat which otherwise would have been rejected via the condenser. However, it is relatively simple to implement, and in practice is much more commonly used than cool gas defrost.

15 Both cool gas defrost and hot gas defrost are more energy efficient than electric defrost, which is the term given to systems in which resistive electric heating elements are arranged between the fins of the evaporator. Such elements consume a great deal of energy and also reach temperatures high enough to generate steam as the ice melts from the evaporator, which
20 transfers heat rapidly to the refrigerated commodity causing major temperature excursions and also re-freezes as unsightly frost on the surface of the commodity. (Some frosting may similarly be observed with hot gas defrost systems.) Electric defrost also is relatively simple to implement and so is commonly used.

25 WO9322606 and WO2012107773 teach cool gas defrost systems in which a heat store is arranged below the evaporator, and heat is transferred from the heat store to the evaporator by means of valving which establishes a closed loop in which the refrigerant is recirculated during the defrost cycle. The condensed refrigerant flows back by gravity to the heat store in which it is re-boiled so that the vapour rises and condenses again in the evaporator. This
30 process is self sustaining as long as a temperature difference remains between the heat store and the evaporator, and does not require any energy from the compressor.

- This arrangement is effective when there is a substantial vertical distance between the evaporator and the heat store, and when the evaporator comprises tubes which fall continuously from the defrost vapour inlet to the condensate outlet so that the condensed refrigerant can drain freely back to the heat store. Evaporators designed for cool gas defrost typically are made this way as far as possible, but evaporators that are designed for electric defrost typically are not. Evaporators designed for hot gas defrost also may not be made this way, since the hot gas is forced through the evaporator tubes under power from the compressor. It is very difficult to design out liquid traps entirely, so even in evaporators designed for hot or cool gas defrost, liquid traps will often be present, particularly in evaporators which have an offset tube array (forming a triangular pattern when viewed from one end) rather than an in-line or square pattern. An offset pattern is often preferred because it offers better heat transfer as the airflow passing between one row of tubes will impinge on the next.
- When an evaporator is ordered from a manufacturer, the refrigeration engineer may specify the number and arrangement (e.g. square or triangular array) of the evaporator tubes which carry the refrigerant, the direction of the airflow, the number and spacing of the fins which define the airflow passage passing between the tubes, and also the number of circuits, which is to say, how many parallel circuits the evaporator is to comprise, and how many tubes are arranged in series to form each circuit. From this specification the technician constructing the evaporator can arrange the required number of tubes in the required pattern to form a finned block within a housing, and can connect the tubes together externally of the housing, typically by U-shaped connecting portions, to define the required number of circuits. However, the engineer typically will not specify which exact tubes of the bundle are to be connected together in what order. Therefore the interconnection pattern of the tubing has traditionally been an art rather than a science, and is left to the skilled technician.

In consequence, it is usual for the tubing of an evaporator to be configured to form liquid traps, which is to say, regions of tubing which turn upwardly at both ends so that any liquid refrigerant present in the tubing will tend to collect in the traps.

The applicant has found that when an evaporator of this type is employed in a cool gas defrost circuit which relies on gravity recirculation of the refrigerant, slugs of condensed refrigerant

collecting in the liquid traps near the vapour inlet can inhibit gravity circulation and also exclude refrigerant vapour from passing further into the evaporator, reducing the surface area which is exposed to the refrigerant vapour and so greatly reducing the rate of heat transfer from the heat store. Moreover, if the volume of refrigerant in the defrost circuit is not substantially
5 greater than the volume that can be contained as condensate in the liquid traps, the condensed refrigerant may collect in the evaporator until the refrigerant conduits in the heat store are empty, at which point no further heat is transferred and the defrosting process stops. This makes it difficult to retrofit a refrigeration system, particularly one designed for inefficient electric defrost, with a cool gas defrost cycle operating by gravity circulation.

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Another problem often observed when defrosting an evaporator using cool gas is that some of the evaporator tubes will tend to defrost more quickly than the rest, which considerably increases the time required to defrost the entire evaporator.

15 To help to overcome these problems, an additional reservoir of refrigerant can be provided to form part of the gravity circuit. However, this disadvantageously increases the total inventory of refrigerant contained in the refrigeration system, which is costly and environmentally undesirable. This is particularly undesirable in a system with multiple evaporators connected to the compressor(s) via supply and exhaust manifolds, wherein each evaporator has a separate
20 gravity circuit so that the evaporators can be defrosted one at a time with the compressor running more or less continuously to maintain the remaining evaporators on the refrigeration cycle. In a manifold system of this type, the additional quantity of refrigerant required to implement reliable gravity defrosting in each evaporator may be very large indeed.

25 In light of the above mentioned problems it is a general object of the present invention in a first aspect to provide an improved cool gas defrost cycle in which heat is transferred from a heat store to an evaporator by means of a reliable gravity circulation. More particularly, the invention sets out to implement a reliable gravity circulation with minimal refrigerant charge, to implement a reliable gravity circulation in an evaporator which is configured to form liquid
30 traps, and most preferably to achieve both of these objectives in combination. In other aspects, the invention sets out to reduce the overall time required to defrost an evaporator using cool gas.

In accordance with the various aspects of the present invention there are provided a retrofit module, a refrigeration apparatus, and a method as defined in the claims.

Further features and advantages will appear from the illustrative embodiments of the invention which will now be described, purely by way of example and without limitation to the scope of the claims, and with reference to the accompanying drawings, in which:

Fig. 1 is a simplified schematic representation of the key elements of a vapour compression refrigeration system including multiple evaporators connected via supply and suction manifolds to a compressor and condenser;

Fig. 2 is an enlarged view of the metering device and refrigerant inlet of one of the evaporators of the system of Fig. 1;

Fig. 3 shows a retrofit module fitted to one of the evaporators of the refrigeration system of Fig. 1;

Fig. 4 and Fig. 5 show two different operational states of the system of Fig. 3 in use;

Fig. 6 shows a modification of the system of Fig. 3;

Fig. 7 shows a further modification of the system of Fig. 3;

Fig. 8 shows a yet further modification of the system of Fig. 3; and

Fig. 9 shows a yet further modification of the system of Fig. 3.

Reference numerals appearing in more than one of the figures represent the same or corresponding features in each of them.

Referring to Figs. 1 and 2, an example refrigeration system comprises a compressor 1, a condenser 2, and a group of evaporators 3, each arranged for example within a respective cold store (not shown) for storing frozen food or the like.

The compressor and condenser are connected to the evaporators via a supply manifold 4 and a suction manifold 5 so that during a refrigeration cycle a refrigerant 6 can flow from the compressor via the condenser to the evaporator and then from the evaporator back to the compressor. It will be understood of course that the system will typically include a receiver and other components not shown in the drawings, including typically electric defrosting elements or a reversing valve or other valve means for implementing a hot gas defrost cycle.

Where hot gas defrost is used, the evaporator will often be fitted with a distributor 7 comprising a group of small diameter distributor tubes 8 through which the refrigerant is conveyed from the metering device 9 (which in the illustrated example is a thermal expansion valve or TEV, hereinafter referred to as the expansion valve) to the tubes 10 of the evaporator during the refrigeration cycle. The metering device functions to control the flow of refrigerant entering the evaporator during the refrigeration cycle. Usually the tubes 10 will be connected together by fins (not shown), and in typical chilled cabinet or cold store applications a fan will be provided to circulate air between them.

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In this specification, a thermal expansion valve, also referred to as a thermostatic expansion valve or TEV, means a valve controlled by a heat sensor (which may be for example an electronic component interacting with an electronic control system or a mechanical component such as a temperature sensing bulb containing a body of fluid) that regulates flow from an inlet to an outlet.

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In the illustrated example, the expansion valve 9 is controlled via a control line 14 (which may be e.g. an electrical connection or a small diameter tube) by a heat sensor 15 proximate the refrigeration outlet from the evaporator 3, i.e. that end of the evaporator which functions as the outlet for refrigerant flowing away from the evaporator during the refrigeration cycle. (Of course, if the expansion valve 9 is electrically controlled then the control line 14 may form part of a larger electrical control system, not shown, and the sensor 15 and expansion valve 9 may be indirectly rather than directly connected.)

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The tubes 10 form conduits which are fluidly connected together by a respective header 11, 12 at each end of the evaporator 3 to define fluidly parallel flowpaths through which refrigerant can flow between the two headers. The distributor tubes 8 of the distributor 7 extend for a short distance into each of the tubes 10 so that the two-phase flow of refrigerant from the expansion valve 9 is evenly divided between them. The header 11 will typically be connected to a condensate return line forming part of the hot gas defrost circuit of the legacy refrigeration system (i.e. the existing refrigeration system before the retrofit module is fitted to it) so that it functions as a defrost outlet (i.e. as a flowpath for condensed liquid refrigerant to flow out of the evaporator during the hot gas defrost cycle), although for clarity that legacy condensate

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return line is not shown. Whilst both the distributor 7 and the header 11 are shown for ease of illustration, it will be understood that if the legacy system uses electric defrost then only one manifold arrangement similar to the illustrated distributor 7 or header 11 may be provided to connect the expansion valve 9 to the tubes 10.

5

Even where an evaporator is designed for hot gas defrost, the tubes 10 will often include liquid traps 13, and these liquid traps may be substantially deeper than shown and capable of retaining a large volume of liquid refrigerant. In addition, the distributor tubes 8 are often bent or coiled during installation so that they extend above the top of the evaporator, which can cause an entire evaporator tube or tubes 10 to form a liquid trap. This problem however can be reduced or eliminated by straightening the tubes 8 during installation of the module so that if a header 11 is not provided then the tubes 8 can be used if necessary as the condensate return flowpath during the defrost cycle.

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Referring to Fig. 3, the refrigeration system of Fig. 1 is adapted to implement a cool gas gravity circulation defrost cycle by fitting it with a retrofit module 16 comprising a heat store 17, a group of valves V1, V2, V3, V4, and a valve control means 18.

20

Typically the group of valves will comprise a number of discrete valve units, comprising solenoid valves, TEVs and/or other suitable valves, connected together by fluid conduits. In use, the group of valves may form all or part of a complete valve assembly of the refrigeration system. Conveniently, all or some of the components of the module may be connected together and enclosed in an outer casing (not shown), with suitable interface connections for connecting the group of valves to the existing expansion valve or other metering device 9, the evaporator 3, and the supply and suction manifolds 4, 5. Alternatively, the module may be supplied in kit form with its components being fitted separately. The expansion valve or other metering device 9 could also be part of the module rather than a legacy component of the refrigeration system.

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In the illustrated embodiment, the valve control means 18 comprises software running on a processor, memory and other electronic hardware components enclosed in the outer casing of the module 16, which may be connected to an external power supply and/or to other components of the refrigeration system (such as the expansion valve 9, if electronically controlled) and/or to an electronic control system of the refrigeration system via a suitable

wiring interface (not shown). The valve control means may also include sensors (not shown) arranged to sense temperature and other parameters at critical points in the refrigeration system, particularly on the defrost circuit, so that the operation of the valves may be controlled responsive to the output from the sensors.

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Fig. 3 shows how the heat store 17 is connected to form part of the refrigeration system including the evaporator 3 by means of a valve assembly 19, which may include the expansion valve 9 and other legacy components of the refrigeration system as well as the group of valves V1, V2, V3, V4 supplied as part of the retrofit module 16. The valves included in the module can
10 be selected as necessary to complement or replace the legacy valve components of the refrigeration system so as to form after installation a complete valve assembly 19 which is controllable by the valve control means 18 to implement a periodic cool gas defrost cycle as further explained below.

15 Optionally, the evaporator 3 may also be replaced with an evaporator designed to avoid liquid traps. Advantageously however, the novel module 16 makes it possible to implement a gravity defrost cycle without replacing the legacy evaporator, even if it includes liquid traps as shown. If the legacy evaporator is fitted with electric defrost elements then the power supply to these elements may be disabled.

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The heat store 17 comprises a body of heat storage material 21 which is thermally coupled to the refrigerant 6 so that during the refrigeration cycle, the refrigerant 6 flows through a refrigeration circuit from the compressor 1 via the condenser 2 and the heat store 17 to the evaporator 3 and then from the evaporator 3 back to the compressor 1. (Of course, it may pass
25 through a receiver and other components of the refrigeration system en route.)

Preferably the heat store 17 incorporates a heat exchanger configured as a conduit 22 that falls continuously from the defrost vapour outlet 23 at the top to the condensate inlet 24 at the bottom. The conduit may comprise multiple folded tubes extending between top and bottom
30 headers or manifolds 25 as shown, or could be a micro-channel heat exchanger defining flowpaths between parallel plates. The conduit is preferably immersed in the heat storage material 21 with the whole assembly being contained in an outer casing 29, optionally insulated.

Preferably the heat storage material 21 is a phase change material which is arranged to solidify when cooled during the defrost cycle and to liquefy when heated during the refrigeration cycle. Phase change materials of this type can be based for example on paraffin wax. A phase change material of this type is strongly preferred for many applications because a given mass of such material can absorb a relatively large amount of heat energy and emit it again within a narrow temperature range. In less preferred embodiments, other thermal storage materials could be used to store heat in the target range without undergoing a phase change, although the quantity required would be commensurately greater.

10 The group of valves included in the module 16 includes a condensate valve V4 which is connected to the distributor 11 forming the defrost outlet of the evaporator by a condensate conduit 20.

Conveniently, the group of valves included in the module 16 may also include a manifold supply valve V1, a manifold suction valve V2, and a defrost control valve V3, which are connected together as shown and controlled via control lines 27 by the valve control means 18 to selectively establish the refrigeration circuit during the refrigeration cycle, and a gravity defrost circuit during a defrost cycle in which the refrigerant is arranged to flow through the evaporator 3 from the defrost inlet formed by the header 12 to the defrost outlet formed by the header 11.

20 In the illustrated example, all three valves V1, V2, V3 are solenoid valves, but other types of valve may be used. It will be understood that in the illustrated configuration, the direction of flow of refrigerant through the evaporator and the heat store in the defrost cycle is opposite to the direction of flow in the refrigeration cycle, although in alternative embodiments the directions could be the same.

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The gravity defrost circuit includes a defrost supply conduit 28 which in the illustrated embodiment is connected at its lower end to a T junction between the manifold suction valve V2 and the defrost control valve V3 and at its upper end to the defrost inlet 12 of the evaporator. The defrost supply conduit serves to convey a flow of refrigerant as a vapour or two-phase flow through the defrost control valve V3 from the heat store 17 to the defrost inlet 12 of the evaporator during the defrost cycle, and during the refrigeration cycle to carry the refrigerant vapour flowing out of the evaporator via the header 12 back through the manifold

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suction valve V2 to the compressor. (Of course, separate conduits could be provided for these functions if desired.)

5 The module 16 is installed, optionally within the cold store or other refrigerated compartment if any, so that the heat store 17 and the condensate valve V4 are positioned as shown at a lower level than the evaporator 3. Advantageously, the condensate conduit 20 may also be arranged inside the refrigerated compartment and may be uninsulated, so that refrigerant will tend to condense inside it at the beginning of the defrost cycle. Preferably the condensate conduit 20 above the condensate valve V4 has a greater vertical dimension than the evaporator 3, which
10 helps to ensure that the gravity head is sufficient to drive the defrost cycle as further explained below. Conveniently the outer casing of the heat store is contained in an outer casing (not shown) of the module which also encloses the valves, wiring and flow connection components of the module, so that the whole module can simply be placed on the floor of the cold store underneath the evaporator and then connected to the existing pipework.

15 During the defrost cycle, V1 and V2 are closed, the expansion valve 9 is closed (e.g. responsive to a signal or responsive to the absence of the pressure gradient between the supply and suction manifolds), and V3 is opened so that the gravity defrost circuit comprising the evaporator, the heat store, and the conduits 20 and 28 is isolated from the compressor and
20 condenser. The refrigerant in the defrost circuit circulates repeatedly between the heat store and the evaporator. The heat contained in the heat store is much greater than the heat contained in the volume of circulating refrigerant, and is transferred very efficiently to the evaporator by the reversible phase change that occurs as the refrigerant boils in the heat store and then condenses again in the evaporator.

25 The beginning and end of the defrost cycle may be triggered for example by a timer or by sensors as known in the art. After the defrost cycle, the refrigeration cycle is re-established by closing V3 and opening V1 and V2. If the expansion valve 9 was closed by a signal then it is commanded to resume its normal function. Preferably V2 is opened initially in pulses so that
30 liquid refrigerant condensate is able to vaporise before it reaches the compressor. As the refrigeration cycle resumes, the refrigerant flowing from the supply manifold 4 via V1 down through the heat store and then up the conduit 26 through the expansion valve 9 into the evaporator will be cooled as it passes through the heat store, so that the initial temperature of

the evaporator is lower than it otherwise would be. This rapidly reverses any temperature excursion in the commodity contained in the refrigerated compartment (if any).

5 In this aspect, the invention recognises that in order to maintain a gravity circulation of refrigerant in the defrost circuit when the evaporator is not perfectly free draining, it is necessary to maintain the defrost cycle in what might be described as a state of dynamic disequilibrium. This is achieved as follows.

10 The condensate valve V4 is positioned at a lower level than the evaporator and arranged to permit a unidirectional flow of liquid refrigerant condensate in a condensate return flow direction D1 from the defrost outlet 11 of the evaporator via the condensate conduit 20 and the condensate valve V4 to the heat store 17 during the defrost cycle.

15 In the illustrated example, the condensate valve is a check valve which opens to permit flow in the condensate return flow direction D1. Preferably the check valve is normally open and is closeable by a negative pressure gradient in the condensate return flow direction. For example, the check valve may be biased by gravity to the open position. Alternatively the check valve may be biased by very light spring pressure to a just closed or neutral position so that it opens under a very slight positive pressure gradient in the condensate return flow direction. The check valve
20 closes to prevent reverse flow in the direction opposite to the condensate return flow direction D1.

Referring also to Figs. 4 and 5, the valve control means 18 is arranged to control the valve assembly 19 in use so as to establish or re-establish a column 6' of liquid refrigerant condensate
25 in the condensate conduit 20 above the condensate valve V4, sufficient to apply a positive pressure gradient in the condensate return flow direction D1 across the condensate valve, by regulating the flow of refrigerant to the evaporator defrost inlet 12 during the defrost cycle. The column may be discontinuous, comprising slugs of liquid refrigerant condensate which fill the bore of the condensate conduit as they travel down the condensate conduit towards the
30 condensate valve, or may be a static column 6' as shown which is replenished at its upper end by condensate droplets flowing down the condensate conduit from the evaporator condensate outlet 11 as it gradually leaks through the condensate valve V4 at its lower end.

The column of liquid refrigerant condensate in the condensate conduit 20 maintains a gravity head which acts in the direction D1 and which is opposed in the opposite direction by a force corresponding to the inertial pressure loss caused by acceleration of refrigerant vapour generated as the refrigerant boils in the heat store, and the frictional pressure loss caused by the resistance to the flow of refrigerant from the heat store through the defrost supply conduit 28 and the evaporator 3, which is particularly high closer to the heat store where this will be a two-phase flow. When these oppositely acting forces exceed the gravity head, the condensate valve V4 prevents flow in the direction opposite to the condensate return flow direction D1, and the refrigerant is driven by the energy contained in the heat store in the desired direction up the conduit 28 and through the evaporator in which the refrigerant vapour condenses as it loses heat by contact with the walls of the evaporator tubes 10, melting the ice on the outside of the tubes and fins. When the gravity head exceeds these oppositely acting forces, liquid refrigerant condensate flows down through the condensate valve V4 and enters the heat store where it boils and continues the cycle.

Fig. 4 shows the condition where the upper end 6'' of the column of liquid refrigerant condensate is high enough to apply a positive pressure gradient in the condensate return flow direction D1 across the condensate valve V4. In this state, the gravity head will drive the condensate down through the condensate valve V4 and any condensed refrigerant that has collected in the evaporator will be drawn out by the resulting pressure differential across the evaporator to replenish the column in the condensate conduit 20, so that the gravity circulation will continue. In practice, the upper end 6'' of the column of liquid refrigerant may extend higher than the position shown, up to the evaporator or even extending into the evaporator coils.

Fig. 5 shows the condition where the upper end 6'' of the column of liquid refrigerant condensate has fallen to a level that is insufficient to apply a positive pressure gradient in the condensate return flow direction D1 across the condensate valve V4. This could result for example from a large volume of condensate collecting in the liquid traps in the evaporator, or from a relatively small initial refrigerant charge in the heat store which has all been vaporised. In this state the valve control means 18 causes an intervention which regulates (i.e. controls or changes) the flow of refrigerant to the evaporator defrost inlet 12 so as to re-establish the column of liquid refrigerant condensate to a sufficient level to drive the condensate down

through the condensate valve V4 so that the gravity circulation will continue. Of course, such intervention could be arranged to occur before gravity circulation stops, so as to maintain the column at or above a minimum level throughout the defrost cycle.

- 5 The intervention can be accomplished in various ways, as follows.

In the illustrated embodiments, the valve assembly 19 is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle, both by controlling (by valve V3) a flowpath via conduit 28 from the heat store to the evaporator defrost inlet 12, and by
10 injecting refrigerant (from the supply manifold via valve V1, or alternatively via an additional TEV 30 as shown in Fig. 6) into the defrost circuit. In these and other embodiments, these interventions may be carried out alternately so that the flow from the heat store is controlled until the heat store is exhausted, and then the refrigerant is replenished in one or more pulses from the supply manifold. In alternative embodiments, only one of these strategies might be
15 adopted.

The valve V3 may be arranged to restrict or to intermittently close and open the flowpath via the conduit 28 during an initial phase of the defrost cycle in order to allow the condensate column to form, and to open the flowpath to permit continuous unrestricted flow during a
20 subsequent phase of the defrost cycle when a stable gravity circulation has become established. In a development, this sequence of operation may be repeated one, two, three or more times, wherein on each repetition of the sequence the column of liquid refrigerant condensate is re-established so as to initiate a new phase of the defrost cycle. The sequence may be triggered for example by a heat sensor, which may be arranged in the condensate return side of the defrost
25 circuit between the defrost outlet of the evaporator and the heat store, for example, at the condensate inlet 24 of the heat store or proximate (above or below) the condensate valve V4. In tests, this repeated sequence of operation is found to defrost higher frost loads by providing more complete transfer of the energy contained in the heat store.

30 Where the valve V3 is a solenoid valve or other valve type which is capable of opening and closing the flowpath, it may be arranged to deliver the refrigerant to the evaporator defrost inlet in a pulse or a series of pulses. In this way, the refrigerant can initially be released from the heat store in pulses of increasing duration so that it is completely or mostly vaporised by the

time it reaches the evaporator. This is advantageous because more heat is transferred by the phase change between liquid and gas than by the sensible heat contained in a particle of liquid refrigerant which is cooled by contact with the wall of the evaporator tubing.

- 5 When condensed refrigerant has accumulated in a liquid trap in the evaporator, it can be cleared by releasing a burst of refrigerant vapour from the heat store so that the sudden pressure change and sustained flow effectively blows the liquid refrigerant through the evaporator to the defrost outlet 11. To accomplish this, the valve V3 may be arranged to deliver the refrigerant to the evaporator defrost inlet 12 in a pulse or series of pulses followed by a
10 period of continuous flow of longer duration than each of said pulse or pulses.

- Alternatively or additionally, the valve assembly may be arranged to regulate the flow of refrigerant to the evaporator defrost inlet 12 during the defrost cycle by injecting refrigerant into the defrost circuit. Each injection of refrigerant will alter the dynamic (dis)equilibrium
15 within the defrost circuit and, by also preventing reverse flow through the condensate valve V4, can be used to urge flow in the desired direction to replenish the column of condensed refrigerant in the condensate conduit 20. The additional refrigerant will also increase the mass of refrigerant contained in the defrost circuit. This means that the initial volume of the defrost circuit may be smaller than that required to ensure a gravity circulation, and so in a system with
20 multiple evaporators which are defrosted sequentially, the total charge of refrigerant may be no greater than that required to accomplish gravity defrost in a single evaporator while the remaining evaporators are on the refrigeration cycle.

- The valve assembly may be arranged to inject refrigerant from the supply manifold via valve V1
25 into the defrost circuit in a pulse or a series of pulses. This can be accomplished by a timer, which could be programmed during initial installation of the module or commissioning of the system to suit the system characteristics, or by sensors which trigger an injection responsive to e.g. a temperature change or a change in the rate of temperature change at a particular part of the defrost circuit.

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Advantageously, the volume of the refrigerant conduit in the heat store may be no more than the volume of refrigerant injected in each pulse, so that more than one pulse is required to supply the mass of refrigerant required to maintain a self sustaining gravity defrost cycle. This is

particularly advantageous in a system with multiple evaporators, each with a heat store as described, because the total system volume which must be filled with refrigerant during the refrigeration cycle will include the volume of all of those heat stores. Consequently, by reducing the volume of the heat store to a minimum, the total refrigerant charge in the system also can
5 be greatly reduced.

Preferably the defrost circuit is filled during the course of the defrost cycle with a volume of liquid refrigerant equal to at least 50%, more preferably at least 55% of the total volume of the defrost circuit, i.e. the total volume isolated by closing valves V1 and V2. This is found to be
10 beneficial in starting and maintaining the gravity circulation.

The valve assembly may be arranged to inject refrigerant into the defrost circuit between the heat store and the evaporator defrost inlet via valve V1, in which case the injected refrigerant will begin to vaporise as it exits the valve V1, or alternatively between the condensate valve and
15 the heat store (which is to say, between the outlet of the condensate valve and the heat store), in which case the injected refrigerant will boil in the heat store before flowing to the evaporator.

In practice it is found that, particularly where the liquid supply manifold or connecting pipework
20 includes many bends or constrictions or where the pressure of the liquid refrigerant supply from the compressor fluctuates, the liquid refrigerant flowing to the heat store from the compressor may flash into vapour even before the defrost control valve V3 is opened, making it difficult to control the mass of liquid refrigerant entering the defrost circuit. To overcome this problem and provide more reliable operation of the defrost cycle, after closing the manifold suction
25 valve V2 at the beginning of the defrost cycle, and with the defrost control valve V3 closed, the manifold supply valve V1 may be opened or left open for an extended period of at least about 20 seconds, more preferably about 40 seconds, yet more preferably about 60 seconds, up to several minutes, to allow the heat exchanger within the heat store to become completely filled with liquid refrigerant before opening the defrost control valve V3. This provides more precise
30 control of the volume of refrigerant released into the evaporator when the defrost control valve V3 is opened for the first time to begin the defrost cycle.

- It will be noted that in the illustrated embodiments, the manifold suction valve V2 and defrost control valve V3 are depicted in an axially aligned, proximate arrangement. Surprisingly however it is found in trial installations that if the valves are physically configured in this way and V3 is opened so that the refrigerant flashes through V3 as a mixture of liquid and vapour, the momentum of the flash mixture (having significantly higher density than pure vapour) is sufficient to cause V2 to open momentarily with consequent loss of part of the refrigerant charge to the suction manifold. This is believed to be due to the use for V2 of a pilot operated valve with a relatively small orifice, reflecting the time delay required for the pressure to equalise across the diaphragm. To avoid this problem, the defrost control valve V3 may be arranged at a distance from the manifold suction valve V2 or separated from it by non-linear pipework. Alternatively or additionally, the defrost control valve V3 may be pulsed rapidly until the vapour pressure in the evaporator has risen to a sufficient value before opening V3 for a longer period or periods.
- In the embodiment of Fig. 6, the valve assembly includes an additional thermal expansion valve 30 for injecting refrigerant from the supply manifold 4 into the defrost circuit. The TEV 30 may be internally or externally equalised as known in the art and may be arranged as shown to inject refrigerant into the defrost circuit between the condensate valve and the heat store (which is to say, between the outlet of the condensate valve and the heat store) and controlled by a heat sensor 31 arranged in the vapour supply side of the defrost circuit, i.e. between the heat store and the evaporator defrost inlet. In this embodiment, the heat sensor of the thermal expansion valve acts as an element of the valve control means, and could even comprise the whole of the valve control means depending on how the rest of the valves are arranged.
- Fig. 6 illustrates two alternative positions for the heat sensor 31, either between the defrost vapour outlet 23 of the heat store and the defrost control valve V3, or on the conduit 28 between the defrost control valve V3 and the evaporator defrost inlet 12. In the event that the refrigerant charge in the heat store is exhausted, the temperature at the heat sensor 31 will drop, causing the valve 30 to open and more refrigerant to be admitted. The valve 30 will close again when refrigerant begins to flow from the heat store towards the evaporator.

Fig. 7 shows another embodiment in which an additional valve V5 is arranged to selectively connect the defrost circuit at a point proximate the evaporator defrost outlet 11 near the top of

the condensate conduit 20 with the suction manifold 5. Valve V5 can be opened responsive to a signal via another control line 27 from the valve control means 18 to momentarily increase the flow of refrigerant to the evaporator inlet 12 by applying suction pressure at the outlet 11, drawing condensed refrigerant out of the liquid traps in the evaporator and re-starting the gravity cycle. This can be followed by an injection of refrigerant into the defrost circuit either before or after the heat store.

In a development, the valve assembly may be arranged to facilitate the injection of refrigerant into the defrost outlet 11 of the evaporator, perhaps near the end of the defrost cycle, so as to apply additional heat to the portions of the evaporator tubes nearest the defrost outlet.

In another development, where a fan is provided to cause an airflow through the evaporator, the fan can be arranged to run in a forward or reverse direction, perhaps at reduced speed or in alternate directions, during the defrost cycle so as to transfer heat between different regions of the evaporator.

In the illustrated embodiments, the module 16 is arranged so that the metering device 9 is connected or connectable to a refrigerant flowpath through the heat store 17 in parallel (i.e. in parallel fluid flow arrangement, not necessarily in a physically parallel position) with the condensate valve V4 and condensate conduit 20 as shown. The metering device 9 may be arranged as shown, proximate the evaporator at an upper end of a refrigeration supply conduit 26 which connects it to the heat store. This advantageously provides that all of the refrigerant in the supply to the metering device 9 at the beginning of the defrost cycle will expand through the heat store and then flow through the evaporator and collect in the condensate conduit 20 to form part of the gravity circulation.

In the examples shown, the expansion valve 9 is electronically controlled and an additional control line 27 is used to close it responsive to a signal from the valve control means 18 so as to close the refrigeration circuit and establish the defrost circuit. Alternatively, and particularly if the metering device 9 is not an electronically controlled TEV, an additional solenoid valve may be present in series with the metering device 9, which may similarly be controlled by the valve control means 18 to close the flowpath through the metering device 9 so as to transition from the refrigeration cycle to the defrost cycle. Many alternative arrangements are possible,

including for example arrangements in which an additional check valve or solenoid valve is arranged in parallel with the metering device 9 to form part of the defrost circuit, or arrangements in which the metering device is arranged to open automatically when a positive pressure gradient is established across it in the condensate return flow direction D1, but to
5 close under a negative pressure gradient less than the supply pressure in the supply manifold. In such arrangements the conduit 26 may not be provided, and the metering device 9 may be arranged instead at the top of the condensate conduit 20 so that the condensate conduit 20 is full of liquid refrigerant at the beginning of the defrost cycle, or at the bottom of the condensate conduit 20, in which case the metering device 9 may be arranged also to function as
10 the condensate valve V4. In both cases the condensate conduit would function also to supply refrigerant to the evaporator during the refrigeration cycle.

In alternative embodiments the condensate valve could be a solenoid valve arranged to close when a sensor or sensors indicate that the positive pressure gradient is absent, which is to say,
15 when there is a negative pressure gradient or no pressure gradient across the valve in the condensate return flow direction D1. Such indication could be an analogue of the pressure condition, e.g. by sensing temperature indicative of the nature of the flow in the condensate conduit. In yet further embodiments the condensate valve could even be integrated into the metering device which is located at the lower end of the condensate conduit and electrically
20 controllable to provide the functions of both devices as previously described. In yet further alternative embodiments, the condensate valve V4 could be in series with the metering device 9 which is arranged to permit gravity flow in the condensate return flow direction D1, with the condensate valve V4 being arranged also to permit flow in the direction opposite to D1 so as to supply refrigerant to the metering device 9 during the refrigeration cycle while preventing flow
25 in the direction opposite to D1 during the defrost cycle.

In embodiments where the valve control means is electronic, it may be software which in use is run on a processor forming part of the refrigeration system, or may include electronic hardware such as a processor and/or a memory which forms part the retrofit module or refrigeration
30 apparatus. For example, the module or apparatus may comprise the heat store and valve assembly together with a data carrier on which the valve control means is stored, or a body of data comprising the valve control means which is located on a remote server, perhaps being downloaded during installation of the module or apparatus. The valve control means could

simply be connection hardware for connecting the valves to an existing control system of the legacy refrigeration system in such a way as to implement the required functions, or could be arranged to carry out the required functions when connected to a power supply or to an electrical control system of the complete refrigeration system of which it forms a part in use.

- 5 Alternatively the valve control means could be a mechanical control system. The valve control means may be programmed or otherwise adapted for optimal performance during installation and commissioning of the various parts of the adapted refrigeration system.

- 10 In this specification, a metering device is any device for controlling the flow of refrigerant into the evaporator. It will usually be an expansion valve, typically a TEV, which could be mechanically controlled by a sensor, usually located at the evaporator outlet, and either internally or externally equalised, or electronically controlled by one or more sensors and/or by a processor forming part of the refrigeration system. The TEV comprising the metering device may also be arranged to close or open in response to a command signal so as to form a part of the valve arrangement which establishes the defrost circuit. Alternatively, the metering device
15 could be simply an orifice plate or other flow restrictor for restricting or regulating the flow of refrigerant into the evaporator, arranged if necessary in series with another valve or valves to prevent undesired flow through the conduit 26 during the defrost cycle. Alternatively, the metering device could be another type of valve, e.g. a float valve or solenoid valve, which may
20 be used for example if the evaporator is a flooded evaporator for controlling the flow of refrigerant directly or via a receiver into the flooded evaporator.

- Advantageously, e.g. by connecting the valve control system to all of the evaporators or by using a timer, the defrost cycles of all of the evaporators can be sequenced so that only one or
25 two evaporators are defrosted at any one time, which minimises the refrigerant charge in the system. Of course, the legacy refrigeration system could comprise just one evaporator rather than a group of evaporators fed from a manifold.

- In alternative embodiments, rather than being configured as a retrofit unit for use in converting
30 a legacy refrigeration system, the system already described and exemplified by Figs. 3 - 7 may be manufactured as a complete original refrigeration system (configured for example as a refrigerated display cabinet, a heat pump, or any other refrigeration apparatus), including the valve assembly and valve control means, the heat store, a compressor and a condenser, either

with a single evaporator or with multiple evaporators (optionally, each having a respective heat store and valved to implement a gravity defrost cycle as previously described) connected to the compressor and condenser by supply and suction manifolds.

- 5 In yet further embodiments, the system already described and exemplified by Figs. 3 - 7 may be manufactured as a complete original refrigeration unit (configured for example as a refrigerated display cabinet or a freezer) including the evaporator, heat store and valve control means and at least a group of valves as described above, so that the unit can be connected to the supply and suction manifolds of an existing refrigeration system including a compressor, condenser and optionally further valves. The unit may then function as previously described with the group of valves forming part of the valve assembly of the system which implements the gravity defrost cycle in use.

15 In practice it is common for the conduits or tubes 10 of the evaporator to be arranged one above the other so that they are connected at different heights to the defrost inlet and outlet, and it is believed that this gives rise to the problem earlier mentioned whereby the uppermost tubes will often tend to defrost more quickly than the lower tubes. This may be due in part to the ice water which flows over the lower tubes from the melting frost on the upper tubes, and when observed in systems adapted in accordance with the above described embodiments may also reflect the tendency of the liquid condensate column, which is somewhat higher at its point of connection to the uppermost tubes 10, to draw condensate preferentially from the uppermost tubes.

25 It is possible of course to arrange the conduits of the evaporator in horizontally spaced relation so that the defrost inlet and outlet connections are positioned at the same height and the meltwater does not flow from the upper to the lower coils. This however may require replacement of the evaporator in a legacy system.

30 Turning now to a further aspect of the invention and referring to Figs. 8 and 9, as also shown in the foregoing figures, the defrost inlet 12 typically comprises a conduit 112 having an upper end 112' and a lower end 112'', with the tubes or conduits 10 being connected to the conduit 112 between its upper and lower ends so that the conduit 112 acts as a manifold or header through which the flow of refrigerant is divided or recombined as it enters or exits the tubes 10.

Although the defrost inlet 12 of the earlier described embodiments is illustrated with the suction line connection in a vertically median position with respect to the tubes or conduits 10, it is found in practice that the connection to the suction line to the compressor (provided by the suction manifold 5 in the illustrated embodiments) is typically positioned at the lower end 112'' of the defrost manifold, since in that position any lubricating oil entrained in the refrigerant and flowing to the bottom of the conduit 112 is able to return via the suction line to the compressor without becoming trapped in the evaporator.

It is found that when the defrost supply conduit 28 is connected at one end of the conduit 112, the mass flow rate of refrigerant during the defrost cycle tends to be higher through the tubes or conduits 10 connected to the further end of the conduit 112 than through those connected to the nearer end of the conduit 112, due to the relatively higher pressure developed at the further end of the conduit 112 as the flow velocity decreases along its length.

Conveniently, the defrost supply conduit 28 may be connected to the conduit 112 at the same point as the suction line. However, since in the conventional arrangement the suction line is connected at the lower end 112'', this results in relatively higher flow rate through the upper tubes 10 which for this reason as well as the reasons mentioned above tend to defrost more quickly than the lower tubes.

It is found that by connecting the defrost supply conduit 28 instead to the upper end 112' of the defrost inlet 12, as illustrated for example in Figs. 8 and 9, the pressure gradient along the length of the conduit 112 improves the flow rate of refrigerant during the defrost cycle through the lower tubes 10 relative to the upper tubes 10, which tends to counteract the tendency of the upper tubes 10 to defrost faster than the lower tubes 10, so that the overall time required to the defrost the evaporator is reduced.

The system of Figs. 8 and 9 is generally as described with reference to the earlier embodiments, with the refrigerant being arranged to flow during the defrost cycle from a heat source (which however need not necessarily be a heat store 17 as illustrated and as earlier described), through the evaporator from the defrost inlet to the defrost outlet and then by gravity back to the heat source without passing through the compressor.

In the example of Fig. 8 the suction line is connected to the lower end of the defrost inlet so that lubricating oil can flow back to the compressor without becoming trapped in the evaporator, with separate pipework connecting the evaporator to each of the valves V2 and V3 within the retrofit module.

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Fig. 9 shows an alternative arrangement in which the suction line and the defrost supply conduit are both connected to the upper end 112' of the defrost inlet, and the lower end 112'' of the defrost inlet is connected to the suction line via a capillary connection 100, which is to say, a connection which is large enough to allow lubricating oil to return to the compressor but too small to provide a significant flowpath for the refrigerant. In the illustrated embodiment the capillary connection is a capillary tube as well known in the art, and the defrost supply conduit 28 and the suction line via the suction manifold 5 are combined at the T connection between V2 and V3, so that, advantageously, only one pipe is required to connect V2 and V3 to the evaporator with the capillary tube 100 being connected to the combined pipe. In alternative
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embodiments the suction line and defrost supply conduit could be separate and connected together only at the upper end 112' of the conduit 112.

In yet further embodiments other means may be adopted to apportion the flow of refrigerant between the tubes 10 during the defrost cycle. For example, each tube 10 could project through a small distance into the conduit 112, with the projecting ends of the tubes 10 being arranged to form an array of scoops which intercept the flow of refrigerant. The tubes 10 could also be crimped or otherwise formed so as to adjust the flow resistance of each tube to compensate for the pressure gradient in the conduit 112.
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The novel defrost inlet connection arrangement may advantageously be used as an adaptation in any of the embodiments earlier described, wherein the heat source for the gravity defrost cycle is a heat store arranged in series with the liquid refrigerant supply to the evaporator during the refrigeration cycle. It will be understood however that it may also be used to improve the operation of a gravity defrost cycle in other refrigeration systems which do not include all the features of the earlier described embodiments. For example, it may be used in systems without a condensate valve, without any means for establishing a column of liquid refrigerant condensate, or without any means for regulating the supply of refrigerant to the defrost header during the gravity defrost cycle. It may be used in systems without a heat store
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as provided in the earlier described embodiments, for example, where the refrigerant flowing in the gravity defrost cycle transports heat to the evaporator from another heat source such as a receiver containing refrigerant (whether arranged in series with the evaporator or otherwise) or an electrically heated heat exchanger.

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In summary, a preferred embodiment provides a condensate valve arranged at the lower end of a condensate conduit forming part of a cool gas gravity circuit for recirculating refrigerant between a heat store and an evaporator during a defrost cycle. A valve assembly is arranged to maintain a column of liquid refrigerant condensate in the condensate conduit above the

10 condensate valve, sufficient to apply a positive pressure gradient in the condensate return flow direction across the condensate valve, by regulating the flow of refrigerant to the evaporator defrost inlet during the defrost cycle. In other aspects, more even and rapid cool gas defrosting is achieved by arranging the cool gas defrost connection at an upper end of the defrost inlet manifold of the evaporator.

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It will be understood that in each aspect of the invention, the valve assembly need not be configured exactly as shown in the illustrated embodiments; many further adaptations within the scope of the claims will be evident to those skilled in the art.

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CLAIMS

1. A retrofit module for use in implementing a defrost cycle in a refrigeration system;
5 the module comprising at least a heat store, a group of valves, and a valve control means;
the module being connectable to form a part of a refrigeration system which includes at least a compressor, a condenser, a refrigerant, and an evaporator, the evaporator having a defrost inlet and a defrost outlet, so that in use said valves form at least a part of a valve
10 assembly of the refrigeration system;
the valve assembly including said group of valves being operable in use to selectively establish a refrigeration circuit during a refrigeration cycle, and a gravity defrost circuit during a defrost cycle in which the refrigerant is arranged to flow through the evaporator from the defrost inlet to the defrost outlet;
- 15 the heat store comprising a body of heat storage material arranged to be thermally coupled to the refrigerant in use so that the refrigerant flows through the refrigeration circuit from the compressor via the condenser and the heat store to the evaporator and then from the evaporator back to the compressor during the refrigeration cycle;
the gravity defrost circuit including a defrost supply conduit for conveying a flow of
20 refrigerant from the heat store to the defrost inlet of the evaporator, and
a condensate valve connected to the defrost outlet of the evaporator by a condensate conduit and arranged to permit a unidirectional flow of liquid refrigerant condensate in a condensate return flow direction from the defrost outlet of the evaporator via the condensate conduit and the condensate valve to the heat store during the defrost cycle;
- 25 wherein the heat store and the condensate valve are arranged to be at a lower level than the evaporator in use;
and wherein the valve control means is arranged to control the valve assembly in use so as to establish or re-establish a column of liquid refrigerant condensate in the condensate conduit above the condensate valve, sufficient to apply a positive pressure gradient in the
30 condensate return flow direction across the condensate valve, by regulating the flow of refrigerant to the evaporator defrost inlet during the defrost cycle.

2. A retrofit module according to claim 1, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by controlling a flowpath from the heat store to the evaporator defrost inlet.
- 5 3. A retrofit module according to claim 2, wherein the valve assembly is arranged to restrict or to intermittently close and open said flowpath during an initial phase of the defrost cycle and to open the flowpath to permit continuous unrestricted flow during a subsequent phase of the defrost cycle.
- 10 4. A retrofit module according to claim 2, wherein the valve assembly is arranged to deliver the refrigerant to the evaporator defrost inlet in a pulse or a series of pulses.
5. A retrofit module according to claim 2, wherein the valve assembly is arranged to deliver the refrigerant to the evaporator defrost inlet in a pulse or series of pulses followed by a
- 15 period of continuous flow of longer duration than each of said pulse or pulses.
6. A retrofit module according to claim 1, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by injecting refrigerant into the defrost circuit.
- 20 7. A retrofit module according to claim 6, wherein the valve assembly is arranged to inject refrigerant into the defrost circuit in a pulse or a series of pulses.
8. A retrofit module according to claim 6, wherein the valve assembly is arranged to inject
- 25 refrigerant into the defrost circuit between the heat store and the evaporator defrost inlet.
9. A retrofit module according to claim 6, wherein the valve assembly is arranged to inject refrigerant into the defrost circuit between the condensate valve and the heat store.
- 30 10. A retrofit module according to claim 6, wherein the valve assembly includes a thermal expansion valve for injecting refrigerant into the defrost circuit

11. A retrofit module according to claim 10, wherein the thermal expansion valve is arranged to inject refrigerant into the defrost circuit between the condensate valve and the heat store and controlled by a heat sensor arranged between the heat store and the evaporator defrost inlet.

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12. A retrofit module according to claim 1, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by controlling a flowpath from the heat store to the evaporator defrost inlet and by injecting refrigerant into the defrost circuit.

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13. A retrofit module according to claim 1, wherein the condensate valve is a check valve which opens to permit flow in the condensate return flow direction.

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14. A retrofit module according to claim 13, wherein the check valve is normally open and is closeable by a negative pressure gradient in the condensate return flow direction.

15. A retrofit module according to claim 1, wherein the refrigeration circuit includes a metering device for controlling a flow of refrigerant entering the evaporator during the refrigeration cycle;

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and the module is arranged so that the metering device is connected or connectable to a refrigerant flowpath through the heat store in parallel with the condensate valve and condensate conduit.

16. A retrofit module according to claim 1, wherein the heat storage material is a phase change material which is arranged to solidify when cooled during the defrost cycle and to liquefy when heated during the refrigeration cycle.

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17. A refrigeration apparatus comprising at least an evaporator, a heat store, a group of valves, and a valve control means;

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said apparatus being arranged to form in use at least a part of a refrigeration system, the system further including at least a compressor, a condenser, and a refrigerant, so that in use said valves form at least a part of a valve assembly of the refrigeration system;

the evaporator having a defrost inlet and a defrost outlet;

the valve assembly including said group of valves being operable in use to selectively establish a refrigeration circuit during a refrigeration cycle, and a gravity defrost circuit during a defrost cycle in which the refrigerant is arranged to flow through the evaporator from the defrost inlet to the defrost outlet;

the heat store comprising a body of heat storage material arranged to be thermally coupled to the refrigerant in use so that the refrigerant flows through the refrigeration circuit from the compressor via the condenser and the heat store to the evaporator and then from the evaporator back to the compressor during the refrigeration cycle;

the gravity defrost circuit including a defrost supply conduit for conveying a flow of refrigerant from the heat store to the defrost inlet of the evaporator;

said group of valves including a condensate valve, the condensate valve being connected to the defrost outlet of the evaporator by a condensate conduit and arranged to permit a unidirectional flow of liquid refrigerant condensate in a condensate return flow direction from the defrost outlet of the evaporator via the condensate conduit and the condensate valve to the heat store during the defrost cycle;

wherein the heat store and the condensate valve are arranged at a lower level than the evaporator;

and wherein the valve control means is arranged to control the valve assembly in use so as to establish or re-establish a column of liquid refrigerant condensate in the condensate conduit above the condensate valve, sufficient to apply a positive pressure gradient in the condensate return flow direction across the condensate valve, by regulating the flow of refrigerant to the evaporator defrost inlet during the defrost cycle.

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18. A refrigeration apparatus according to claim 17, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by controlling a flowpath from the heat store to the evaporator defrost inlet.

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19. A refrigeration apparatus according to claim 18, wherein the valve assembly is arranged to restrict or to intermittently close and open said flowpath during an initial phase of the defrost cycle and to open the flowpath to permit continuous unrestricted flow during a subsequent phase of the defrost cycle.

20. A refrigeration apparatus according to claim 18, wherein the valve assembly is arranged to deliver the refrigerant to the evaporator defrost inlet in a pulse or a series of pulses.

5 21. A refrigeration apparatus according to claim 18, wherein the valve assembly is arranged to deliver the refrigerant to the evaporator defrost inlet in a pulse or series of pulses followed by a period of continuous flow of longer duration than each of said pulse or pulses.

10 22. A refrigeration apparatus according to claim 17, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by injecting refrigerant into the defrost circuit.

23. A refrigeration apparatus according to claim 22, wherein the valve assembly is arranged to inject refrigerant into the defrost circuit in a pulse or a series of pulses.

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24. A refrigeration apparatus according to claim 22, wherein the valve assembly is arranged to inject refrigerant into the defrost circuit between the heat store and the evaporator defrost inlet.

20 25. A refrigeration apparatus according to claim 22, wherein the valve assembly is arranged to inject refrigerant into the defrost circuit between the condensate valve and the heat store.

26. A refrigeration apparatus according to claim 22, wherein the valve assembly includes a thermal expansion valve for injecting refrigerant into the defrost circuit

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27. A refrigeration apparatus according to claim 26, wherein the thermal expansion valve is arranged to inject refrigerant into the defrost circuit between the condensate valve and the heat store and controlled by a heat sensor arranged between the heat store and the evaporator defrost inlet.

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28. A refrigeration apparatus according to claim 17, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by

controlling a flowpath from the heat store to the evaporator defrost inlet and by injecting refrigerant into the defrost circuit.

29. A refrigeration apparatus according to claim 17, wherein the condensate valve is a
5 check valve which opens to permit flow in the condensate return flow direction.

30. A refrigeration apparatus according to claim 29, wherein the check valve is normally open and is closeable by a negative pressure gradient in the condensate return flow direction.

10 31. A refrigeration apparatus according to claim 17, wherein the condensate conduit is arranged inside a refrigerated compartment.

32. A refrigeration apparatus according to claim 17, wherein the condensate conduit has a greater vertical dimension than the evaporator.

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33. A refrigeration apparatus according to claim 17, wherein the evaporator is configured to form liquid traps between the defrost inlet and the defrost outlet.

34. A refrigeration apparatus according to claim 17, wherein the refrigeration circuit
20 includes a metering device for controlling a flow of refrigerant entering the evaporator during the refrigeration cycle;

and the metering device is connected to a refrigerant flowpath through the heat store in parallel with the condensate valve and condensate conduit.

25 35. A refrigeration apparatus according to claim 17, wherein the heat storage material is a phase change material which is arranged to solidify when cooled during the defrost cycle and to liquefy when heated during the refrigeration cycle.

36. A method of implementing a defrost cycle in a refrigeration system, the system
30 including a compressor, a condenser, an evaporator, a valve assembly, a refrigerant, and a heat store comprising a body of heat storage material, the evaporator having a defrost inlet and a defrost outlet; the method comprising:

arranging the valve assembly to selectively establish a refrigeration circuit during a refrigeration cycle, and a gravity defrost circuit during a defrost cycle in which the refrigerant is arranged to flow through the evaporator from the defrost inlet to the defrost outlet,

the gravity defrost circuit including a defrost supply conduit for conveying a flow of
5 refrigerant from the heat store to the defrost inlet of the evaporator;

arranging the body of heat storage material to be thermally coupled to the refrigerant so that the refrigerant flows through the refrigeration circuit from the compressor via the condenser and the heat store to the evaporator and then from the evaporator back to the compressor during the refrigeration cycle;

10 providing a condensate valve, the condensate valve being connected to the defrost outlet of the evaporator by a condensate conduit and arranged to permit a unidirectional flow of liquid refrigerant condensate in a condensate return flow direction from the defrost outlet of the evaporator via the condensate conduit and the condensate valve to the heat store during the defrost cycle;

15 arranging the heat store and the condensate valve at a lower level than the evaporator; and controlling the valve assembly so as to establish or re-establish a column of liquid refrigerant condensate in the condensate conduit above the condensate valve, sufficient to apply a positive pressure gradient in the condensate return flow direction across the condensate valve, by regulating the flow of refrigerant to the evaporator defrost inlet during the
20 defrost cycle.

37. A method according to claim 36, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by controlling a flowpath from the heat store to the evaporator defrost inlet.

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38. A method according to claim 37, wherein the valve assembly is arranged to restrict or to intermittently close and open said flowpath during an initial phase of the defrost cycle and to open the flowpath to permit continuous unrestricted flow during a subsequent phase of the defrost cycle.

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39. A method according to claim 37, wherein the valve assembly is arranged to deliver the refrigerant to the evaporator defrost inlet in a pulse or a series of pulses.

40. A method according to claim 37, wherein the valve assembly is arranged to deliver the refrigerant to the evaporator defrost inlet in a pulse or series of pulses followed by a period of continuous flow of longer duration than each of said pulse or pulses.
- 5 41. A method according to claim 36, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by injecting refrigerant into the defrost circuit.
42. A method according to claim 41, wherein the valve assembly is arranged to inject
10 refrigerant into the defrost circuit in a pulse or a series of pulses.
43. A method according to claim 41, wherein the valve assembly is arranged to inject refrigerant into the defrost circuit between the heat store and the evaporator defrost inlet.
- 15 44. A method according to claim 41, wherein the valve assembly is arranged to inject refrigerant into the defrost circuit between the condensate valve and the heat store.
45. A method according to claim 41, wherein the valve assembly includes a thermal expansion valve for injecting refrigerant into the defrost circuit
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46. A method according to claim 45, wherein the thermal expansion valve is arranged to inject refrigerant into the defrost circuit between the condensate valve and the heat store and controlled by a heat sensor arranged between the heat store and the evaporator defrost inlet.
- 25 47. A method according to claim 36, wherein the valve assembly is arranged to regulate the flow of refrigerant to the evaporator defrost inlet during the defrost cycle by controlling a flowpath from the heat store to the evaporator defrost inlet and by injecting refrigerant into the defrost circuit.
- 30 48. A method according to claim 36, wherein the condensate valve is a check valve which opens to permit flow in the condensate return flow direction.

49. A method according to claim 48, wherein the check valve is normally open and is closeable by a negative pressure gradient in the condensate return flow direction.

50. A method according to claim 36, wherein the condensate conduit is arranged inside a refrigerated compartment.

51. A method according to claim 36, wherein the condensate conduit has a greater vertical dimension than the evaporator.

52. A method according to claim 36, wherein the evaporator is configured to form liquid traps between the defrost inlet and the defrost outlet.

53. A method according to claim 36, wherein the refrigeration circuit includes a metering device for controlling a flow of refrigerant entering the evaporator during the refrigeration cycle;

and the metering device is connected to a refrigerant flowpath through the heat store in parallel with the condensate valve and condensate conduit.

54. A method according to claim 36, wherein the heat storage material is a phase change material which is arranged to solidify when cooled during the defrost cycle and to liquefy when heated during the refrigeration cycle.

55. A retrofit module for use in implementing a defrost cycle in a refrigeration system; the module comprising at least a group of valves, and a valve control means;

the module being connectable to form a part of a refrigeration system which includes at least a compressor, a condenser, a refrigerant, an evaporator, and a heat source, the evaporator comprising a plurality of conduits fluidly connected together at a defrost inlet and a defrost outlet, so that in use said valves form at least a part of a valve assembly of the refrigeration system;

the valve assembly including said group of valves being operable in use to selectively establish :

a refrigeration circuit during a refrigeration cycle in which the refrigerant is arranged to flow through the refrigeration circuit from the compressor via the condenser to the evaporator and then from the defrost inlet of the evaporator via a suction line back to the compressor, and

5 a gravity defrost circuit during a defrost cycle in which the refrigerant is arranged to flow from the heat source through the evaporator from the defrost inlet to the defrost outlet and then by gravity back to the heat source without passing through the compressor;

the gravity defrost circuit including a defrost supply conduit for conveying a flow of refrigerant from the heat source to the defrost inlet of the evaporator;

10 wherein the defrost inlet comprises a conduit having an upper end and a lower end, and the defrost supply conduit is connected to the upper end of the defrost inlet.

56. A retrofit module according to claim 55, wherein the suction line is connected to the lower end of the defrost inlet.

15 57. A retrofit module according to claim 55, wherein the suction line and the defrost supply conduit are both connected to the upper end of the defrost inlet, and the lower end of the defrost inlet is connected to the suction line via a capillary connection.

20 58. A refrigeration apparatus comprising at least an evaporator, a group of valves, and a valve control means;

said apparatus being arranged to form in use at least a part of a refrigeration system, the system further including at least a compressor, a condenser, a heat source, and a refrigerant, so that in use said valves form at least a part of a valve assembly of the refrigeration system;

25 the evaporator comprising a plurality of conduits fluidly connected together at a defrost inlet and a defrost outlet;

the valve assembly including said group of valves being operable in use to selectively establish :

30 a refrigeration circuit during a refrigeration cycle in which the refrigerant is arranged to flow through the refrigeration circuit from the compressor via the condenser to the evaporator and then from the defrost inlet of the evaporator via a suction line back to the compressor, and

a gravity defrost circuit during a defrost cycle in which the refrigerant is arranged to flow from the heat source through the evaporator from the defrost inlet to the defrost outlet and then by gravity back to the heat source without passing through the compressor;

the gravity defrost circuit including a defrost supply conduit for conveying a flow of
5 refrigerant from the heat source to the defrost inlet of the evaporator;

wherein the defrost inlet comprises a conduit having an upper end and a lower end,
and the defrost supply conduit is connected to the upper end of the defrost inlet.

59. A refrigeration apparatus according to claim 58, wherein the suction line is connected to
10 the lower end of the defrost inlet.

60. A refrigeration apparatus according to claim 58, wherein the suction line and the
defrost supply conduit are both connected to the upper end of the defrost inlet, and the lower
end of the defrost inlet is connected to the suction line via a capillary connection.

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61. A method of implementing a defrost cycle in a refrigeration system, the system
including a compressor, a condenser, an evaporator, a valve assembly, a refrigerant, and a heat
source, the evaporator comprising a plurality of conduits fluidly connected together at a defrost
inlet and a defrost outlet, the defrost inlet comprising a conduit having an upper end and a
20 lower end, the method comprising:

arranging the valve assembly to selectively establish:

a refrigeration circuit during a refrigeration cycle in which the refrigerant is arranged to
flow through the refrigeration circuit from the compressor via the condenser to the evaporator
and then from the defrost inlet of the evaporator via a suction line back to the compressor, and

25 a gravity defrost circuit during a defrost cycle in which the refrigerant is arranged to
flow from the heat source through the evaporator from the defrost inlet to the defrost outlet
and then by gravity back to the heat source without passing through the compressor;

and arranging a defrost supply conduit to convey a flow of refrigerant from the heat
source to the defrost inlet of the evaporator during the defrost cycle;

30 wherein the defrost supply conduit is connected to the upper end of the defrost inlet.

62. A method according to claim 61, wherein the suction line is connected to the lower end
of the defrost inlet.

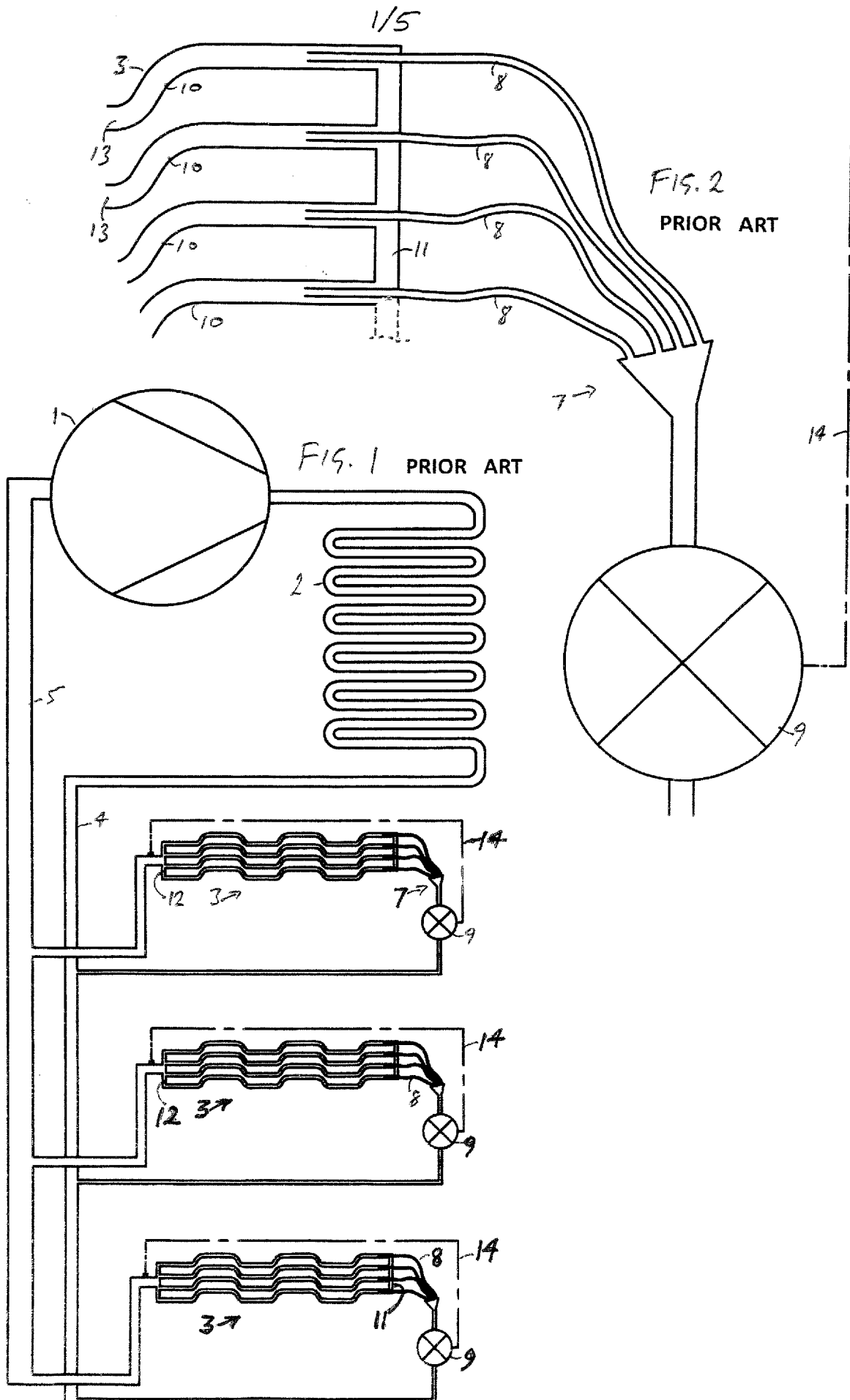
63. A method according to claim 61, wherein the suction line and the defrost supply conduit are both connected to the upper end of the defrost inlet, and the lower end of the defrost inlet is connected to the suction line via a capillary connection.

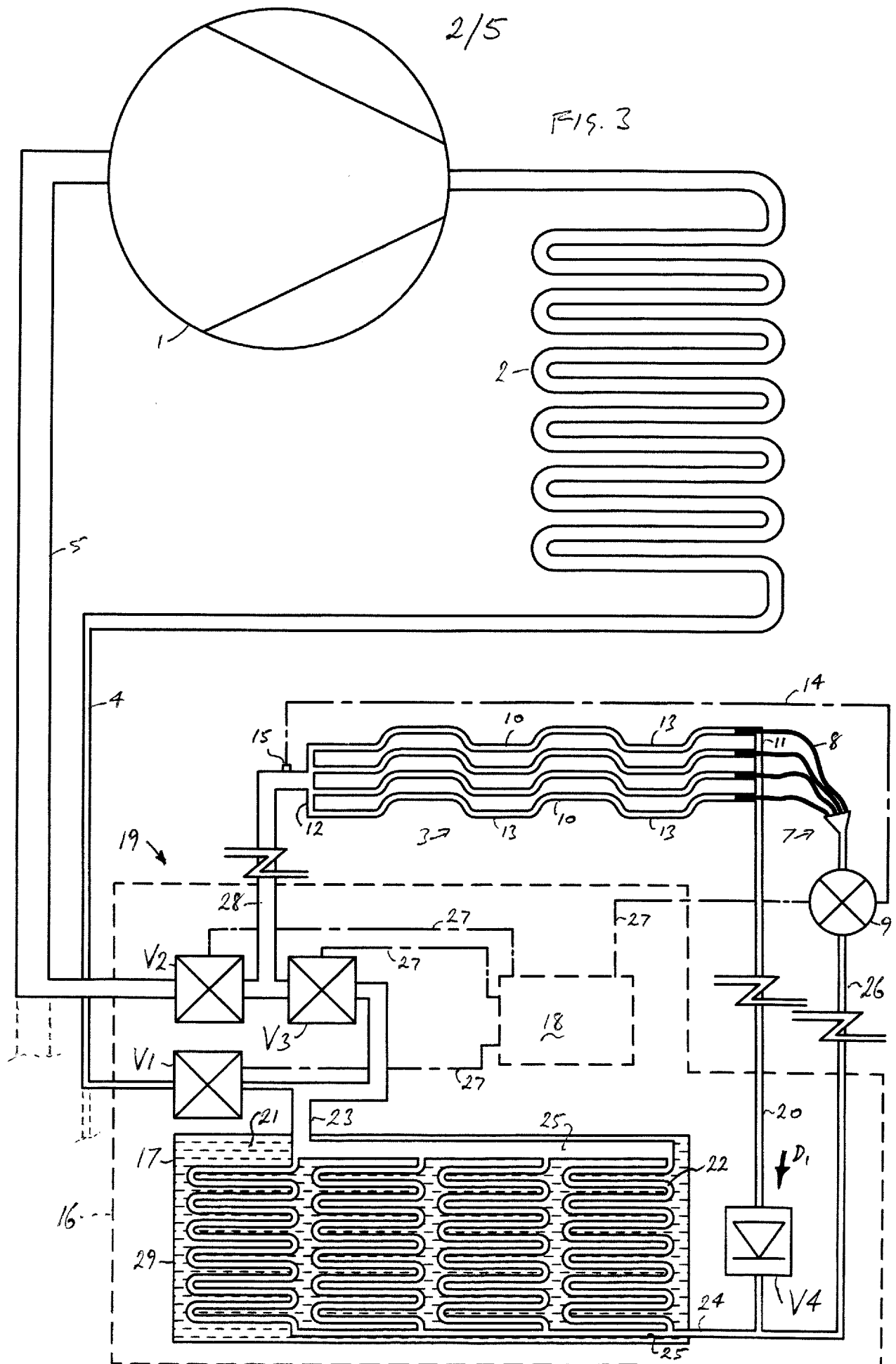
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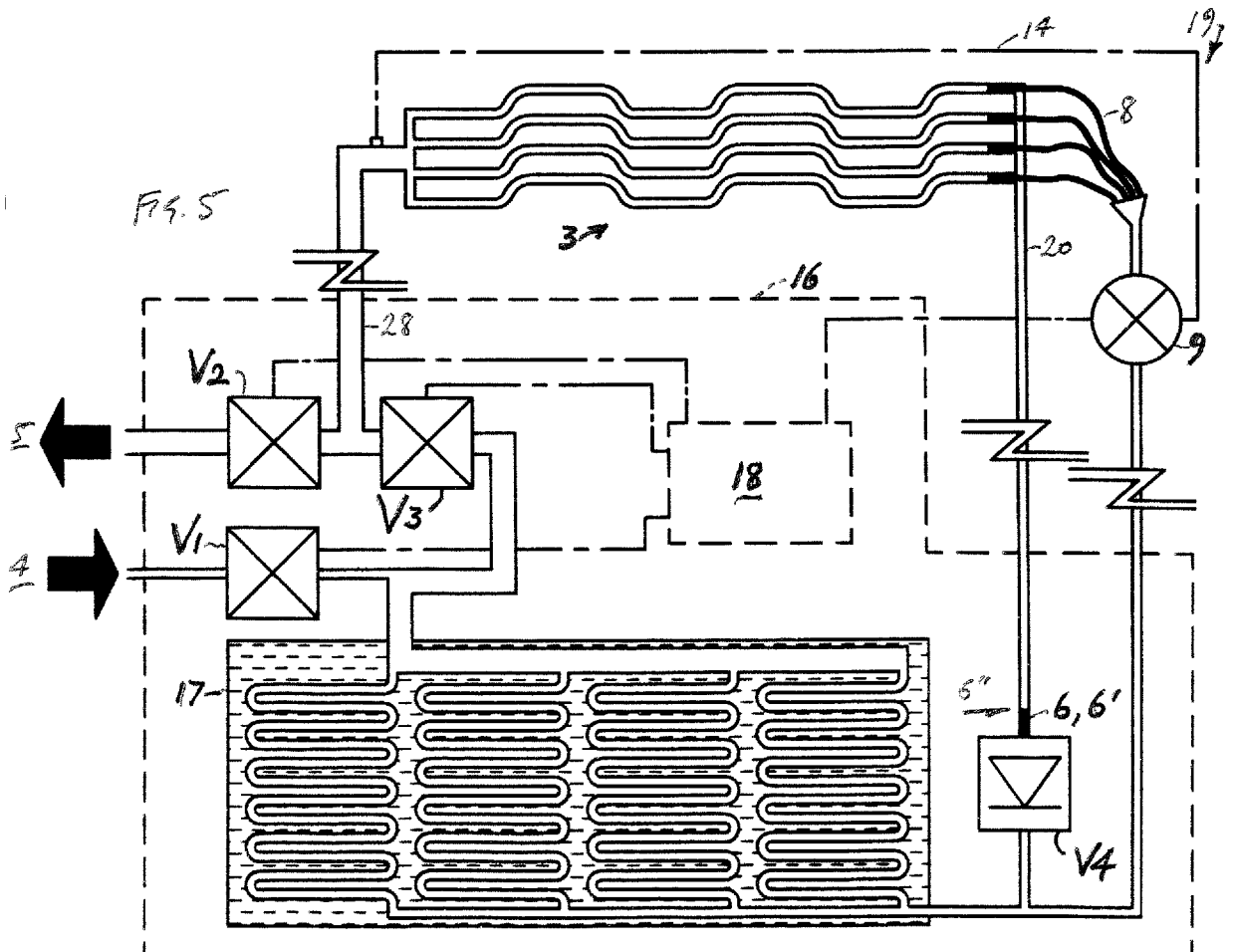
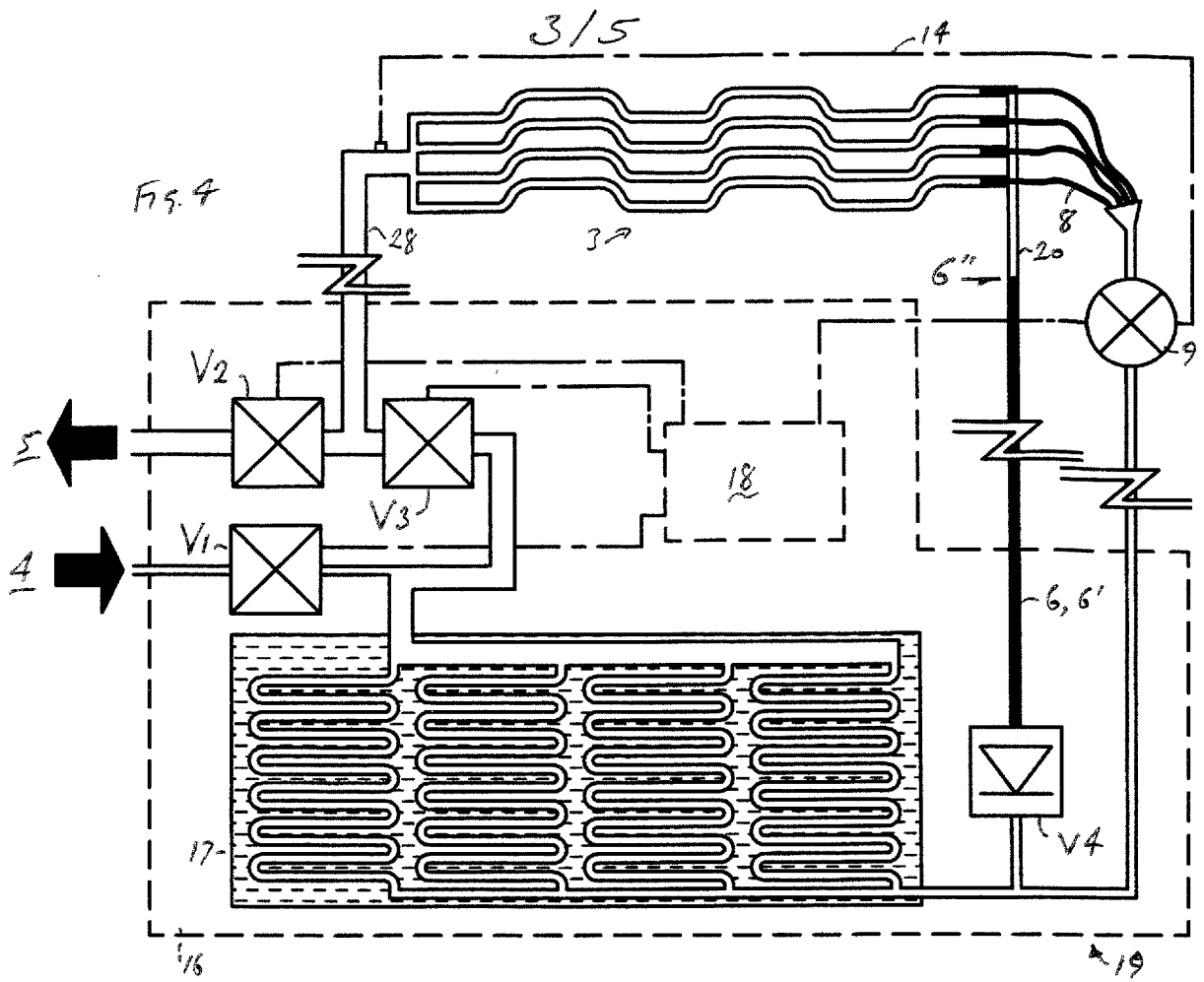
64. A retrofit module substantially as described with reference to the drawings.

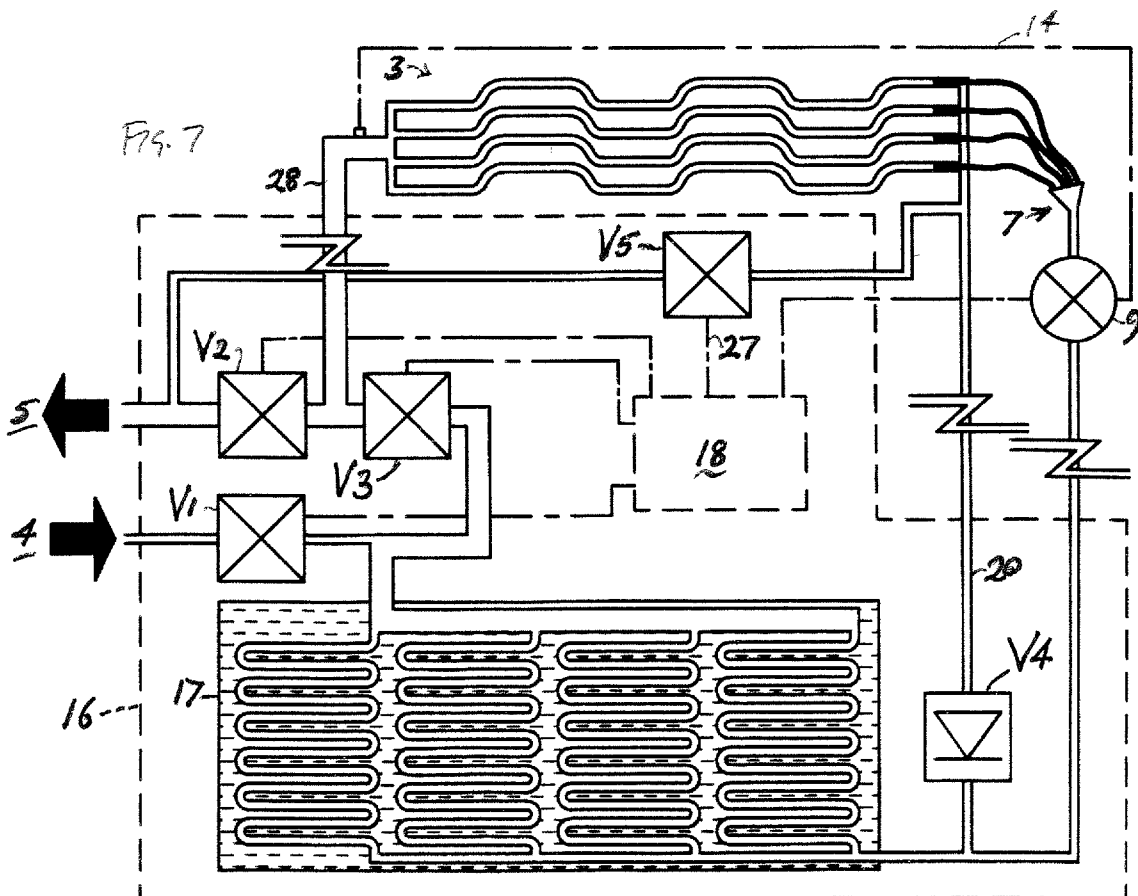
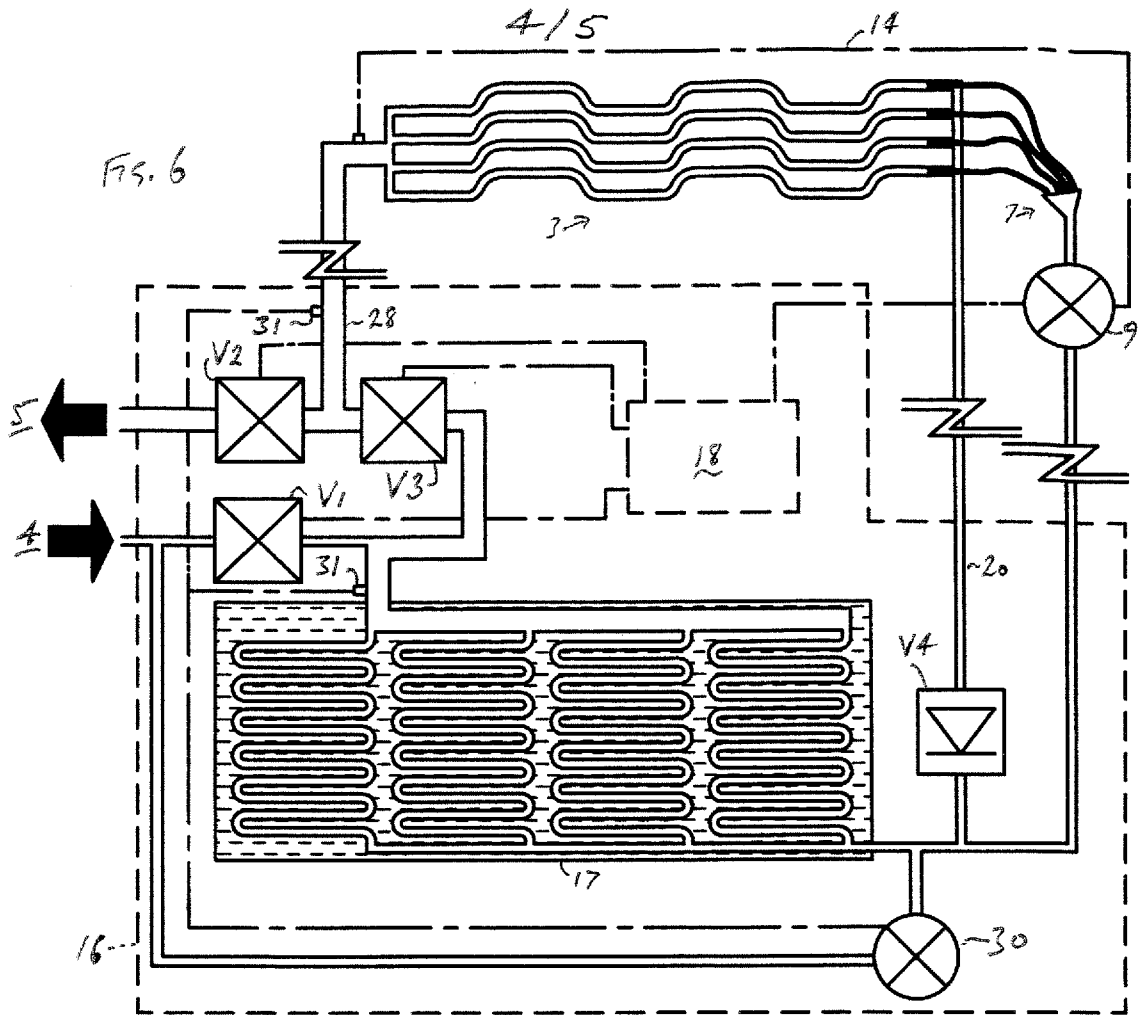
65. A refrigeration apparatus substantially as described with reference to the drawings.

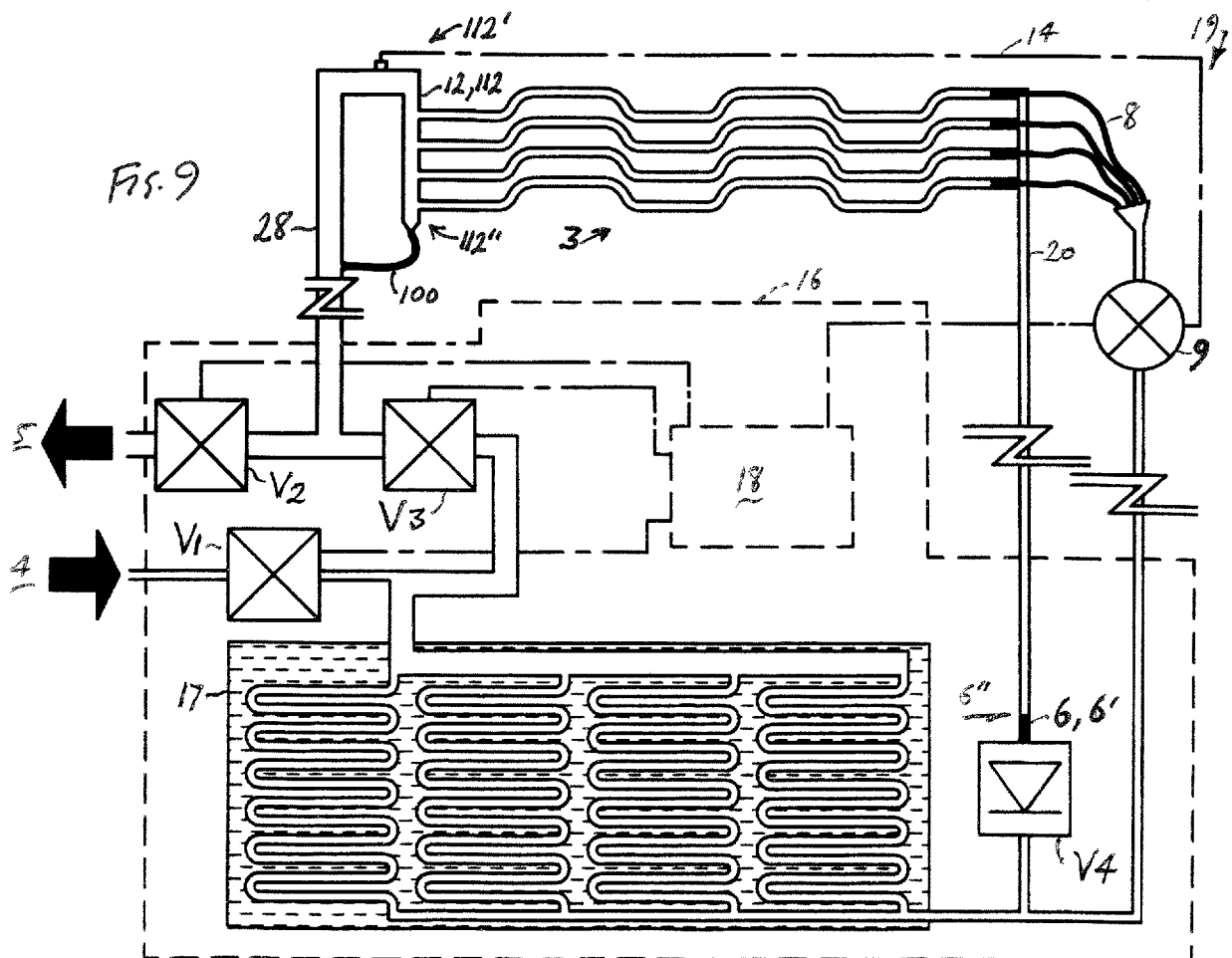
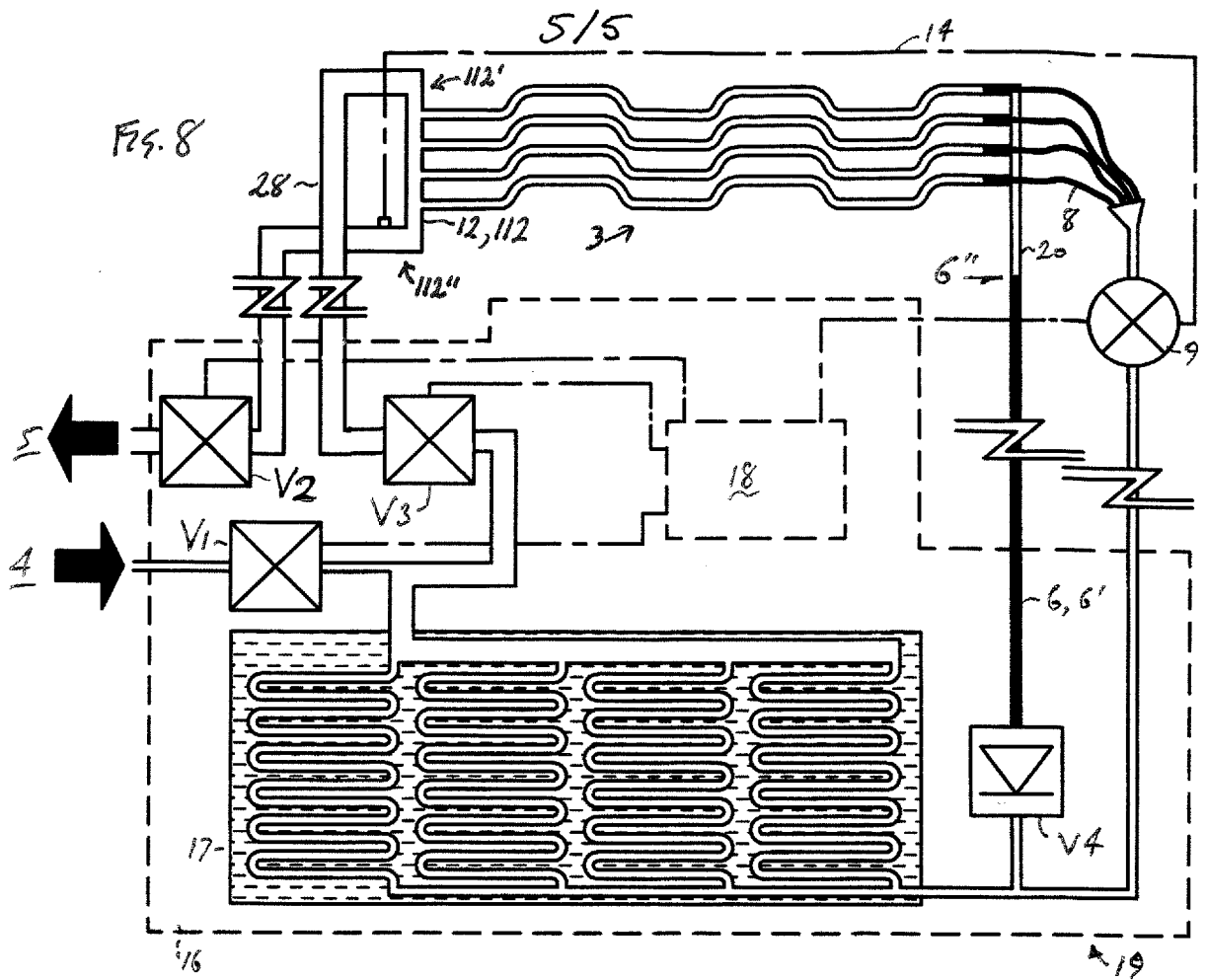
10 66. A method substantially as described with reference to the drawings.











INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/051181

A. CLASSIFICATION OF SUBJECT MATTER

INV. F25B47/02 F25D21/06 F25B41/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B F25D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 487 975 A (FRIGESCO LTD [GB]) 15 August 2012 (2012-08-15) page 4 - page 11; figures 2, 5 -----	1-66
X	WO 93/22606 A1 (DINH KHANH [US]) 11 November 1993 (1993-11-11) page 5 - page 12; figure 2 -----	1-66
X	US 3 922 875 A (MORRIS JR WILLIAM F) 2 December 1975 (1975-12-02) -----	1-35, 55-60, 64-66
A	column 2 - column 5; figures 1,2 -----	36-54, 61-63



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 June 2016

Date of mailing of the international search report

04/07/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Amous, Moez

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2016/051181

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2487975	A	15-08-2012	AU 2012215130 A1 26-09-2013 CA 2827053 A1 16-08-2012 CN 103429974 A 04-12-2013 EP 2673578 A2 18-12-2013 GB 2487975 A 15-08-2012 GB 2495672 A 17-04-2013 JP 5934257 B2 15-06-2016 JP 2014505230 A 27-02-2014 KR 20140007891 A 20-01-2014 NZ 615009 A 26-09-2014 RU 2013141537 A 20-03-2015 US 2013312437 A1 28-11-2013 WO 2012107773 A2 16-08-2012
WO 9322606	A1	11-11-1993	EP 0636233 A1 01-02-1995 JP H07508091 A 07-09-1995 US 5269151 A 14-12-1993 WO 9322606 A1 11-11-1993
US 3922875	A	02-12-1975	CA 1001855 A 21-12-1976 US 3922875 A 02-12-1975