(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 795 110 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
31.03.1999 Bulletin 1999/13

(21) Application number: **95941207.3**

(22) Date of filing: **20.12.1995**

(51) Int Cl.6: **F25B 43/00**, F25B 1/00

(86) International application number:
PCT/GB95/02982

(87) International publication number:
WO 96/20378 (04.07.1996 Gazette 1996/30)

(54) VAPOUR COMPRESSION SYSTEM AND METHOD OF OPERATING THE SAME

DAMPFKOMPRESSIONSSYSTEM UND VERFAHREN ZUM BETREIBEN DESSELBEN

SYSTEME DE COMPRESSION DE VAPEUR ET METHODE D'UTILISATION DE CELUI-CI

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IE IT LI NL PT SE

(30) Priority: **23.12.1994 GB 9426207**

(43) Date of publication of application:
17.09.1997 Bulletin 1997/38

(73) Proprietor: **BTG INTERNATIONAL INC. (a Delaware corp.)**
Gulph Mills PA 19406 (US)

(72) Inventor: **HASELDEN, Geoffrey, Gordon**
Leeds LS12 8RA (GB)

(74) Representative: **Neville, Peter Warwick**
Patents Department
British Technology Group Ltd
10 Fleet Place
London EC4M 7SB (GB)

(56) References cited:

EP-A- 0 104 750	WO-A-92/06339
DE-A- 2 602 582	DE-A- 3 545 013
GB-A- 1 502 607	GB-A- 2 164 736
US-A- 1 884 186	US-A- 2 432 859
US-A- 2 953 906	US-A- 3 111 819
US-A- 3 370 440	US-A- 3 600 904
US-A- 3 735 603	US-A- 5 027 602

EP 0 795 110 B1

Description

[0001] The present invention relates to vapour compression systems such as might be used in, for example, air conditioners, refrigerators and heat pumps, and to components of vapour compression systems such as condensers, evaporators and expansion devices. The invention addresses issues of control of such systems and components. The systems of the invention are suitable for use with mixtures of mutually soluble refrigerant substances with different boiling points (such that the mixture boils or condenses through a temperature range), and can enable power savings identified through the use of such mixtures to be achieved.

[0002] Conventional vapour compression systems comprise an evaporator, a condenser, and a compressor for raising the pressure of refrigerant vapour from that which prevails in the evaporator (where the refrigerant takes in heat) to that which prevails in the condenser (where the refrigerant loses heat). Condensed liquid refrigerant is supplied from the condenser to the evaporator through an expansion device which maintains the pressure difference between the condenser and the evaporator and regulates the flow of refrigerant through the system. In many, applications, the components of such systems are assembled together into integrated sealed units.

[0003] Patent specification US-A-1884186 (Peltier) describes such a system, in which a quantity of a refrigerant circulates between at least two pressure levels in a condenser and an evaporator respectively, comprising

- a compressor for increasing the pressure of refrigerant vapour;
- a condenser for high pressure refrigerant vapour received from the compressor;
- an expansion device across which the pressure differential between the condenser and the evaporator is maintained. to control the withdrawal of liquid refrigerant from the condenser according to the volume of liquid refrigerant that is within or behind it;
- an evaporator for liquid refrigerant received from the condenser;
- a receiver into which refrigerant is discharged from the evaporator, the receiver including a reservoir into which liquid refrigerant discharged from the evaporated collects;
- a vapour withdrawal conduit through which vapour is withdrawn from the receiver for supply to the compressor; and
- a liquid withdrawal conduit through which liquid refrigerant is withdrawn from the reservoir and supplied at a venturi into the vapour withdrawal conduit.

[0004] Particularly when a vapour compression system is required to cool a fluid through a temperature range while rejecting heat to another fluid which warms up through a temperature range, the efficiency of the system can be increased by using a refrigerant which consists of two or more mutually soluble substances which do not form an azeotrope, and can therefore condense or boil over a range of temperatures. The normal boiling points of the two substances are separated by about 15 to 60°C. By appropriate selection of substances for the mixed refrigerant, the changing boiling point of the mixed refrigerant as it condenses can be arranged to follow closely the temperature of the fluid being heated in the condenser throughout the length of the condenser with the refrigerant and heat transfer fluid flowing in countercurrent relationship with each other. Similar considerations apply to the evaporator. As a result, less power is required in order to drive the compressor because the pressure ratio required of the compressor is reduced.

[0005] It is appropriate for effective operation of a system with a mixed refrigerant for the relative proportions of the various components of the mixture to remain substantially constant throughout the system. It is also preferred that the two phases of the refrigerant flow cocurrently at least through the evaporator and the condenser, so that the separate phases are each well mixed and there is effective mixing between the phases. This condition can be referred to as equilibrium evaporation or condensation. It can arise for example when liquid and vapour flow cocurrently with vapour flowing down the bore of the channel, and liquid flowing along the walls of the evaporator or the condenser, effectively as a varying thickness film around the flowing vapour. Preferably, the equilibrium conditions of evaporation or condensation are sustained throughout substantially the entire length of the evaporator or condenser (as the case may be). This can be difficult to achieve because the change in phase is accompanied by a large change in volume, which affects the flow condition of the two phases.

[0006] A vapour compression system is disclosed in WO-A-92/06339 which incorporates a two-section evaporator which discharges refrigerant into a low pressure receiver. Subject matter disclosed in that document is incorporated in the specification of the present application by this reference. The first (or major) section of the evaporator receives liquid from the condenser through an expansion device, and discharges refrigerant vapour together with a small quantity of liquid into the low pressure receiver, from which vapour is supplied to the compressor. Liquid from the receiver is supplied to the second section of the evaporator and ensures that, under steady state operating conditions of the system, the discharge from the first section of the evaporator remains wet. The system includes a modulating float valve as the expansion device, which opens when the quantity of liquid within or behind it exceeds a pre-determined level, the force required to open the valve being substantially independent of the pressure drop across it. The valve ensures that liquid does not accumulate in the condenser and is supplied steadily to the evaporator.

[0007] The system disclosed in WO-A-92/06339 operates satisfactorily, enabling the heat exchange surfaces in both evaporator and condenser to be optimally employed independent of the duty required of the system. This enables the power consumption of the compressor to be reduced. It has demonstrated that the power saving advantages of mixed refrigerants (that have long been identified as possible) can be realised.

[0008] A two-section evaporator such as is incorporated in the system disclosed in WO-A-92/06339 can be complicated, especially when liquid refrigerant must be distributed amongst an array of separate tubes fed from the receiver, to maintain an appropriate flow rate of refrigerant through the second section of the evaporator. The distribution should be such that each tube in the array is maintained active, even when the load on the system is light.

[0009] According to the present invention, it has been found that, in a closed system, the wetness of refrigerant discharged from an evaporator into a receiver can be ensured by the controlled steady removal of a small quantity of liquid refrigerant from the receiver in proportion to the amount of refrigerant that is removed from the receiver as vapour, so as to control the wetness of the refrigerant discharged into the receiver from the evaporator to ensure that it is wet under normal operating conditions of the system.

[0010] Accordingly, in one aspect, the invention provides a method of operating a vapour compression system in which a quantity of a refrigerant circulates between at least two pressure levels in a condenser and an evaporator respectively, wherein the refrigerant consists of two or more mutually soluble refrigerant substances which do not form an azeotrope, comprising:

(a) a compressor for increasing the pressure of refrigerant vapour;

(b) the condenser for high pressure refrigerant vapour received from the compressor;

(c) an expansion device which admits liquid refrigerant to the evaporator from the condenser at the rate at which it is produced in the condenser, across which device the pressure differential between the condenser and the evaporator is maintained, to control the withdrawal of liquid refrigerant from the condenser according to the volume of liquid refrigerant that is within or behind the expansion device;

(d) the evaporator for liquid refrigerant received from the condenser; and

(e) a receiver into which refrigerant is discharged from the evaporator, the receiver including:

a reservoir into which liquid refrigerant discharged from the evaporator collects, to control supply of liquid refrigerant to the compressor,

a vapour withdrawal conduit through which refrigerant vapour is withdrawn from the receiver for supply to the compressor, and

a liquid withdrawal conduit through which liquid refrigerant is withdrawn from the reservoir and supplied into the vapour withdrawal conduit for supply to the compressor,

the method comprising supplying wet refrigerant to the compressor and controlling the rate of removal of liquid refrigerant from the receiver in proportion to the amount of refrigerant that is removed from the receiver as vapour so as to control the wetness of the refrigerant discharged into the receiver from the evaporator to ensure that substantially the entire heat exchange surface of the evaporator remains wet under normal operating conditions of the system.

[0011] It has been demonstrated by the present invention that removal of a controlled small quantity of liquid refrigerant from the receiver at a steady rate can lead to a controlled small degree of wetness in the discharge from the evaporator, which in turn can lead to substantially the entire heat exchange surface of the evaporator remaining wet. Accordingly, a high heat transfer coefficient can be maintained as a result of heat transfer along the entire length of the evaporator, substantially independent of the loading placed on the system and on the composition of the refrigerant. Preferably, the rate of removal of liquid from the receiver is such that the wetness of the refrigerant discharged from the evaporator is not more than about 5% by weight, more preferably not more than about 3.5% by weight, especially not more than about 2.5%, for example between about 1 and 2% by weight.

[0012] The invention can also ensure that the liquid content in the refrigerant that is supplied to the compressor is controlled so that the amount of liquid is kept steady without significant fluctuations. The wetness of the refrigerant supplied to the compressor can be similar to the wetness of the refrigerant that is discharged from the evaporator to the receiver. However, in many circumstances, the two wetnesses will be different. The differences between the two wetnesses can be accounted for by, for example, evaporation of some of the liquid refrigerant that is removed from the receiver. The differences can also be balanced by the receiver.

[0013] In another aspect, the invention provides a vapour compression system in which a quantity of a refrigerant circulates between at least two pressure levels in a condenser and an evaporator respectively, comprising

(a) a compressor for increasing the pressure of refrigerant vapour;

(b) the condenser for high pressure refrigerant vapour received from the compressor;

(c) an expansion device which admits liquid refrigerant to the evaporator from the condenser at the rate at which it is produced in the condenser, across which device the pressure differential between the condenser and the evaporator is maintained, to control the withdrawal of liquid refrigerant from the condenser according to the volume of liquid refrigerant that is within or behind the expansion device;

(d) the evaporator for liquid refrigerant received from the condenser;

(e) a receiver into which refrigerant is discharged from the evaporator, the receiver including a reservoir into which liquid refrigerant discharged from the evaporator collects, to control supply of liquid refrigerant to the compressor;

(f) a vapour withdrawal conduit through which vapour is withdrawn from the receiver for supply to the compressor;

(g) a liquid withdrawal conduit through which liquid refrigerant is withdrawn from the reservoir into the vapour withdrawal conduit for supply to the compressor; and

(h) means for controlling the rate of removal of liquid refrigerant from the reservoir in proportion to the amount of refrigerant that is removed from the receiver as vapour so that refrigerant from the controlling means supplied to the compressor is of such composition that the refrigerant subsequently discharged into the receiver from the evaporator is wet under normal operating conditions of the system.

[0014] Preferably, the receiver is arranged so that liquid refrigerant contained in the reservoir is retained in the reservoir at shut-down of the system.

[0015] The control of the flow of liquid refrigerant from the receiver can be achieved using a liquid withdrawal conduit through which liquid is supplied to the conduit for vapour feed from the receiver to the compressor, due to a pressure drop along the vapour withdrawal conduit downstream of the reservoir. The control can be achieved through use of a receiver into which refrigerant is discharged from the evaporator, which includes:

- a reservoir for liquid refrigerant,
- a vapour withdrawal conduit through which refrigerant vapour is supplied from the receiver to the compressor, and
- a liquid withdrawal conduit through which liquid refrigerant is supplied from the reservoir into the vapour withdrawal conduit,

the vapour withdrawal conduit being arranged so that the pressure of vapour flowing in it is reduced at a point downstream of the reservoir relative to the pressure in the reservoir, so that liquid refrigerant in the reservoir is drawn into the vapour withdrawal conduit through the liquid withdrawal conduit.

[0016] A system which includes such a receiver with means for removing a controlled quantity of liquid refrigerant has the advantage that appropriate control of the wetness of the refrigerant supply to the receiver can be achieved without having to include a two-section evaporator. This enables the power consumptions available from use of mixed refrigerants to be obtained, while also minimising equipment costs by avoiding the use of certain complicated multi-tube heat exchanger constructions. By appropriate design of the flow resistance of the vapour and liquid withdrawal conduits including their disposition relative to the reservoir, it is possible to ensure that, at steady state operation of the system, the liquid supplied from the receiver to the vapour withdrawal conduit (for supply to the compressor) is such that the refrigerant discharged from the evaporator to the receiver has an appropriate low degree of wetness. Such operation of the system involves optimum use of the heat exchange surfaces of the evaporator, and can allow the advantages of reduced power consumption from the use of mixed refrigerants to be realised.

[0017] A further advantage that arises from the use of the receiver referred to above is that the optimised use of the heat exchange surfaces of the evaporator is achieved without deterioration of the control due to accumulation of compressor oil. This is in contrast to the system disclosed in WO-A-92/06339 in which compressor oil can tend to accumulate excessively in the second evaporator section, especially if the velocity of the refrigerant in the second section drops too low as can happen if the tubes in the second section are not appropriately manifolded. Such accumulation of oil can give rise to operational instability, especially when the duty required of the system is reduced or when the system is restarted after a temporary shut-down.

[0018] The quantity of liquid refrigerant that is removed from the reservoir is controlled so that it is removed at a substantially steady rate. The rate at which liquid refrigerant is removed from the reservoir is preferably determined in relation to the quantity of refrigerant that is removed as vapour; this can be achieved by means of so-called proportionating devices. Details of such devices are set out below.

[0019] Provided that the rate of flow of liquid refrigerant is substantially steady, it has been found that the quantity of liquid, required to be removed from the reservoir and supplied to the compressor to promote appropriate wet discharge from the evaporator, need not give rise to mechanical difficulties in operation of the system, or affect adversely the efficiency of the compressor.

[0020] Preferably, the receiver is arranged such that not more than about 4% by weight of the compressor throughput of refrigerant passes through the liquid withdrawal conduit, the remainder passing through the vapour withdrawal conduit. More preferably, the liquid withdrawal conduit carries not more than about 3% by weight of the compressor throughput. Preferably, the liquid withdrawal conduit carries at least about 0.5% of the compressor throughput, more preferably at least about 1%. For example, the receiver can be arranged so that about 2% by weight of the compressor throughput of refrigerant passes through the liquid withdrawal conduit.

[0021] Preferably, the junction between the vapour and liquid withdrawal conduits is at a level that is about or slightly above the level of liquid refrigerant in the reservoir when the system is at steady state operation. This has the advantage that the tendency of liquid refrigerant to drain into the vapour withdrawal conduit during temporary shut down of the system is reduced. The level of the said junction should preferably be only slightly above the steady state liquid level so that the system provides about the same proportion of liquid injected into the liquid withdrawal conduit over a range of duties.

[0022] Preferably, the opening for vapour to enter the vapour withdrawal conduit for supply to the compressor is located above the level of the refrigerant liquid in the reservoir, and is preferably at or towards the top of the reservoir. This arrangement has the advantage that it reduces the tendency for liquid refrigerant to be drawn with refrigerant vapour from the reservoir or the discharge from the evaporator or both, and transferred to the compressor suction. Generally, in this arrangement, the vapour withdrawal conduit will include a section which extends downwardly to a level below the level of liquid in the reservoir when the system is in operation.

[0023] Preferably, the opening for liquid to enter the liquid withdrawal conduit to flow to the vapour feed line is located close to the bottom of the reservoir, more preferably in the base of the reservoir, so that liquid will continue to be drawn from the reservoir, even when the level of liquid in the reservoir is low.

[0024] Preferably, the opening from the liquid withdrawal conduit into the vapour withdrawal conduit discharges liquid refrigerant into the vapour withdrawal conduit at a point at least about one quarter of the distance across the vapour withdrawal conduit, more preferably at least about one third of that distance. This has the advantage that it encourages the dispersion of the liquid refrigerant into the vapour in droplet form.

[0025] The cross-sectional area of the vapour withdrawal conduit can be greater at a point downstream of the junction with the liquid withdrawal conduit than at a point upstream of that junction, so that the overall pressure drop in the compressor suction is minimised.

[0026] The change in cross-sectional area of the vapour withdrawal conduit can be associated with a constriction in the conduit. The constriction can be such that a venturi is provided in the vapour withdrawal conduit. Preferably, the venturi is mounted horizontally, with its centre-line at about the normal level of liquid in the reservoir when the system is operating in a steady state condition. It has been found that injection of a small quantity of liquid refrigerant into the stream of refrigerant vapour at the throat of a venturi constriction does not significantly affect pressure recovery adversely. Consequently, the pressure drop in the vapour conduit between the receiver and the compressor suction remains low, providing energy efficient performance. An arrangement using a venturi can lead to liquid refrigerant being removed from the reservoir in proportion to the amount of refrigerant removed as vapour.

[0027] The liquid withdrawal conduit can include an n-shaped portion with two limbs and a connecting portion extending between them, in which liquid is drawn from the reservoir and made to flow initially upwardly from the reservoir along a first one of the limbs, and downwardly to the junction with the vapour flow conduit along the other of the limbs, thus acting as a syphon. The height of the n-shaped portion of the liquid withdrawal conduit above the normal level of liquid refrigerant in the reservoir will be selected so that the n-shaped portion is at least as high as the highest anticipated level of liquid that will be contained in the reservoir at any time during operation of the system, to ensure that liquid refrigerant will not drain from the reservoir to the compressor, particularly at shut down. The second down-flow limb will preferably include the capillary flow resistance conduit. An arrangement in which the liquid withdrawal conduit includes an n-shaped portion can lead to liquid refrigerant being removed from the reservoir in proportion to the amount of refrigerant removed as vapour.

[0028] The reservoir, into which refrigerant is discharged from the first evaporator section, will generally be arranged so that refrigerant collected within it has a large surface area. For example, the surface area of liquid refrigerant may be at least about twice the square of the height of the reservoir, preferably, at least about three times the square of that height. This has the advantage that variation in the amount of liquid refrigerant contained in the reservoir does not affect significantly the depth of the liquid and frothing of the refrigerant in the reservoir is less likely to lead to liquid refrigerant being supplied to the compressor. This allows a significant gap to be maintained between the upper surface of collected liquid refrigerant, and the outlet through which vapour is supplied to the compressor, thus minimising and preferably avoiding the possibility of liquid refrigerant being supplied in bulk to the compressor under any possible operating conditions.

[0029] It is particularly preferred to use a vapour withdrawal conduit with a venturi provided in it by a constriction, together with a liquid withdrawal conduit which includes an n-shaped portion as described above. The venturi can give rise to a significant pressure difference between the reservoir and the exit from the vapour withdrawal conduit at the junction with the liquid withdrawal conduit. The pressure difference can be arranged such that liquid refrigerant is drawn up the first limb of the n-shaped portion of the liquid withdrawal conduit, at a rate appropriate to maintain the discharge from the evaporator wet as discussed above. This arrangement has the advantage of reduced power loss due to frictional effects in the vapour withdrawal conduit can be reduced, because the pressure loss involved in accelerating the vapour through the throat of the venturi is largely recovered in the divergent diffuser section.

[0030] The liquid withdrawal conduit is designed to have an overall pressure drop, when supplying liquid refrigerant at the desired flow rate, which equals the overall pressure drop in the exit vapour conduit between the receiver and the point of liquid injection into the liquid conduit. This can be achieved by selection of the configurations of the vapour and liquid withdrawal conduits such that the pressure drop in the vapour withdrawal conduit between the reservoir and the junction with the liquid withdrawal conduit provides a controlled flow of liquid along the liquid withdrawal conduit from the reservoir to the said junction in proportion with the suction flow rate of vapour to the compressor. The selection involves parameters such as cross-sectional areas and of lengths the conduits between the junction between them and the reservoir. Accordingly, the conduit may be in the form of a capillary tube having a small cross-section, along at least a part of its length. Alternatively or in addition, the cross-sectional configuration of the vapour withdrawal conduit can differ between the portions upstream and downstream respectively of the junction with the liquid withdrawal conduit.

[0031] The vapour withdrawal conduit can include a U-shaped portion with two limbs and a connecting portion extending between them. The upstream limb of the U-shaped portion can then provide a downwardly extending section of the vapour withdrawal conduit, from the opening for vapour to enter the vapour feed line for supply to the compressor, above the level of the refrigerant liquid. In this arrangement, it will generally be preferred for the junction between the vapour withdrawal conduit and the liquid withdrawal conduit is located in the downstream limb of the U-shaped portion of the vapour withdrawal conduit.

[0032] The drop in pressure in the vapour withdrawal conduit between the reservoir and the junction with the liquid withdrawal conduit preferably corresponds to a head of liquid refrigerant of between 45 and 200 mm, more preferably between 65 and 160 mm, especially between 80 and 130 mm.

[0033] The liquid withdrawal conduit may be configured so that liquid contained in it is placed in heat exchange relationship with liquid refrigerant discharged from the condenser so that it is heated by the said liquid refrigerant, between discharge into the conduit from the reservoir and discharge from the conduit into the vapour withdrawal conduit. In this construction, the liquid withdrawal conduit includes a constriction in it, by which flow of refrigerant along the conduit is controlled. It will be preferred for this refrigerant stream to flow generally upwardly while in heat exchange relationship with the condensate.

[0034] Examples of materials which are suitable for use as refrigerants in a single refrigerant system include those designated by the marks R22 and R134a. A particular advantage of the system of the invention is that it is well suited to the use of a wide boiling non-azeotropic mixed refrigerant in which it is particularly, desirable that, at all places within the condenser and the evaporator, liquid and vapour refrigerant flow together co-currently and are in equilibrium, whilst the refrigerant mixture flows essentially counter-currently with the fluid with which it is exchanging heat. This objective can be achieved by the system of the invention, particularly when it includes both an expansion valve where the force required to open it is substantially, independent of the pressure drop across it. The vapour compression system of the invention therefore makes possible the power saving which is available from the use of a wide boiling mixed refrigerant. In addition, further power saving can be achieved because of the ability of the system of the invention to adapt to varying duty, start-up conditions, varying ambient conditions and so on, while operating at optimum efficiency.

[0035] Thus, the refrigerant preferably consists of two or more mutually soluble refrigerant substances which do not form an azeotrope. Examples of suitable mixed refrigerants include those designated by the marks R23/R134a and R32/R227. Suitable mixtures of refrigerant substances can have boiling points separated by at least about 10°C, for example at least about 20°C. The difference in boiling points will often be less than about 70°C, preferably, less than about 60°C, for example less than about 50°C.

[0036] It will be understood that the term "refrigerant", used in this document to denote the fluid circulating in the vapour compression system, is applicable to the fluid which circulates in systems which function as air conditioners or heat pumps.

[0037] The duty performed by the vapour compression system is determined by appropriate adjustment of the flow rate of the refrigerant vapour through the system. This can be achieved in a number of ways: for example, the throughput of the compressor can be adjusted, for example by adjustment of its speed or by unloading one or more cylinders, or more than one compressor may be provided of which some or all may be used according to the quantity of refrigerant required to be circulated.

[0038] Alternatively, the desired duty may be obtained by selectively switching the compressor on and off as necessary.

[0039] The control of the compressor through-put may be in response to a detected change in temperature in the medium required to be heated or cooled by the system. For example, in a refrigeration system, a temperature sensor may be used to cause the through-put of a compressor to increase on detecting an increase in temperature of a cold chamber.

[0040] When air is used as the heat transfer medium in the condenser or the evaporator, and in cases where the duty of the unit varies widely, variable output fans may be used to modulate air flow and to conserve power.

[0041] The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of a vapour compression system in accordance with the present invention;

Figure 2 is a schematic illustration of a receiver suitable for use in the vapour compression system shown in Figure 1;

Figure 3 is a schematic illustration of another embodiment of receiver;

Figure 4 is a schematic illustration of another vapour compression system in accordance with the present invention; and

Figure 5 is a schematic illustration of a vapour compression system in which condensed refrigerant is split into two streams which are split between two evaporators.

[0042] Referring to the drawings, Figure 1 shows a vapour compression system which comprises a compressor 1 for increasing the pressure of refrigerant vapour, and for forcing the vapour through a first conduit 3 to a condenser 5. The condenser 5 comprises an array of condenser tubes 7, connected both in series and in parallel, which are attached to a plurality of fins which facilitate heat transfer between a cooling medium which flows over the fins and the refrigerant contained within the condenser tube. The medium might be for example air when the system forms part of an air conditioning unit or a refrigerator. The flow directions of the two fluids are essentially countercurrent so this design is suitable for mixed refrigerants as well as pure refrigerants.

[0043] Refrigerant is discharged from the condenser 5 into a second conduit 11 through a valve 13. A vapour return tube 14 is provided to ensure that the inlet to the valve 13 does not become vapour locked. The valve 13 is arranged to open when the quantity of the condensed liquid refrigerant behind or within it, exceeds a predetermined level. The construction of an appropriate valve is disclosed in WO-A-92/06339. An appropriate valve will be one in which the force required to open it is substantially independent of the pressure drop across it.

[0044] The refrigerant from the condenser passes to an evaporator 15 through the valve 13 and the second conduit 11. The evaporator 15 comprises an array of tubes connected in series and in parallel. It further comprises evaporator fins over which a fluid flows so as to transfer heat and to cause the refrigerant to evaporate. The fluid is cooled as a result. The fluid might be, for example, air when the refrigeration system forms part of an air conditioning unit or a refrigerator.

[0045] The refrigerant is discharged from the evaporator 15 into a receiver 21. Liquid refrigerant discharged from the evaporator collects in the reservoir 23 of the receiver which can provide buffer storage of the liquid refrigerant. A vapour withdrawal conduit 25 extends from the top of the reservoir 23, to convey the major part of the refrigerant as vapour (that is, essentially liquid-free vapour) from the reservoir to the compressor. It will therefore be understood that refrigerant can be separated in the receiver, into liquid and vapour phases.

[0046] The receiver includes a liquid withdrawal conduit 27 through which liquid refrigerant is supplied from the reservoir into the vapour withdrawal conduit 25. By selection of its diameter and length, taking into account restrictions to flow such as are provided by bends, the vapour withdrawal conduit is arranged so that the pressure of vapour flowing in is reduced at a point downstream of the reservoir related to the pressure in the reservoir, so that liquid refrigerant in the reservoir is drawn into the vapour withdrawal conduit 25 through the liquid withdrawal conduit 27 at a rate proportional to the vapour flow. The pressure drop corresponds approximately to a head of liquid refrigerant of about 100 mm.

[0047] The evaporator, receiver and flow proportioning means in combination ensure that all of the evaporator surface is employed for heat transfer, irrespective of the duty required of the system. When the system is running, the arrangement of vapour and liquid withdrawal conduits in the receiver will ensure that liquid is drawn from the reservoir at a controlled rate. Consequently, the level of liquid in the reservoir will tend to go down. The use of an expansion device which opens when the quantity of condensed liquid refrigerant within or behind it reaches a pre-determined level ensures that liquid cannot accumulate anywhere in the system other than in the reservoir, because the expansion device ensures that liquid does not accumulate in the condenser. Liquid is admitted to the evaporator from the condenser at the rate at which it is produced in the condenser. The system will therefore tend towards a steady state condition in which the liquid refrigerant removed from the reservoir by means of the liquid withdrawal conduit is exactly compensated by the liquid component of the two phase refrigerant discharged into the reservoir from the evaporator. The pressure in the evaporator will adjust itself automatically to achieve this balance. This means that all of the evaporator surface must be wet during such steady state operation.

[0048] Figures 2 and 3 show constructions of receivers in more detail. Referring first to Figure 2, in which the disclosed construction comprises a reservoir 31, into which refrigerant is discharged from the evaporator through a discharge conduit 33. The outlet from the discharge conduit is located towards the top of the reservoir 31. The vapour withdrawal conduit 25 from which the refrigerant vapour is supplied from the reservoir 31 to the compressor is located towards the top of the reservoir.

[0049] The vapour withdrawal conduit 25 has a U-shaped portion 35 immediately downstream of the reservoir 31. The U-shaped portion comprises first and second limbs 37, 39 and a connecting base portion. The base portion is located at a level well below the normal level 41 of liquid refrigerant contained in the reservoir 31 when the system is running in a steady state condition.

[0050] The second limb 39 of the U-shaped portion of the vapour withdrawal conduit is flared.

[0051] A liquid withdrawal conduit 43 extends from the base of the reservoir 31 (well below the normal liquid level 41) and joins the second limb 39 of the U-shaped portion of the vapour withdrawal conduit. The junction between the liquid and vapour withdrawal conduits 25, 43 is at a point just upstream of the flare in the vapour withdrawal conduit. The opening from the liquid withdrawal conduit into the vapour withdrawal conduit discharqes liquid refrigerant into the vapour withdrawal conduit at a point about one third of the distance across the vapour withdrawal conduit, so that the liquid refrigerant discharged into the vapour will tend to atomise as it is discharged.

[0052] The liquid withdrawal conduit 43 is provided by a capillary tube. The diameter and length of the capillary tube are selected so that, for a rate of liquid injection into the vapour withdrawal conduit 25 at the desired ratio (for example about 2% by weight of the throughput of refrigerant through the compressor), the pressure drop across the liquid withdrawal conduit is equal to the pressure drop in the vapour withdrawal conduit 25. The junction between the vapour and liquid withdrawal conduits is at a level that is about or slightly above the level of liquid refrigerant in the reservoir when the system is at a steady stage operation.

[0053] Figure 3 shows an alternative construction of receiver 51. It comprises a reservoir 53 into which refrigerant is discharged from the evaporator through a conduit 55.

[0054] A vapour withdrawal conduit 57 has an opening towards the top of the reservoir for entry of vapour for supply to the compressor. The vapour withdrawal conduit includes a downwardly extending portion and a portion which extends approximately parallel to the surface of liquid refrigerant contained in the reservoir, at about the level of liquid when the system is running in a steady state condition.

[0055] A constriction in the vapour withdrawal conduit provides a venturi 59, by which the pressure of the vapour in the vapour withdrawal conduit is decreased and then increased.

[0056] A liquid withdrawal conduit 61 is provided in the form of an n-shaped tube, with its opening 63 for entry of liquid located towards the base of the reservoir 53.

[0057] The opening 65 for discharge of liquid refrigerant into the vapour withdrawal conduit 57 is located relative to the venturi 59 such that liquid refrigerant is drawn from the reservoir 53 into the vapour withdrawal conduit through the liquid withdrawal conduit as a result of the pressure changes imposed on vapour in the vapour withdrawal conduit by the venturi.

[0058] The quantity of liquid that is drawn into the vapour withdrawal conduit is controlled at least partially by the dimensions of the venturi.

[0059] Figure 4 shows a vapour compression system which comprises a compressor 81 for increasing the pressure of refrigerant vapour, and for forcing the vapour through a first conduit 83 to a condenser 85. Refrigerant is discharged from the condenser into a second conduit 91 through a valve 93. A vapour return tube can be provided to ensure that the inlet to the valve does not become vapour locked. The valve is arranged to open when the quantity of the condensed liquid refrigerant behind or within it exceeds a pre-determined level.

[0060] The refrigerant from the condenser passes through an evaporator 95 through the valve 93 and the second conduit 91. The refrigerant is discharged from the evaporator 95 into a receiver 101. Liquid refrigerant discharged from the evaporator collects in the reservoir 103 of the receiver. A vapour withdrawal conduit 105 extends from the top of the reservoir, and to convey the major part of the refrigerant as vapour from the reservoir to the compressor.

[0061] The receiver includes a liquid withdrawal conduit 107 through which liquid refrigerant is supplied from the reservoir into the vapour withdrawal conduit. The liquid conduit includes a constriction 108 which provides a resistance to flow. Liquid refrigerant in the conduit 107 is exposed to heat imparted by liquid refrigerant that is discharged from the condenser as it flows generally upwardly through a heat exchanger 109 (such that the point of entry to the heat exchanger is lower than the point of exit) so that the liquid refrigerant is evaporated, at least partially. The refrigerant from the heat exchanger is then injected into the vapour withdrawal conduit 105 for supply to the compressor.

[0062] The valve 93 comprises a float 111 which is exposed to saturated liquid refrigerant from the condenser, and valve orifices 113 which are exposed to liquid refrigerant that has been sub-cooled by passage through the heat exchanger 109. The float 111 and the needles by which the valve orifices are closed are connected by an elongate rod 115 in a close fitting tube which are such that the flow of liquid that is permitted between the float chamber and the valve orifices through the resulting annular passage is negligible. Accordingly, saturated refrigerant condensate is caused to flow from the base of the float chamber, through the heat exchanger, into the valve body, where it expands through the orifices of the valve.

[0063] The evaporator, receiver and flow proportioning means in combination ensure that all of the evaporator surface is effectively employed for heat transfer, irrespective of the duty required of the system. When the system is running, the arrangement of vapour and liquid withdrawal conduits in the receiver will ensure that liquid is drawn from the reservoir at a controlled rate. Consequently, the level of liquid in the reservoir will tend to go down. The use of an expansion device which opens when the quantity of condensed liquid refrigerant within or behind it reaches a pre-determined level ensures that liquid cannot accumulate anywhere in the system other than in the reservoir, because the expansion device ensures that liquid does not accumulate in the condenser. The system will therefore tend towards a steady state condition in which the liquid refrigerant removed from the reservoir by means of the liquid withdrawal conduit is exactly compensated by the liquid component of two phase refrigerant discharged into the reservoir from the evaporator. The pressure in the evaporator will adjust itself automatically to achieve this balance. This means that all of the evaporator surface must be wet during such steady state operation.

[0064] Figure 5 shows a system which can accommodate a temperature change in the evaporator which is significantly greater than that in the condenser, for example by as much as a factor of two or more. For example, the temperature change across the condenser might be about 10°C (between say 19 and 29°C), while the temperature change across the evaporator might be about 22°C (in two stages from say 27 to 16°C and 16 to 5°C).

[0065] The system includes a receiver 120 into which liquid is discharged from the condenser 122. Liquid from the reservoir is split between two streams, each of which supplies refrigerant into first and second evaporators 124, 126. Flow of refrigerant into the evaporators is controlled by means of valves 128, 130.

[0066] Refrigerant is discharged from the evaporators into respective reservoirs 132, 134, in liquid and vapour phases, from which refrigerant vapour is withdrawn for supply to the compressor assembly 136. The reservoirs also supply liquid refrigerant in small controlled quantities to the compressor through liquid withdrawal conduits 138, 140 which join the vapour withdrawal conduits, in the manner described above with reference to Figure 2 or Figure 3.

[0067] The valves 128, 130 are controlled by level sensors for liquid in the reservoirs.

[0068] The compressor assembly 136 comprises two separate compressors, which operate at high and low pressures respectively. The use of two compressors in this way facilitates operation of the two evaporators of the system over different temperature profiles.

[0069] The components are arranged so that the receiver can hold all of the free refrigerant in the system when the reservoirs do not hold any. The reservoirs are sufficiently large that they can hold liquid refrigerant without frothing into the compressor.

Claims

1. A vapour compression system in which a quantity of a refrigerant circulates between at least two pressure levels in a condenser (5) and an evaporator (15) respectively, comprising:

(a) a compressor (1) for increasing the pressure of refrigerant vapour;

(b) the condenser for high pressure refrigerant vapour received from the compressor;

(c) an expansion device (13) which admits liquid refrigerant to the evaporator from the condenser at the rate at which it is produced in the condenser, across which device the pressure differential between the condenser and the evaporator is maintained, to control the withdrawal of liquid refrigerant from the condenser according to the volume of liquid refrigerant that is within or behind it;

(d) the evaporator for liquid refrigerant received from the condenser;

(e) a receiver (21) into which refrigerant is discharged from the evaporator, the receiver including a reservoir into which liquid refrigerant discharged from the evaporator collects, to control supply of liquid refrigerant to the compressor;

(f) a vapour withdrawal conduit (25) through which vapour is withdrawn from the receiver for supply to the compressor;

(g) a liquid withdrawal conduit (27) through which liquid refrigerant is withdrawn from the reservoir into the vapour withdrawal conduit for supply to the compressor; and

(h) means (35) for controlling the rate of removal of liquid refrigerant from the reservoir in proportion to the amount of refrigerant that is removed from the receiver as vapour so that refrigerant from the controlling means supplied to the compressor is of such composition that the refrigerant subsequently discharged into the receiver from the evaporator is wet under normal operating conditions of the system.

2. A vapour compression system as claimed in claim 1, in which the receiver is arranged so that liquid refrigerant contained in the reservoir is retained in the reservoir at shut-down of the system.

3. A vapour compression system as claimed in claim 1 or claim 2, in which the vapour withdrawal conduit is arranged so that the pressure of vapour flowing in it is reduced at a point downstream of the reservoir relative to the pressure in the reservoir, and in which the liquid withdrawal conduit is arranged so that liquid refrigerant in the reservoir is drawn through the liquid withdrawal conduit into the vapour withdrawal conduit.

4. A vapour compression system as claimed in claim 3, in which the configuration of the vapour withdrawal conduit and the configuration of the liquid withdrawal conduit are selected such that the pressure drop in the vapour withdrawal conduit between the reservoir and where it joins the liquid withdrawal conduit provides a controlled flow of liquid along the liquid withdrawal conduit from the reservoir to the junction.

5. A vapour compression system as claimed in claim 4, in which the cross-sectional configuration of the vapour withdrawal conduit differs between the portions upstream and downstream respectively of the junction with the liquid withdrawal conduit.

6. A vapour compression system as claimed in any one of claims 3 to 5, in which the junction between the vapour and liquid withdrawal conduits is at a level that is about or slightly above the level of liquid refrigerant in the reservoir when the system is at steady state operation.

7. A vapour compression system as claimed in claim 6, in which the opening from the liquid withdrawal conduit into the vapour withdrawal conduit discharges liquid refrigerant into the vapour withdrawal conduit at a point at least about one third of the distance across the vapour withdrawal conduit.

8. A vapour compression system as claimed in claim 3, in which the vapour withdrawal conduit has a constriction in it.

9. A vapour compression system as claimed in claim 8, in which the said constriction provides a venturi.

10. A vapour compression system as claimed in any one of claims 3 to 9, in which the liquid withdrawal conduit includes an n-shaped portion with two limbs and a connecting portion extending between them, in which liquid is drawn from the reservoir and made to flow initially upwardly from the reservoir along a first one of the limbs, and downwardly to the junction with the vapour flow conduit along the other of the limbs.

11. A vapour compression system as claimed in any one of claims 3 to 10, in which the liquid withdrawal conduit includes a section that is a capillary.

12. A vapour compression system as claimed in any one of claims 3 to 11, in which the opening for vapour to enter the vapour withdrawal conduit is at or towards the top of the reservoir, and in which the vapour withdrawal conduit includes a section which extends downwardly to a level below the level of liquid in the reservoir when the system is in operation.

13. A vapour compression system as claimed in claim 12, in which the vapour withdrawal conduit includes a U-shaped portion with two limbs and a connecting portion extending between them, in which the upstream limb of the U-shaped portion provides the said downwardly extending section.

14. A vapour compression system as claimed in 13, in which the junction between the vapour withdrawal conduit and the liquid withdrawal conduit is located in the downstream limb of the U-shaped portion of the vapour withdrawal conduit.

15. A vapour compression system as claimed in claim 14, in which the junction between the vapour withdrawal conduit and the liquid withdrawal conduit is located at approximately the level of liquid in the reservoir when the system is in operation.

16. A vapour compression system as claimed in claim 1, in which the liquid withdrawal conduit is configured so that liquid contained in it is placed in heat exchange relationship with liquid refrigerant discharged from the condenser so that it is heated and at least partially evaporated by the said liquid refrigerant, between discharge into the conduit from the reservoir and discharge from the conduit into the vapour withdrawal conduit.

17. A vapour compression system as claimed in claim 16, in which the liquid withdrawal conduit includes a constriction in it, by which flow of refrigerant along the conduit is controlled.

18. A vapour compression system as claimed in claim 16 or claim 17, in which the opening into the liquid withdrawal conduit for liquid from the reservoir is located in the base of the reservoir.

19. A vapour compression system as claimed in any one of claims 16 to 18, in which refrigerant flows generally upwardly while in heat exchange relation-

ship with the condensate.

20. A vapour compression system as claimed in any one of claims 1 to 20, in which the means for controlling the rate of removal of liquid refrigerant from the receiver is arranged such that the wetness of the refrigerant discharged from the evaporator into the receiver is not more than about 5%, preferably not more than about 3.5%.

21. A vapour compression system as claimed in any preceding claim, which includes a refrigerant which consists of two or more mutually soluble refrigerant substances which do not form an azeotrope.

22. A vapour compression system as claimed in any preceding claim, which includes two evaporators arranged to cool a fluid in sequence, through successive temperature ranges.

23. A vapour compression system as claimed in claim 22, which includes respective reservoirs, into which refrigerant is discharged from the evaporators.

24. A vapour compression system as claimed in claim 23, which includes valves for controlling the flow of fluid between the evaporators, the valves being controlled according to the level of liquid refrigerant in the reservoirs.

25. A method of operating a vapour compression system in which a quantity of a refrigerant circulates between at least two pressure levels in a condenser (5) and an evaporator (15) respectively, wherein the refrigerant consists of two or more mutually soluble refrigerant substances which do not form an azeotrope, the system comprising:

(a) a compressor (1) for increasing the pressure of refrigerant vapour;

(b) the condenser for high pressure refrigerant vapour received from the compressor;

(c) an expansion device (13) which admits liquid refrigerant to the evaporator from the condenser at the rate at which it is produced in the condenser, across which device the pressure differential between the condenser and the evaporator is maintained, to control the withdrawal of liquid refrigerant from the condenser according to the volume of liquid refrigerant that is within or behind it;

(d) the evaporator for liquid refrigerant received from the condenser; and

(e) a receiver (21) into which receiver refrigerant is dicharged from the evaporator, the receiver including:

- a reservoir into which liquid refrigerant discharged from the evaporator collects, to control supply of liquid refrigerant to the compressor,
- a vapour withdrawal conduit (25) through which refrigerant vapour is withdrawn from the receiver for supply to the compressor, and
- a liquid withdrawal conduit (27) throught which liquid refrigerant is withdrawn from the reservoir into the vapour withdrawal conduit for supply to the compressor,

the method comprising supplying wet refrigerant to the compressor and controlling the rate of removal of liquid refrigerant from the receiver in proportion to the amount of refrigerant that is removed from the receiver as vapour so as to contol the wetness of the refrigerant discharged into the receiver from the evaporator to ensure that substantially the entire heat exchange surface of the evaporator remains wet under normal operating conditions of the system.

26. A method as claimed in claim 25, in which the vapour withdrawal conduit is arranged so that the pressure of vapour flowing in it is reduced at a point downstream of the reservoir relative to the pressure in the reservoir, so that liquid refrigerant in the reservoir is drawn into the vapour withdrawal conduit through the liquid withdrawal conduit.

27. A method as claimed in claim 25, in which the liquid withdrawal conduit is configured so that liquid contained in it is placed in heat exchange relationship with liquid refrigerant discharged from the condenser so that it is heated and at least partially evaporated by the said liquid refrigerant, between discharge into the conduit from the reservoir and discharge from the conduit into the vapour withdrawal conduit.

Patentansprüche

1. Dampfkompressionssystem, in dem eine Menge eines Kühlmittels zwischen mindestens zwei Druckpegeln in einem Verflüssiger (5) bzw. einem Verdampfer (15) zirkuliert, mit:

(a) einem Kompressor (1) zum Erhöhen des Drucks des Kühlmitteldampfes;
(b) dem Verflüssiger für vom Kompressor emp-

fangenen Kühlmitteldampf unter hohem Druck;
(c) einer Expansionseinrichtung (13), die dem Verdampfer vom Verflüssiger flüssiges Kühlmittel mit der Rate zuführt, mit der es im Verflüssiger erzeugt wird, wobei über die Einrichtung die Druckdifferenz zwischen dem Verflüssiger und dem Verdampfer aufrechterhalten wird, um den Abzug von flüssigem Kühlmittel aus dem Verflüssiger nach dem Volumen an flüssigem Kühlmittel zu steuern, das in oder hinter ihm ist;
(d) dem Verdampfer für vom Verflüssiger empfangenes flüssiges Kühlmittel;
(e) einem Sammelgefäß (21), in das Kühlmittel vom Verdampfer ausströmt, wobei das Sammelgefäß ein Reservoir enthält, in das sich vom Verdampfer ausgeströmtes flüssiges Kühlmittel sammelt, um die Zufuhr von flüssigem Kühlmittel zum Kompressor zu steuern;
(f) einer Dampfabzugsleitung (25), durch die Dampf aus dem Sammelgefäß für die Zufuhr zum Kompressor abgezogen wird;
(g) einer Flüssigkeitsabzugsleitung (27), durch die flüssiges Kühlmittel aus dem Reservoir in die Dampfabzugsleitung für die Zufuhr zum Kompressor abgezogen wird; und
(h) einer Einrichtung (35) zum Steuern der Rate einer Entnahme von flüssigem Kühlmittel aus dem Reservoir im Verhältnis zur Kühlmittelmenge, die aus dem Sammelgefäß als Dampf entnommen wird, so daß das von der Steuereinrichtung an den Kompressor gelieferte Kühlmittel eine derartige Zusammensetzung aufweist, daß das vom Verdampfer anschließend in das Sammelgefäß abgegebene Kühlmittel unter normalen Betriebsbedingungen des Systems feucht ist.

2. Dampfkompressionssystem nach Anspruch 1, in dem das Sammelgefäß so eingerichtet ist, daß im Reservoir enthaltenes flüssiges Kühlmittel beim Abschalten des Systems im Reservoir zurückgehalten wird.

3. Dampfkompressionssystem nach Anspruch 1 oder Anspruch 2, in dem die Dampfabzugsleitung so angeordnet ist, daß der Druck von in ihr strömendem Dampf an einem Punkt stromabwärts des Reservoirs in bezug auf den Druck im Reservoir verringert ist, und in dem die Flüssigkeitsabzugsleitung so angeordnet ist, daß flüssiges Kühlmittel im Reservoir durch die Flüssigkeitsabzugsleitung in die Dampfabzugsleitung gezogen wird.

4. Dampfkompressionssystem nach Anspruch 3, in dem die Anordnung der Dampfabzugsleitung und die Anordnung der Flüssigkeitsabzugsleitung so ausgewählt sind, daß der Druckabfall in der Dampfabzugsleitung zwischen dem Reservoir und der Stelle, an der sie mit der Flüssigkeitsabzugsleitung verbunden ist, einen gesteuerten Flüssigkeitsstrom entlang der Flüssigkeitsabzugsleitung vom Reservoir zur Verbindungsstelle liefert.

5. Dampfkompressionssystem nach Anspruch 4, in dem sich die Querschnittsform der Dampfabzugsleitung zwischen den Teilen stromaufwärts bzw. stromabwärts der Verbindungsstelle von der Flüssigkeitsabzugsleitung unterscheidet.

6. Dampfkompressionssystem nach einem der Ansprüche 3 bis 5, in dem die Verbindungsstelle zwischen der Dampf- und Flüssigkeitsabzugsleitung bei einem Pegel liegt, der etwa der Pegel des flüssigen Kühlmittels im Reservoir ist oder geringfügig höher liegt, wenn das System in einem stationären Betrieb ist.

7. Dampfkompressionssystem nach Anspruch 6, in dem die Öffnung von der Flüssigkeitsabzugsleitung in die Dampfabzugsleitung flüssiges Kühlmittel in die Dampfabzugsleitung an einem Punkt mindestens bei etwa einem Drittel der Distanz über die Dampfabzugsleitung ausströmen läßt.

8. Dampfkompressionssystem nach Anspruch 3, in dem die Dampfabzugsleitung eine Verengung in ihr aufweist.

9. Dampfkompressionssystem nach Anspruch 8, in dem die Verengung eine Venturiverengung schafft.

10. Dampfkompressionssystem nach einem der Ansprüche 3 bis 9, in dem die Flüssigkeitsabzugsleitung einen n-förmigen Teil mit zwei Schenkeln und einem zwischen ihnen verlaufenden Verbindungsteil enthält, in der Flüssigkeit aus dem Reservoir gezogen wird und man diese vom Reservoir entlang einem ersten Schenkel anfangs nach oben und entlang dem anderen Schenkel nach unten zur Verbindungsstelle mit der Dampfstromleitung strömen läßt.

11. Dampfkompressionssystem nach einem der Ansprüche 3 bis 10, in dem die Flüssigkeitsabzugsleitung einen Abschnitt enthält, der eine Kapillare ist.

12. Dampfkompressionssystem nach einem der Ansprüche 3 bis 11, in dem die Öffnung zum Eintreten des Dampfes in die Dampfabzugsleitung beim oder in Richtung des oberen Endes des Reservoirs liegt, und in dem die Dampfabzugsleitung einen Abschnitt enthält, der nach unten zu einem Pegel unterhalb des Flüssigkeitspegels im Reservoir verläuft, wenn das System in Betrieb ist.

13. Dampfkompressionssystem nach Anspruch 12, in dem die Dampfabzugsleitung einen U-förmigen Teil mit zwei Schenkeln und einem zwischen ihnen verlaufenden Verbindungsteil enthält, worin der stromaufwärtige Schenkel des U-förmigen Teils den nach unten verlaufenden Abschnitt liefert.

14. Dampfkompressionssystem nach Anspruch 13, in dem die Verbindungsstelle zwischen der Dampfabzugsleitung und der Flüssigkeitsabzugsleitung im stromabwärtigen Schenkel des U-förmigen Teils der Dampfabzugsleitung liegt.

15. Dampfkompressionssystem nach Anspruch 14, in dem die Verbindungsstelle zwischen der Dampfabzugsleitung und der Flüssigkeitsabzugsleitung bei ungefähr dem Flüssigkeitspegel im Reservoir liegt, wenn das System in Betrieb ist.

16. Dampfkompressionssystem nach Anspruch 1, in dem die Flüssigkeitsabzugsleitung so gestaltet ist, daß in ihr enthaltene Flüssigkeit in einer Wärmeaustauschbeziehung mit vom Verflüssiger ausgeströmtem flüssigem Kühlmittel angeordnet ist, so daß sie durch das flüssige Kühlmittel erwärmt und zumindest teilweise verdampft wird, zwischen einem Austritt in die Leitung vom Reservoir und einem Austritt aus der Leitung in die Dampfabzugsleitung.

17. Dampfkompressionssystem nach Anspruch 16, in dem die Flüssigkeitsabzugsleitung eine Verengung in ihr enthält, durch die ein Kühlmittelstrom entlang der Leitung gesteuert wird.

18. Dampfkompressionssystem nach Anspruch 16 oder Anspruch 17, in dem sich die Öffnung in die Flüssigkeitsabzugsleitung für Flüssigkeit aus dem Reservoir im Boden des Reservoirs befindet.

19. Dampfkompressionssystem nach einem der Ansprüche 16 bis 18, in dem Kühlmittel während einer Wärmeaustauschbeziehung mit dem Kondensat im allgemeinen nach oben strömt.

20. Dampfkompressionssystem nach einem der Ansprüche 1 bis 19, in dem die Einrichtung zum Steuern der Rate einer Entnahme von flüssigem Kühlmittel aus dem Reservoir so eingerichtet ist, daß die Feuchtigkeit des aus dem Verdampfer in das Reservoir ausgeströmten Kühlmittels nicht mehr als 5%, vorzugsweise nicht mehr als etwa 3,5% beträgt.

21. Dampfkompressionssystem nach einem der vorhergehenden Ansprüche, das ein Kühlmittel enthält, das aus zwei oder mehr wechselseitig löslichen Kühlmittelsubstanzen besteht, die keine azeotrope Mischung bilden.

22. Dampfkompressionssystem nach einem der vorhergehenden Ansprüche, das zwei Verdampfer enthält, die so angeordnet sind, daß ein Fluid nacheinander über aufeinanderfolgende Temperaturbereiche gekühlt wird.

23. Dampfkompressionssystem nach Anspruch 22, das jeweilige Reservoire enthält, in die man Kühlmittel aus den Verdampfern ausströmen läßt.

24. Dampfkompressionssystem nach Anspruch 23, das Ventile zum Steuern des Fluidstroms zwischen den Verdampfern enthält, wobei die Ventile gemäß dem Pegel des flüssigen Kühlmittels in den Reservoiren gesteuert werden.

25. Verfahren zum Betreiben eines Dampfkompressionssystems, in dem eine Kühlmittelmenge zwischen zumindest zwei Druckpegeln in einem Verflüssiger (5) bzw. einem Verdampfer (15) zirkuliert, worin das Kühlmittel aus zwei oder mehr gegenseitig löslichen Kühlmittelsubstanzen besteht, die keine azeotrope Mischung bilden, wobei das System aufweist:

(a) einen Kompressor (1) zum Erhöhen des Drucks des Kühlmitteldampfes;
(b) den Verflüssiger für vom Kompressor empfangenen Kühlmitteldampf unter hohem Druck;
(c) eine Expansionseinrichtung (13), die dem Verdampfer vom Verflüssiger flüssiges Kühlmittel mit der Rate zuführt, mit der es im Verflüssiger erzeugt wird, wobei über die Einrichtung die Druckdifferenz zwischen dem Verflüssiger und dem Verdampfer aufrechterhalten wird, um den Abzug von flüssigem Kühlmittel aus dem Verflüssiger nach dem Volumen an flüssigem Kühlmittel zu steuern, das in oder hinter ihm ist;
(d) den Verdampfer für vom Verflüssiger empfangenes flüssiges Kühlmittel;
(e) ein Sammelgefäß (21), in das man das Kühlmittel vom Verdampfer ausströmen läßt, wobei das Sammelgefäß enthält:

- ein Reservoir, in das sich vom Verdampfer ausgeströmtes flüssiges Kühlmittel sammelt, um die Zufuhr von flüssigem Kühlmittel zum Kompressor zu steuern;
- eine Dampfabzugsleitung (25), durch die Kühlmitteldampf aus dem Sammelgefäß für die Zufuhr zum Kompressor abgezogen wird; und
- eine Flüssigkeitsabzugsleitung (27), durch die flüssiges Kühlmittel aus dem Reservoir in die Dampfabzugsleitung für die Zufuhr

zum Kompressor abgezogen wird,

wobei das Verfahren umfaßt: Zuführen eines feuchten Kühlmittels zum Kompressor und Steuern der Rate einer Entnahme von flüssigem Kühlmittel aus dem Reservoir im Verhältnis zur Kühlmittelmenge, die aus dem Sammelgefäß als Dampf entnommen wird, um die Feuchtigkeit des aus dem Verdampfer in das Sammelgefäß ausgeströmten Kühlmittels zu steuern, um sicherzustellen, daß im wesentlichen die gesamte Wärmeaustauschoberfläche des Verdampfers unter normalen Betriebsbedingungen des Systems feucht bleibt.

26. Verfahren nach Anspruch 25, in dem die Dampfabzugsleitung so angeordnet ist, daß der Druck von in ihr strömendem Dampf an einem Punkt stromabwärts des Reservoirs in bezug auf den Druck im Reservoir verringert ist, so daß flüssiges Kühlmittel im Reservoir durch die Flüssigkeitsabzugsleitung in die Dampfabzugsleitung gezogen wird.

27. Verfahren nach Anspruch 25, in dem die Flüssigkeitsabzugsleitung so angeordnet ist, daß in ihr enthaltene Flüssigkeit in einer Wärmeaustauschbeziehung mit aus dem Verflüssiger ausgeströmtem flüssigem Kühlmittel so angeordnet ist, daß es durch das flüssige Kühlmittel erwärmt und zumindest teilweise verdampft wird, zwischen einem Austritt aus dem Reservoir in die Leitung und einem Austritt aus der Leitung in die Dampfabzugsleitung.

Revendications

1. Système de compression de vapeur dans lequel une certaine quantité de réfrigérant circule entre au moins deux niveaux de pression dans un condenseur (5) et un évaporateur (15), respectivement, comprenant :

(a) un compresseur (1) pour augmenter la pression de vapeur de réfrigérant ;
(b) le condenseur pour une vapeur de réfrigérant à haute pression reçue du compresseur ;
(c) un dispositif de détente (13) qui admet du réfrigérant liquide dans l'évaporateur depuis le condenseur au débit auquel il est produit dans le condenseur, dispositif à travers lequel le différentiel de pression entre le condenseur et l'évaporateur est maintenu, de façon à contrôler le retrait du réfrigérant liquide du condenseur en fonction du volume de réfrigérant liquide qui se trouve à l'intérieur de celui-ci ou derrière celui-ci ;
(d) l'évaporateur pour du réfrigérant liquide reçu du condenseur ;
(e) un récepteur (21) dans lequel du réfrigérant est déchargé depuis l'évaporateur, le récepteur comprenant un réservoir dans lequel du réfrigérant liquide déchargé de l'évaporateur est recueilli, pour contrôler la délivrance de réfrigérant liquide au compresseur ;
(f) un conduit de retrait de vapeur (25) à travers lequel de la vapeur est retirée du récepteur pour être délivrée au compresseur ;
(g) un conduit de retrait de liquide (27) à travers lequel du réfrigérant liquide est retiré du réservoir dans le conduit de retrait de vapeur pour être délivré au compresseur ; et
(h) des moyens (35) pour contrôler le débit de retrait de réfrigérant liquide depuis le réservoir proportionnellement à la quantité de réfrigérant qui est retiré du récepteur sous la forme de vapeur, de telle sorte que le réfrigérant venant des moyens de contrôle qui est délivré au compresseur ait une composition telle que le réfrigérant déchargé ensuite dans le récepteur depuis l'évaporateur soit humide dans les conditions de fonctionnement normal du système.

2. Système de compression de vapeur selon la revendication 1, dans lequel le récepteur est agencé de telle sorte que du réfrigérant liquide contenu dans le réservoir soit maintenu dans le réservoir lors de l'arrêt du système.

3. Système de compression de vapeur selon la revendication 1 ou la revendication 2, dans lequel le conduit de retrait de vapeur est agencé de telle sorte que la pression de vapeur circulant dans celui-ci soit réduite en un point en aval du réservoir par rapport à la pression dans le réservoir, et dans lequel le conduit de retrait de liquide est agencé de telle sorte que du réfrigérant liquide dans le réservoir soit aspiré à travers le conduit de retrait de liquide dans le conduit de retrait de vapeur.

4. Système de compression de vapeur selon la revendication 3, dans lequel la configuration du conduit de retrait de vapeur et la configuration du conduit de retrait de liquide sont sélectionnées de telle sorte que la chute de pression dans le conduit de retrait de vapeur entre le réservoir et l'endroit où il rejoint le conduit de retrait du liquide assure un écoulement contrôlé de liquide le long du conduit de retrait de liquide du réservoir à la jonction.

5. Système de compression de vapeur selon la revendication 4, dans lequel la configuration de section transversale du conduit de retrait de vapeur diffère entre les parties en amont et en aval, respectivement, de la jonction avec le conduit de retrait de liquide.

6. Système de compression de vapeur selon l'une quelconque des revendications 3 à 5, dans lequel la jonction entre les conduits de retrait de vapeur et de liquide se trouve à un niveau qui est à peu près au niveau de réfrigérant liquide dans le réservoir lorsque le système est en fonctionnement à l'état stable, ou légèrement au-dessus de ce niveau.

7. Système de compression de vapeur selon la revendication 6, dans lequel l'ouverture du conduit de retrait de liquide dans le conduit de retrait de vapeur décharge du réfrigérant liquide dans le conduit de retrait de vapeur en un point qui se trouve à peu près au moins à un tiers de la distance dans le conduit de retrait de vapeur.

8. Système de compression de vapeur selon la revendication 3, dans lequel le conduit de retrait de vapeur comporte un étranglement dans celui-ci.

9. Système de compression de vapeur selon la revendication 8, dans lequel ledit étranglement constitue un venturi.

10. Système de compression de vapeur selon l'une quelconque des revendications 3 à 9, dans lequel le conduit de retrait de liquide comprend une partie en forme de n avec deux branches et une partie de raccordement s'étendant entre elles, dans laquelle du liquide est aspiré depuis le réservoir et amené à s'écouler initialement vers le haut à partir du réservoir le long d'une première des branches, et vers le bas, vers la jonction avec le conduit d'écoulement de vapeur le long de l'autre des branches.

11. Système de compression de vapeur selon l'une quelconque des revendications 3 à 10, dans lequel le conduit de retrait de liquide comprend une section qui est un capillaire.

12. Système de compression de vapeur selon l'une quelconque des revendications 3 à 11, dans lequel l'ouverture pour que la vapeur rentre dans le conduit de retrait de vapeur se trouve au sommet du réservoir ou près de celui-ci, et dans lequel le conduit de retrait de vapeur comprend une section qui s'étend vers le bas jusqu'à un niveau inférieur au niveau de liquide dans le réservoir lorsque le système fonctionne.

13. Système de compression de vapeur selon la revendication 12, dans lequel le conduit de retrait de vapeur comprend une partie en forme de U avec deux branches et une partie de raccordement s'étendant entre elles, dans lequel la branche amont de la partie en forme de U constitue ladite section s'étendant vers le bas.

14. Système de compression de vapeur selon la revendication 13, dans lequel la jonction entre le conduit de retrait de vapeur et le conduit de retrait de liquide est disposée dans la branche aval de la partie en forme de U du conduit de retrait de vapeur.

15. Système de compression de vapeur selon la revendication 14, dans lequel la jonction entre le conduit de retrait de vapeur et le conduit de retrait de liquide est disposée approximativement au niveau du liquide dans le réservoir lorsque le système fonctionne.

16. Système de compression de vapeur selon la revendication 1, dans lequel le conduit de retrait de liquide est configuré de telle sorte que du liquide contenu dans celui-ci soit mis en relation d'échange thermique avec du réfrigérant liquide déchargé du condenseur, de telle sorte qu'il soit chauffé et au moins partiellement évaporé par ledit réfrigérant liquide, entre la décharge dans le conduit depuis le réservoir et la décharge depuis le conduit dans le conduit de retrait de vapeur.

17. Système de compression de vapeur selon la revendication 16, dans lequel le conduit de retrait de liquide comprend un étranglement dans celui-ci, grâce auquel l'écoulement de réfrigérant le long du conduit est contrôlé.

18. Système de compression de vapeur selon la revendication 16 ou la revendication 17, dans lequel l'ouverture dans le conduit de retrait de liquide pour le liquide venant du réservoir est disposée à la base du réservoir.

19. Système de compression de vapeur selon l'une quelconque des revendications 16 à 18, dans lequel du réfrigérant s'écoule généralement vers le haut lorsqu'il est en relation d'échange thermique avec le condenseur.

20. Système de compression de vapeur selon l'une quelconque des revendications 1 à 20, dans lequel les moyens pour contrôler le débit de retrait de réfrigérant liquide depuis le récepteur sont agencés de telle sorte que l'humidité du réfrigérant déchargé de l'évaporateur dans le récepteur ne soit pas supérieure à environ 5%, et, de préférence, pas supérieure à environ 3,5%.

21. Système de compression de vapeur selon l'une quelconque des revendications précédentes, qui comprend un réfrigérant qui se compose de deux ou plusieurs substances de réfrigérant mutuellement solubles qui ne forment pas un azéotrope.

22. Système de compression de vapeur selon l'une quelconque des revendications précédentes, qui comprend deux évaporateurs agencés pour refroidir un fluide en séquence, par des plages de température successives.

23. Système de compression de vapeur selon la revendication 22, qui comprend des réservoirs respectifs, dans lesquels du réfrigérant est déchargé depuis les évaporateurs.

24. Système de compression de vapeur selon la revendication 23, qui comprend des vannes pour contrôler l'écoulement de fluide entre les évaporateurs, les vannes étant commandées en fonction du niveau de réfrigérant liquide dans les réservoirs.

25. Procédé pour faire fonctionner un système de compression de vapeur dans lequel une certaine quantité d'un réfrigérant circule entre au moins deux niveaux de pression dans un condenseur (5) et un évaporateur (15), respectivement, dans lequel le réfrigérant se compose de deux ou plusieurs substances de réfrigérant mutuellement solubles qui ne forment pas un azéotrope, le système comprenant :

(a) un compresseur (1) pour augmenter la pression de vapeur de réfrigérant ;
(b) le condenseur pour de la vapeur de réfrigérant à haute pression reçue du compresseur ;
(c) un dispositif de détente (13) qui admet du réfrigérant liquide dans l'évaporateur depuis le condenseur au débit auquel il est produit dans le condenseur, dispositif à travers lequel le différentiel de pression entre le condenseur et l'évaporateur est maintenu, de façon à contrôler le retrait du réfrigérant liquide depuis le condenseur en fonction du volume de réfrigérant liquide qui se trouve à l'intérieur de celui-ci ou derrière celui-ci ;
(d) l'évaporateur pour du réfrigérant liquide reçu depuis le condenseur ; et
(e) un récepteur (21), récepteur dans lequel du réfrigérant est déchargé depuis l'évaporateur, le récepteur comprenant :

. un réservoir dans lequel du réfrigérant liquide déchargé depuis l'évaporateur est recueilli, de façon à contrôler la délivrance de réfrigérant liquide au compresseur,
. un conduit de retrait de vapeur (25) à travers lequel de la vapeur de réfrigérant est retirée du récepteur pour être délivrée au compresseur, et
. un conduit de retrait de liquide (27) à travers lequel du réfrigérant liquide est retiré du réservoir dans le conduit de retrait de vapeur pour être délivré au compresseur,

le procédé comprenant la délivrance de réfrigérant humide au compresseur et le contrôle du débit de retrait du réfrigérant liquide depuis le récepteur proportionnellement à la quantité de réfrigérant qui est retiré du récepteur sous la forme de vapeur, de façon à contrôler l'humidité du réfrigérant déchargé dans le récepteur depuis l'évaporateur afin d'assurer que sensiblement toute la surface d'échange thermique de l'évaporateur reste humide dans les conditions de fonctionnement normal du système.

26. Procédé selon la revendication 25, dans lequel le conduit de retrait de vapeur est agencé de telle sorte que la pression de vapeur circulant dans celui-ci soit réduite en un point situé en aval du réservoir par rapport à la pression dans le réservoir, de telle sorte que le réfrigérant liquide dans le réservoir soit aspiré dans le conduit de retrait de vapeur à travers le conduit de retrait de liquide.

27. Procédé selon la revendication 25, dans lequel le conduit de retrait de liquide est configuré de telle sorte que du liquide contenu dans celui-ci soit mis en relation d'échange thermique avec du réfrigérant liquide déchargé du condenseur, de telle sorte qu'il soit chauffé et au moins partiellement évaporé par ledit réfrigérant liquide, entre la décharge dans le conduit depuis le réservoir et la décharge depuis le conduit dans le conduit de retrait de vapeur.

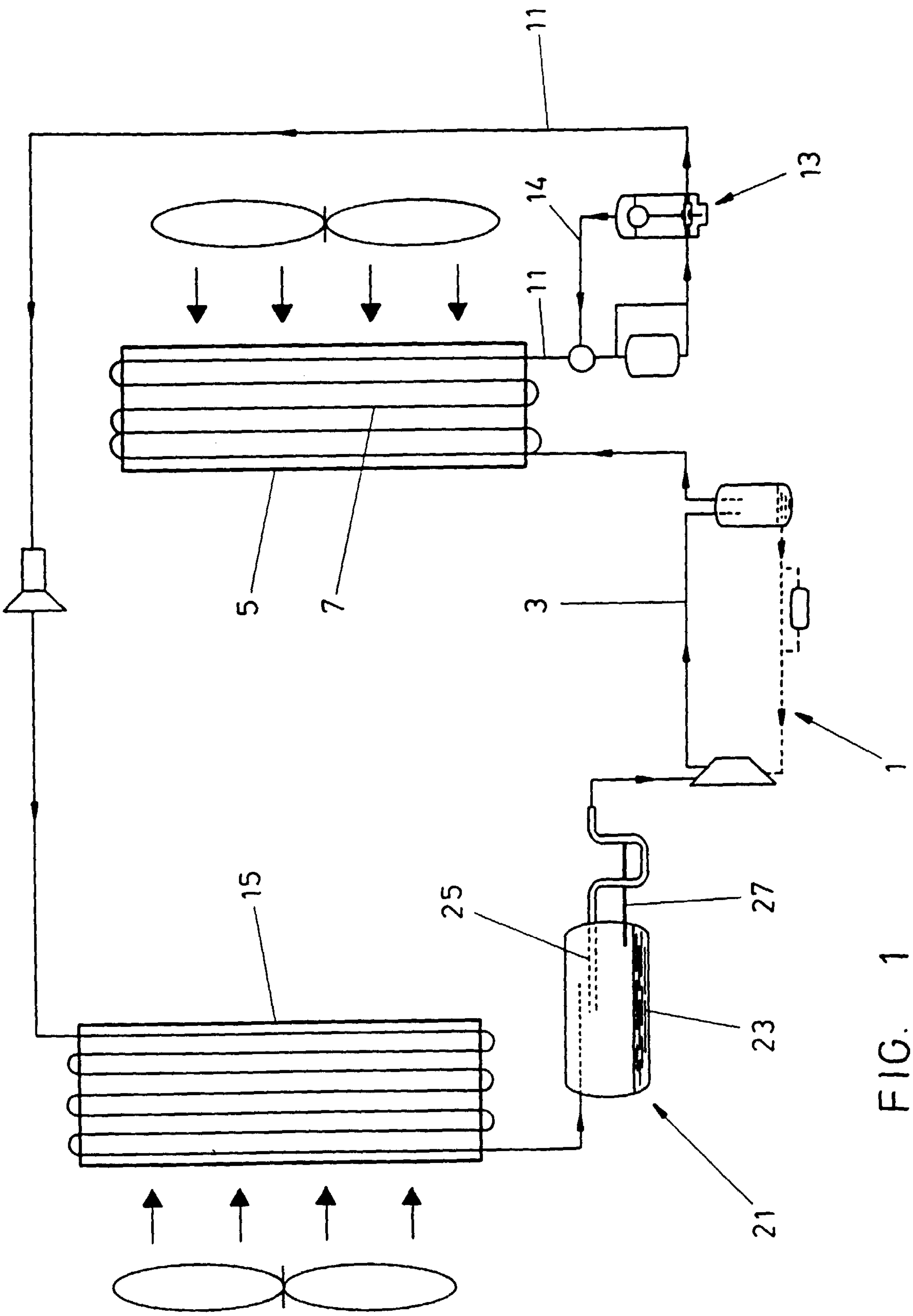

FIG. 1

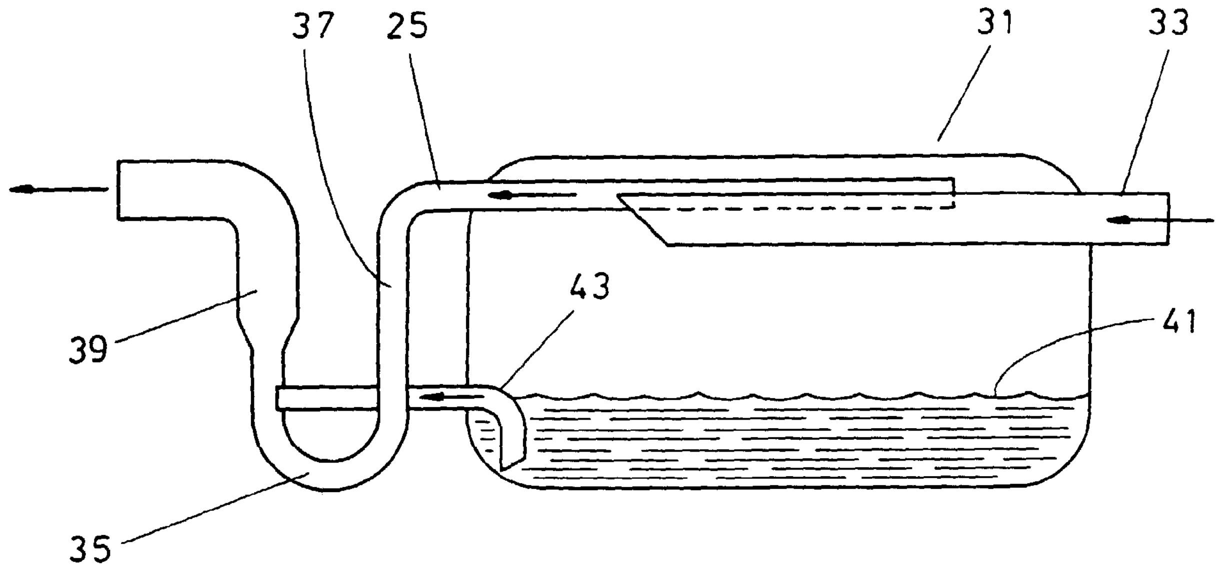

FIG. 2

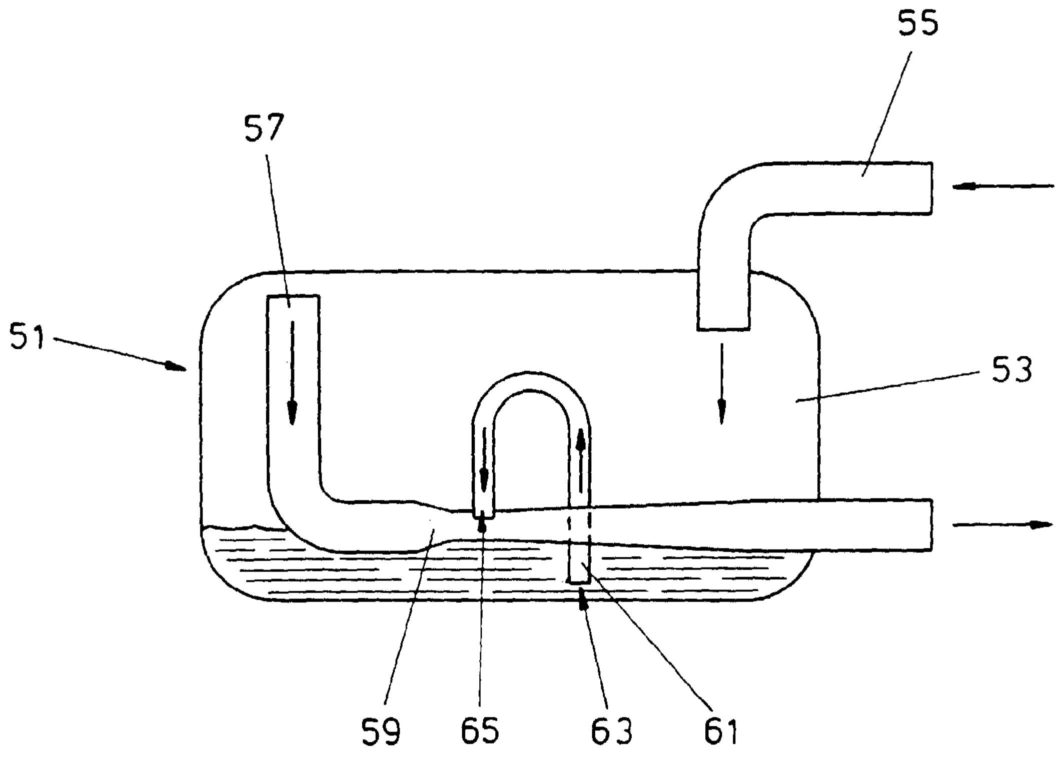

FIG. 3

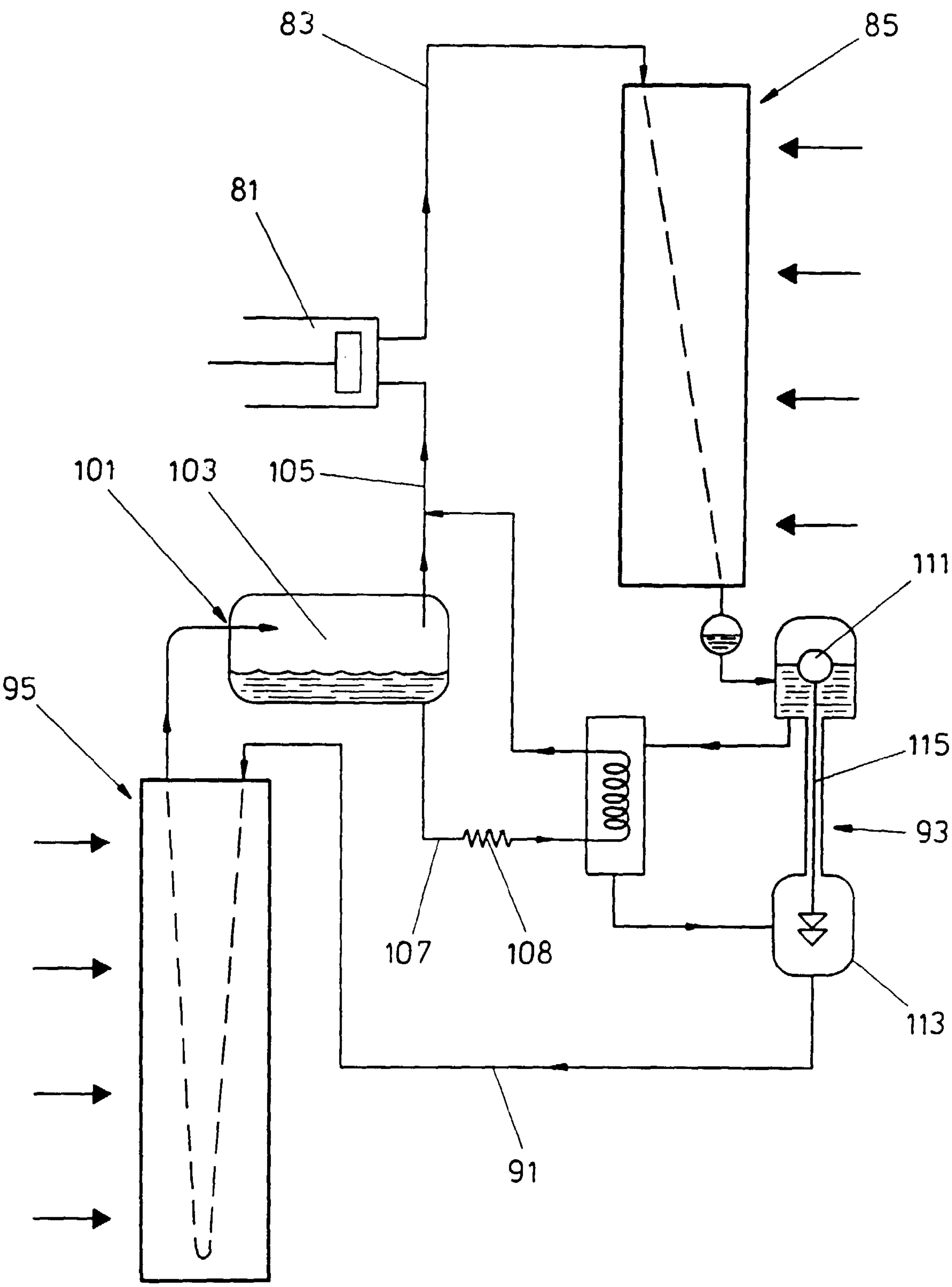

FIG. 4

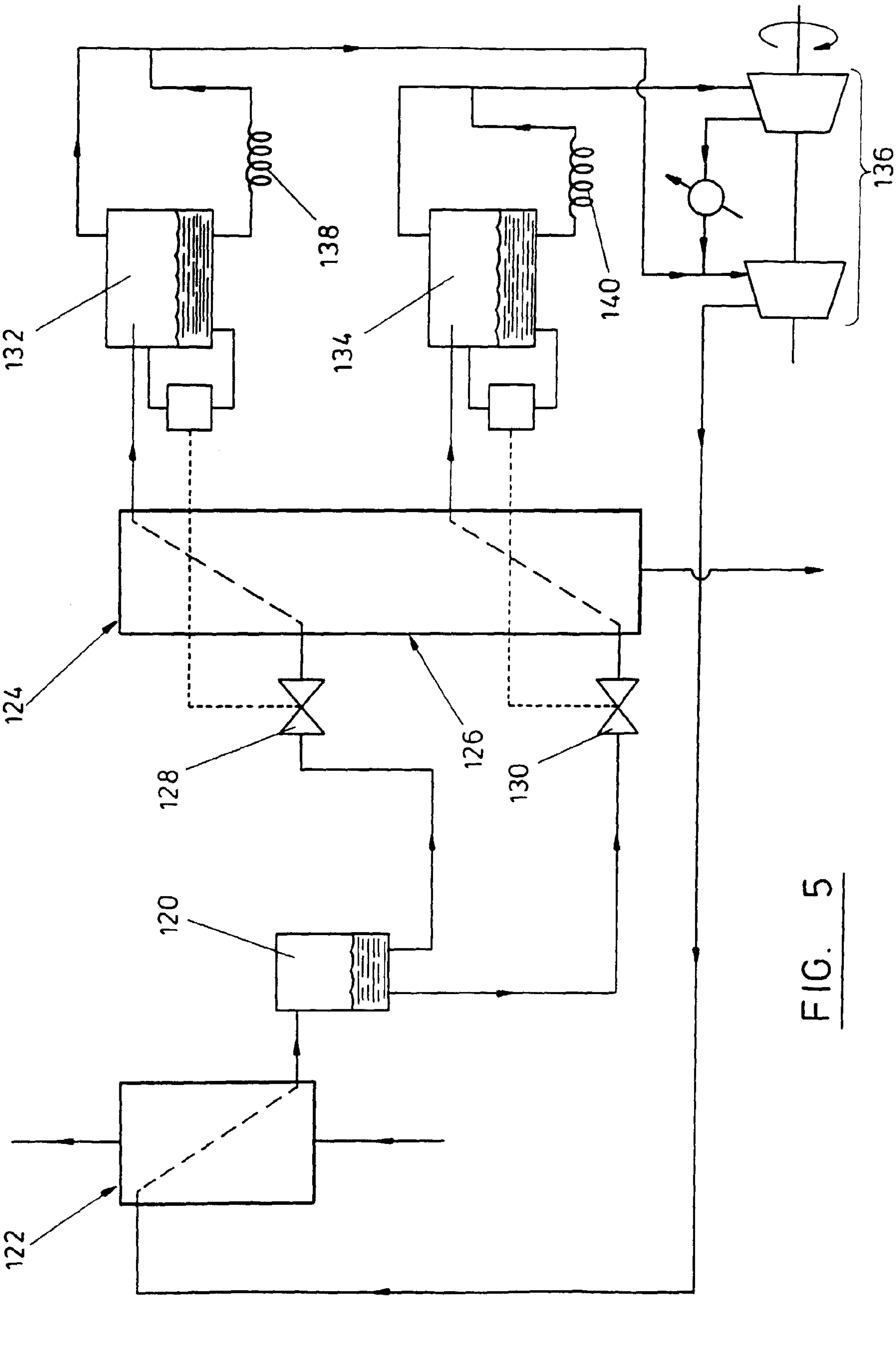

FIG. 5