

HEAT-PUMP HEATING APPARATUS

FIELD OF INVENTION

This invention relates to a multistage heat-pump heating apparatus in
5 which a fluid is heated by passing through a plurality of heat-pumps.

BACKGROUND TO THE INVENTION

The concept of heat transfer is governed by a relationship of variables
wherein the rate of heat transfer, Q , is proportional to the flow rate, F , multiplied
10 by the temperature difference, ΔT , across a heat exchanger. The relationship
can be expressed in the formula below:

$$Q = k \times F \times \Delta T$$

where k is a constant according to the properties of the heat transfer fluid.

15 The formula implies that for a constant heat source, and constant flow
rate, the temperature difference will be constant. The invention disclosed
herein relies on the principle of this formula. A heat source is provided by a
heat-pump while fluid to be heated is circulated continuously through a heat
exchanger that receives thermal energy from the condenser of the heat-pump.

20 A heat-pump heating apparatus should normally operate with high water
flow rates resulting in a small temperature increment of 5°C to 10°C in the fluid
passing through the condenser with the main objective of removing thermal
energy imparted to the refrigerant quickly. The condenser is hence, kept
relatively small in size while the circulating pump operates with a high flow rate.
25 However, the normal demand of a heat pump heating apparatus would be

expected to provide a temperature increment typically around 50°C. It would then imply that many stages are needed when many heat pumps are configured in series operation; unless a means to raise the temperature of the fluid before entering the condenser is available. Otherwise, the setup would require a very low flow rate of fluid flowing through a very large condenser and perhaps also coupled to a large capacity heat-pump which seems unreasonable.

It is thus a primary objective of the present invention to provide a multistage heat-pump heating apparatus that can provide a large overall temperature increment with fewer number of stages.

SUMMARY OF THE INVENTION

Fluid is fed through a plurality of fluid flow loops, each coupled to a condenser of a heat-pump, via a system inlet and circulated by a pump continuously to flow through said condenser, and exit a loop outlet to the subsequent stage of each fluid flow loop; and discharged via a system outlet after the last fluid flow loop. However, at each loop outlet, a feedback fluid line leads some of the hotter fluid back to the input point of the respective loop, to mix with colder fluid entering the fluid flow loop from the respective loop inlet, thus raising the temperature of the incoming fluid to an intermediate temperature before absorbing thermal energy with a small temperature increment on passing through each respective condenser. In addition, the fluid flow loops are arranged in series.

Said fluid flow loops are superimposed onto a system flow circuit that feeds fluid to be heated from a colder fluid source to arrive at the final target temperature of the system. As the system flow from one stage to the next, it will

gain a temperature rise which is higher than the temperature rise created within the heat pump stage thus reducing the total number of stages required. The condensing temperature of each succeeding heat pump is higher than that of the respective preceding heat pump so that fluid circulating in the respective fluid flow loop is at a higher temperature than that flowing into the fluid flow loop from the respective loop inlet.

To achieve a higher temperature rise when system fluid passes through one stage to the next, the inlet fluid to the next heat pump stage is increased by mixing with hotter fluid from a feedback fluid line before flowing through the condenser to raise its temperature by a predetermined increment. As such, the temperature increment across each fluid flow loop is higher than if the fluid passes straight through the condensers in direct serial connection. Consequently, the total number of fluid flow loops is significantly reduced.

15 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic diagram of the invention;

DETAILED DESCRIPTION OF THE INVENTION

A detailed description of preferred embodiments of the invention is disclosed herein. It should be understood, however, the disclosed preferred embodiments are merely exemplary of the invention, which may be embodied in various forms. Therefore, the details disclosed herein are not to be interpreted as limiting, but merely as the basis for the claims and for teaching one skilled in the art on the invention.

In general, the fluid to be heated is a liquid such as water or other thermal fluids, such as oil. Water is commonly used in a hot water supply system while water or oil can be used as a secondary heat transfer medium in some factory processes. A multistage heat-pump heating apparatus is capable
5 to impart a large overall temperature increment with the final hot fluid temperature reaching 100°C or above. There would be many applications thereof; such as providing preheated fluid for subsequent heating by other means or directly applied to a manufacturing process or the like.

The preferred embodiment of the heat-pump heating apparatus **1**
10 includes a plurality of fluid flow loops **110 to n10**, each fluid flow loop **110 to n10** comprises a loop inlet **113 to n13**, a circulating pump **111 to n11**, a feedback flow line **112 to n12**, a hot mixing fluid line **117 to n17** connected at one end to the inlet of the circulating pump **111 to n11** and at the other end to the loop inlet **113 to n13** and one end of a feedback fluid line **112 to n12**, a
15 condenser **132 to n32** of a heat-pump **130 to n30**, a pre-heating fluid line **118 to n18** for carrying fluid from the outlet of the circulating pump **111 to n11** to the inlet of the condenser **132 to n32**, a loop outlet **114 to n14** and a post-heating fluid line **119 to n19** connected at one end to the outlet of the condenser **132 to n32** and at the other end to the loop outlet **114 to n14** and the other end of the
20 feedback fluid line **112 to n12**.

In addition, the heat-pump heating apparatus **1** further includes a plurality of heat-pumps **130 to n30**, with one heat-pump **130 to n30** coupled to each fluid flow loop **110 to n10** and each heat-pump **130 to n30** comprises a sealed refrigeration system that includes a compressor **131 to n31**, a condenser **132 to**
25 **n32** having a fluid flow path separate from the refrigerant, a metering device

133 to n33, an evaporator **134 to n34**, in fluid communication with each other, such that a refrigerant within the system circulates from compressor **131 to n31** to condenser **132 to n32** to metering device **133 to n33** to evaporator **134 to n34** and back to compressor **131 to n34**, in so doing, thermal energy is absorbed via said evaporator **134 to n34** and transferred to said condenser **132 to n32**, respectively.

Said plurality of fluid flow loops **110 to n10** are connected in series with the loop outlet **114 to (n-1)14** of the preceding fluid flow loop **110 to (n-1)10** in fluid communication with the loop inlet **213 to n13** of the succeeding fluid flow loop where n is an integer greater than one throughout this specification.

Said fluid flow loops **110 to n10** are superimposed onto a system flow circuit **10** comprising a system inlet **101** connected to a fluid source; a system feed pump **103** feeding fluid to be heated from said system inlet **101** to the loop inlet **113** of the first fluid flow loop **110**; and a system outlet **102** in fluid communication with the loop outlet **114** of the last fluid flow loop **n10** for discharging heated fluid.

The condensing temperature of each succeeding heat pump **230 to n30** is higher than that of the respective preceding heat pump **130 to (n-1)30** so that fluid circulating in the respective fluid flow loop **110 to n10** is at a higher temperature than that flowing into the fluid flow loop **110 to n10** from the respective loop inlet **113 to n13**.

The fluid flowing into the hot mixing fluid line **117 to n17** comprises a mixture of colder fluid flowing into the fluid flow loop **110 to n10** via the loop inlet **113 to n13** and hotter fluid from the feedback fluid line **112 to n12**. The circulating pump **111 to n11** continuously circulates fluid from the hot mixing

fluid line **117 to n17** to said condenser **132 to n32** for heating. Some of the heated up fluid return via the feedback fluid line **112 to n12**, while the balance flow out of the fluid flow loop **110 to n10** via the respective loop outlet **114 to n14**.

5 The flow rate of fluid through each fluid flow loop **110 to n10** is significant higher than the flow rate through the system flow circuit **10**. The relatively higher flow rate of fluid flowing through each fluid flow loop **110 to n10** facilitates continuous removal of thermal energy from refrigerant flowing through the condenser **132 to n32** that is continuously pumped by the compressor **131 to**
10 **n31** of each heat-pump **130 to n31**. The relatively higher flow rate of fluid flowing through each fluid flow loop **110 to n10** also balances with the capacity of the heat pump as well as maintaining a small temperature increment across the condenser **132 to n32**.

 A flow control means is provided to adjust the flow rate of fluid flowing
15 through the system in a continuously variable manner to achieve the designed system output temperature. Said flow control means comprises a temperature sensor **104** disposed at the system outlet **102** to detect temperature of heated fluid being discharged, and a controller **105** that respond to signals from said temperature sensor **104**.

20 The steady state fluid flow mechanism by which fluid is heated will now be described.

 Fluid from the fluid source is fed by said system feed pump **103** to flow into the inlet **113** of the first fluid flow loop **110**. This colder incoming fluid will meet and mix with hotter fluid from feedback fluid line **112**, thus having its
25 temperature raised to an intermediate temperature between that of the colder

incoming fluid and the hotter fluid from feedback fluid line **112**. This mixed fluid is drawn into the circulating pump **111** by its suction pressure and pumped to flow into inlet of condenser **132**. This fluid upon passing through the condenser **132** will have its temperature raised by a predetermined quantum, typically a small increment between 5° to 10° C, before exiting the outlet of the condenser **132**. When this heated fluid reaches the node where the post-heating fluid line **119** joins the loop outlet **114** and the feedback fluid line **112**, some of it will flow towards the loop outlet **114** of the first fluid flow loop **110** and into the loop inlet **213** of the second fluid flow loop **210**, while the balance is drawn back towards the hot mixing fluid line **117 to n17** of the first fluid flow loop **110** to mix with colder incoming fluid from the loop inlet **113**. In the condenser **132**, the flow direction of the fluid to be heated up is preferably opposite to the flow direction of the refrigerant flowing through the refrigerant circuit.

The raising of fluid temperature by mixing colder fluid into each subsequent loop inlet **213 to n13** with hotter fluid from feedback fluid line **112 to n12** and further having the fluid temperature raised by a small increment passing through condenser **232 to n32** is repeated respectively until the last fluid flow loop **n10**. At the last fluid flow loop **n10**, hot fluid is discharged via the system outlet **102**.

When the heat-pump heating apparatus **1** is started from cold condition, fluid within each fluid flow loop **110 to n10** will be circulated within each loop to gain temperature increment as the fluid passes through the condenser **132 to n32**. The temperature sensor at the system outlet **102** would signal to the controller **105** that further reduces the flow rate of fluid fed into the system circuit. As the temperature of hot fluid discharged at system outlet **102**

increases, the flow rate of fluid fed into the system circuit increases in tandem until steady state is achieved.

In the preferred embodiment, all the heat-pumps **130 to n30** use the same refrigerant but are provided with different operating parameters. The varied operating parameters also result in varied ratings of the heat-pumps **130 to n30** so that with the appropriate selection of ratings, the overall efficiency can be maintained at an optimum level. In actual practice, different refrigerant can be used for each heat-pump, if it necessary to improve performance or efficiency.

In addition, the temperature increment of fluid passing through each fluid flow loop **110 to n10** is substantially divided over the fluid flow loops **110 to n10**, but need not be equal. For example, in a two-stage heat-pump heating apparatus, the inlet fluid temperature may be 25°C and the outlet fluid temperature may be 70°C. The overall difference of 45°C may be divided into 20°C and 25°C resulting in temperatures at loop outlets **114, 214** of fluid flow loops **110, 210** being at 45°C and 70°C, respectively. However, the temperature increment across each heat exchanger is maintained at a low 5°C to 10°C. The intermediate temperature after mixing of the fluids in each fluid flow loop will be adjusted by setting the appropriate heat-pump operating parameters and the flow rate of fluid flowing through each fluid flow loop to achieve the desired temperature increment of 20°C and 25°C, respectively.

It is clear then, that the heat-pump heating apparatus **1** of the present invention can provide a low number of heating stages, only two in this example, compared to 5 to 9 stages if the fluid passes straight through each condenser

when the temperature increment across each condenser is only maintained at a low 5°C to 10°C.

Furthermore, the temperature of fluid entering each loop inlet **113 to n13** is independent of the temperature of fluid exiting the loop outlet **114 to n14** of a preceding fluid flow loop. This feature of the heat-pump heating apparatus **1** of the present invention detracts from prior art for series connected multistage heat-pump heating apparatus where for each stage, the temperature of fluid of each stage is dependent on the temperature of fluid of a preceding stage. In the heat-pump heating apparatus **1** of the present invention, each fluid flow loop **110 to n10** can be fine tuned independently by various parameters, such as fluid flow rate or operating parameter of the associated connected heat-pump, so that the temperature increment for each fluid flow loop **110 to n10** can be adjusted independently, in order that the final target fluid temperature is achieved. All these adjustments are carried out during the design and commissioning stages.

The adjustment of the final target temperature of fluid during operation is achieved via said controller **105** that responds to signals from a temperature sensor **104** predisposed at the system outlet **102**. When the discharge fluid temperature at the system outlet **102** is lower than the target temperature, said controller means **105** will respond by reducing the flow rate of fluid pumped by the system feed pump **103** and vice versa. The changes in temperature of the discharged fluid can occur by virtue of changes in demand for hot fluid and/or changes in temperature of fluid fed into the system via said system feed pump **103** but the controller **105** will respond appropriately to stabilise the final target temperature.

Consequently, when the demand increases or reduces, the temperature of fluid discharged via the system outlet **102** will be reduced or increased respectively; so the controller **105** will respond by reducing or increasing the flow rate of fluid fed by the system feed pump **103**, respectively. Further, when the temperature of cold incoming fluid fed into the system via the system inlet **101** increases or reduces, the temperature of fluid discharged via the system outlet **102** will be increased or reduced respectively; so the controller **105** will respond by increasing or reducing the flow rate of fluid fed by the system feed pump **103**, respectively.

Furthermore, the final target temperature of the fluid can also be varied by adjusting the temperature set point while utilizing the same system in the preferred embodiment.

The foregoing discussion had emphasized the fluid flow behavior, raising the temperature of colder fluid fed into each fluid flow loop **110 to n10** via the respective loop inlet **113 to n13** before gaining a small temperature increment passing through each condenser **132 to n32** and control of temperature of hot fluid discharged via the system outlet **102**. The temperature increment of fluid flowing through each fluid flow loop **110 to n10** is decided and adjusted during the design and commissioning stages, as described earlier. However, the actual temperature increment of fluid through each fluid flow loop **110 to n10** need not be controlled at all. It is self-modulating by the heating capacity of each fluid flow loop **110 to n10**.

The flow rate of fluid fed by the system feed pump **103** can be achieved by various means. One method is by using a motorised valve in fluid communication with said system feed pump **103**, preferably at the discharge

end of the system. A suitable controller **105** is one that can drive the actuator of the actuated valve variably between full open and full close, hence, adjusting the flow rate of fluid flowing through the system. Another method is by using a variable speed drive to increase or decrease the rotational speed of the motor driving said system feed pump **103**, hence, adjusting the flow rate of fluid flowing through the system. These methods are given as mere examples and are not meant to be limiting. The flow rate of fluid pumped by the system feed pump **103** will also determine the delivery rate of hot fluid for the heat-pump heating apparatus **1** of the present invention.

Said fluid source can be fluid from a storage tank or a pipe supplying the fluid continuously. In the case that the fluid is water, said fluid source may be the municipal water supply. In the case that the fluid is water or oil, said fluid source may be water or oil in a storage tank or the return pipe of used process oil in a factory. Consequently, one skilled in the art can understand that the heat-pump heating apparatus **1** of the present invention is independent of the fluid source; the choice of fluid source is dependent on how or where the heated fluid will be used.

Hot fluid discharging from system outlet **102** may be directly supplied to point of usage or stored in a storage tank to be used when there is demand for hot fluid.

The heat-pump heating apparatus **1** of the present invention has thus provided a simple setup of fluid flow paths with a plurality of loops such that a large overall temperature increment can be achieved with a small number of heat-pump stages.

Thus, since the invention disclosed herein may be embodied in other specific embodiments without departing from the scope or general characteristics thereof, the embodiments described herein are to be considered in all respects illustrative and not restrictive. The scope of the invention is to be indicated by the appended claims and all changes which come within the meaning and range of equivalence of the claims are intended to be embraced therein.

CLAIMS

1. A heat-pump heating apparatus (1) for heating fluids, having a plurality of heat-pumps (130 to n30), each comprising a sealed refrigeration system
5 that includes a compressor (131 to n31), a condenser (132 to n32) having a fluid flow path separate from the refrigerant, a metering device (133 to n33), an evaporator (134 to n34), in fluid communication with each other, such that a refrigerant within the system circulates from compressor (131 to n31) to condenser (132 to n32) to metering device
10 (133 to n33) to evaporator (134 to n34) and back to compressor (131 to n34), in so doing, thermal energy is absorbed via said evaporator (134 to n34) and transferred to said condenser (132 to n32), respectively, where n is an integer greater than one;
- characterised in that said heat-pump heating apparatus (1) further
15 comprises a plurality of fluid flow loops (110 to n10), each fluid flow loop (110 to n10) comprising:
- a loop inlet (113 to n13);
 - a circulating pump (111 to n11) having an inlet and an outlet;
 - a feedback fluid line (112 to n12);
 - 20 a hot mixing fluid line (117 to n17) connected at one end to the inlet of the circulating pump (111 to n11) and at the other end to the loop inlet (113 to n13) and an end of a feedback fluid line (112 to n12);
 - a condenser (132 to n32) of a heat-pump (130 to n30) having an
25 inlet and an outlet;

a pre-heating fluid line (**118 to n18**) connecting the outlet of the circulating pump (**111 to n11**) to the inlet of the condenser (**132 to n32**);

a loop outlet (**114 to n14**); and

5 a post-heating fluid line (**119 to n19**) connected at one end to the outlet of the condenser (**132 to n32**) and at the other end to the loop outlet (**114 to n14**) and the other end of the feedback fluid line (**112 to n12**);

said plurality of fluid flow loops (**110 to n10**) connected in series,
10 with the loop outlet (**114 to (n-1)14**) of the preceding fluid flow loop (**110 to (n-1)10**) in fluid communication with the loop inlet (**213 to n13**) of the succeeding fluid flow loop;

wherein said plurality of series connected fluid flow loops (**110 to n10**) are superimposed onto a system flow circuit (**10**) comprising:

15 a system inlet (**101**) connected to a fluid source;

a system outlet (**102**) in fluid communication with the loop outlet (**n14**) of the last fluid flow loop (**n10**) for discharging heated fluid; and

a system feed pump (**103**) feeding fluid to be heated from said
20 system inlet (**101**) to the loop inlet (**113**) of the first fluid flow loop (**110**) and driving fluid to be heated to flow from said system inlet (**101**) through each fluid flow loop (**110 to n10**) in succession and finally discharge through said system outlet (**102**);

the condensing temperature of each succeeding heat pump (230 to n30) is higher than that of the respective preceding heat pump (130 to (n-1)30) so that fluid circulating in the respective fluid flow loop (110 to n10) is at a higher temperature than that flowing into the fluid flow loop (110 to n10) from the respective loop inlet (113 to n13); and

wherein, in each fluid flow loop (110 to n10), relatively colder fluid entering each loop inlet (113 to n13) is mixed with hotter fluid from the feedback fluid line (112 to n12) thus raising the temperature of the fluid quickly to an intermediate temperature between the temperatures of the colder and hotter fluids before gaining a temperature increment on passing through the condenser (132 to n32) and wherein some of the heated up fluid in the post-heating fluid line (119 to n19) return via the feedback fluid line (112 to n12), while the balance flow out of the fluid flow loop (110 to n10) via the respective loop outlet (114 to n14) and finally discharge into said system outlet (102).

2. The heat-pump heating apparatus (1) as in claim 1, wherein the flow rate of fluid flowing in each of the fluid flow loop (110 to n10) is relatively higher than the colder fluid flowing into said system inlet (101) of said system flow circuit (10) such that the temperature increment of fluid flowing through each fluid flow loop (110 to n10) is significantly higher than the temperature increment if the fluid were to pass straight through the condenser (132 to n32), resulting in a high temperature increment between system outlet (102) and system inlet (101) being achieved with a low number of fluid flow loops (110 to n10).

3. The heat-pump heating apparatus (1) as in claim 1, wherein the temperature increment of fluid flowing through each fluid flow loop (110 to n10) is self-modulating by the heating capacity of each fluid flow loop (110 to n10).
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4. The heat-pump heating apparatus (1) as in claim 1, wherein a flow control means is provided to adjust the flow rate of fluid flowing through the system flow circuit (10) in a continuously variable manner so that the temperature of hot fluid at the system outlet (102) is maintained at
10 designed temperature.
5. The heat-pump heating apparatus (1) as in claim 4, wherein the flow control means is an actuator that is controlled by a controller (105) based on signals from a temperature sensor (104) disposed at the system outlet
15 (102).
6. The heat-pump heating apparatus (1) as in claim 4, wherein the flow control means is a variable speed drive that is controlled by the controller (105) such that the rotational speed of the system feed pump (103) is
20 appropriately adjusted based on signals from said temperature sensor (104) disposed at the system outlet (102).
7. The heat-pump heating apparatus (1) as in claim 1, wherein said respective heat-pumps (130 to n30) are provided with varied ratings.

8. The heat-pump heating apparatus (1) as in claim 1, wherein said respective circulating pumps (111 to n11) are provided with varied ratings.
- 5 9. The heat-pump heating apparatus (1) as in claim 1, wherein the fluid to be heated is oil.
- 10 10. The heat-pump heating apparatus (1) as in claim 1, wherein the fluid to be heated is water.
11. The heat-pump heating apparatus (1) as in claim 10, wherein the source of supply of water is direct municipal water.
- 15 12. The heat-pump heating apparatus (1) as in claim 10, wherein the source of supply of water is from a storage tank.