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(54) Heat transfer system

(57) A refrigeration apparatus for cooling food products, comprising an evaporator (1) through which refrigerant fluid is passed, an electronic expansion valve (4b) for controlling the flow of said fluid as a liquid at the inlet of the evaporator, and sensor means (18; 18') sensing the presence of liquid at the outlet of the evaporator. The sensor means may include a heating element associated with a temperature sensor. Alternatively, the sensor means may generate a signal in dependence upon vapour pressure, the signal recording the amount of superheat. A second sensor means (20) may be present responsive to the temperature around the evaporator. Control means (12) operates the valve (4b) to adjust the liquid flow in response to the output of the second sensor means (20) so as to maintain the products within a predetermined range of temperature, subject to limiting or interrupting the input liquid flow if the sensor means (18; 18') indicates that the superheat is substantially zero or is below a predetermined minimum value.

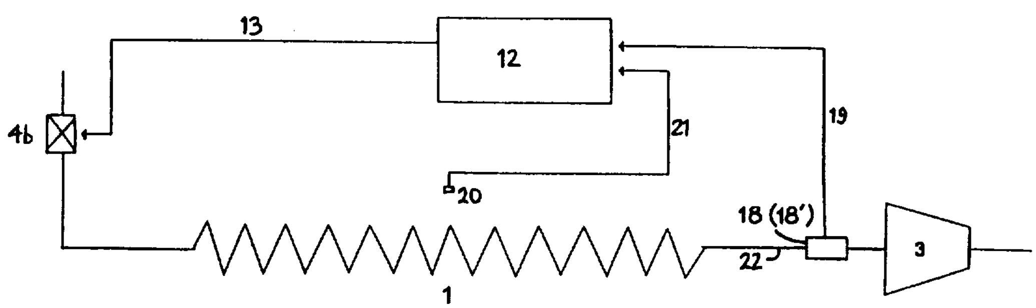

Fig. 4

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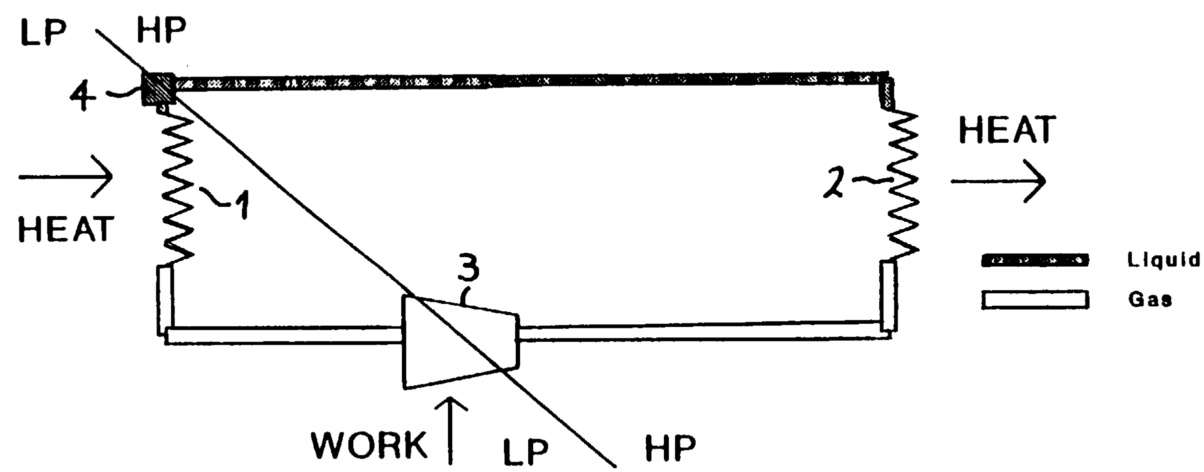

Fig. 1

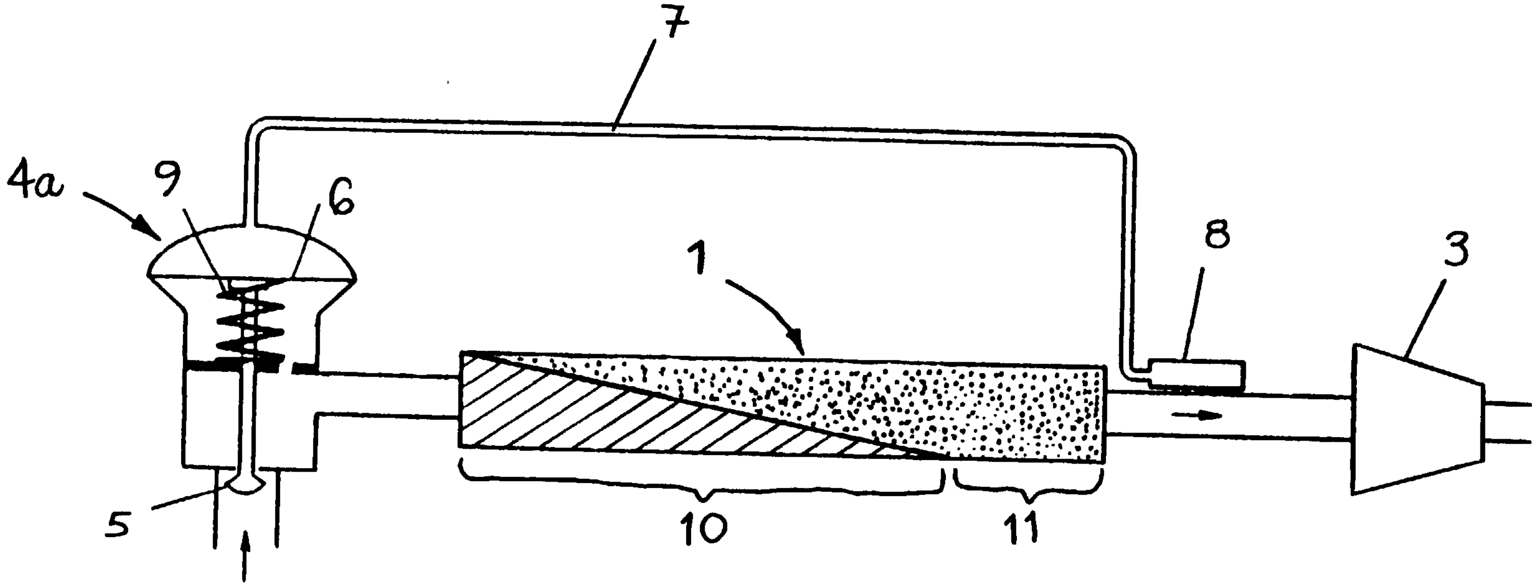

Fig. 2

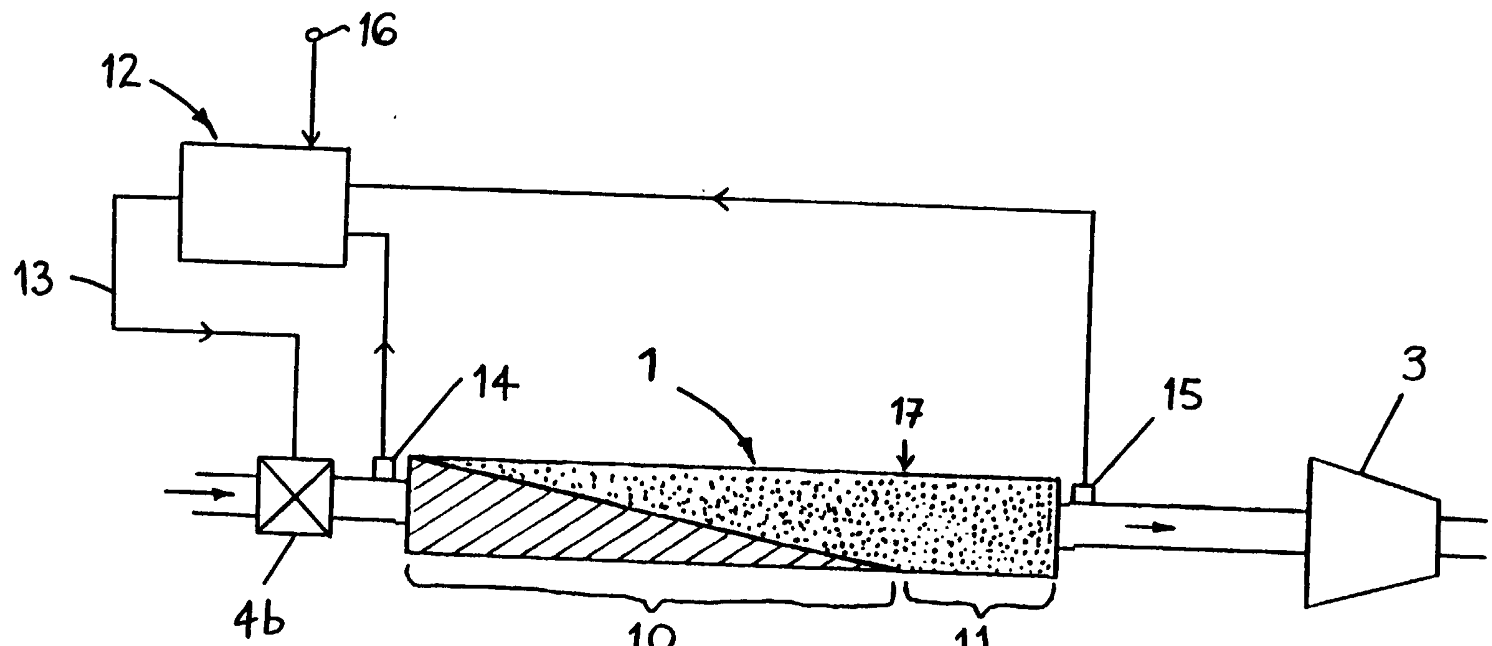

Fig.3

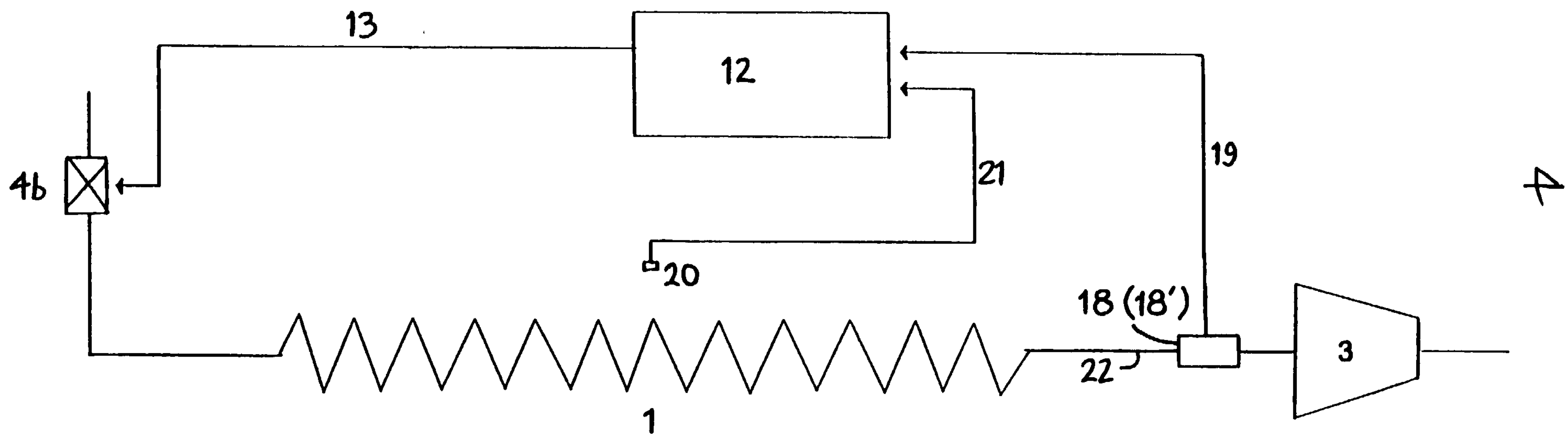

Fig. 4

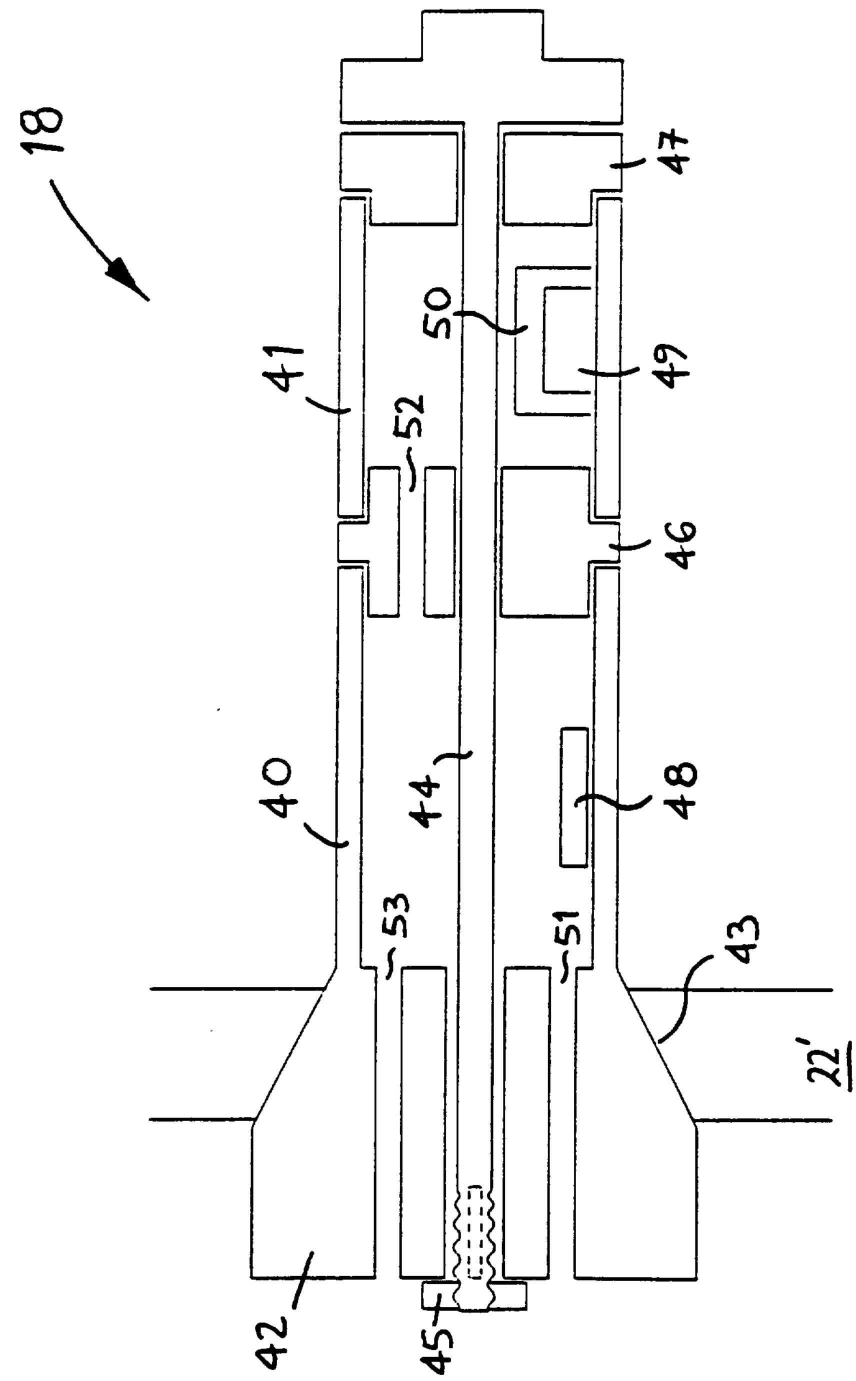

Fig. 5

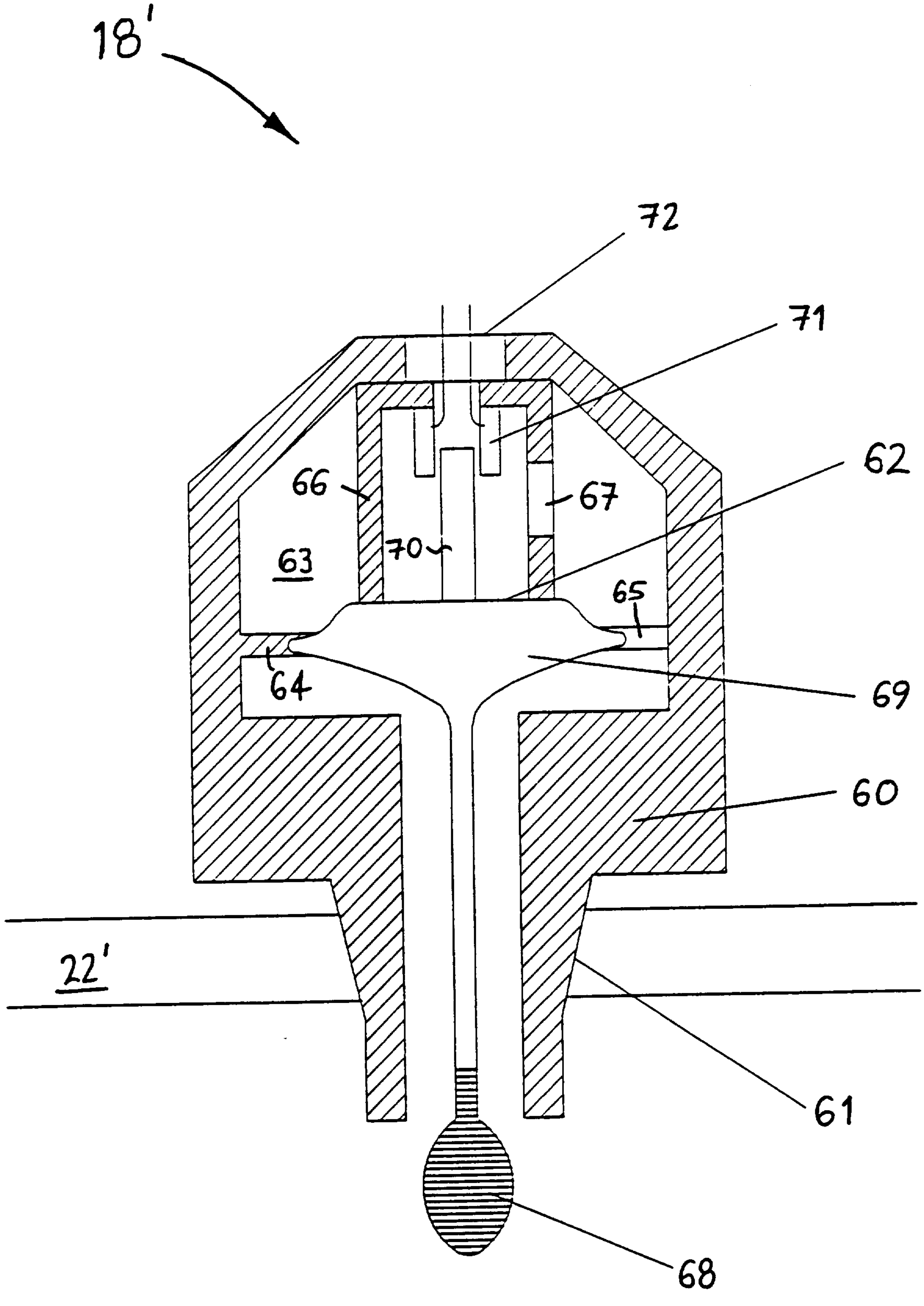

Fig. 6

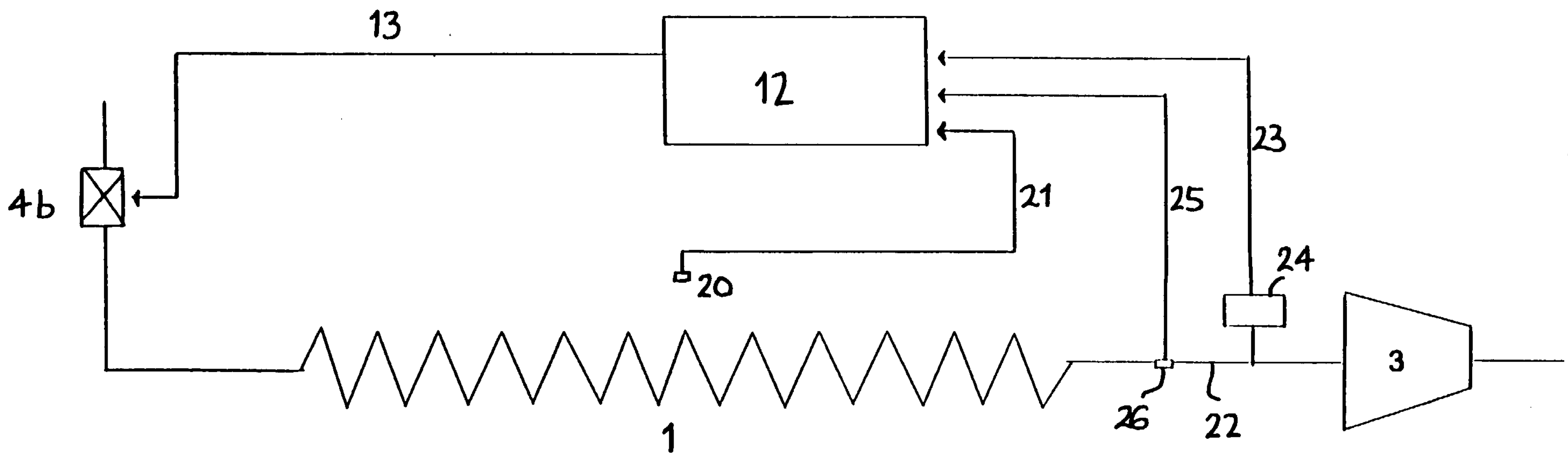

Fig. 7

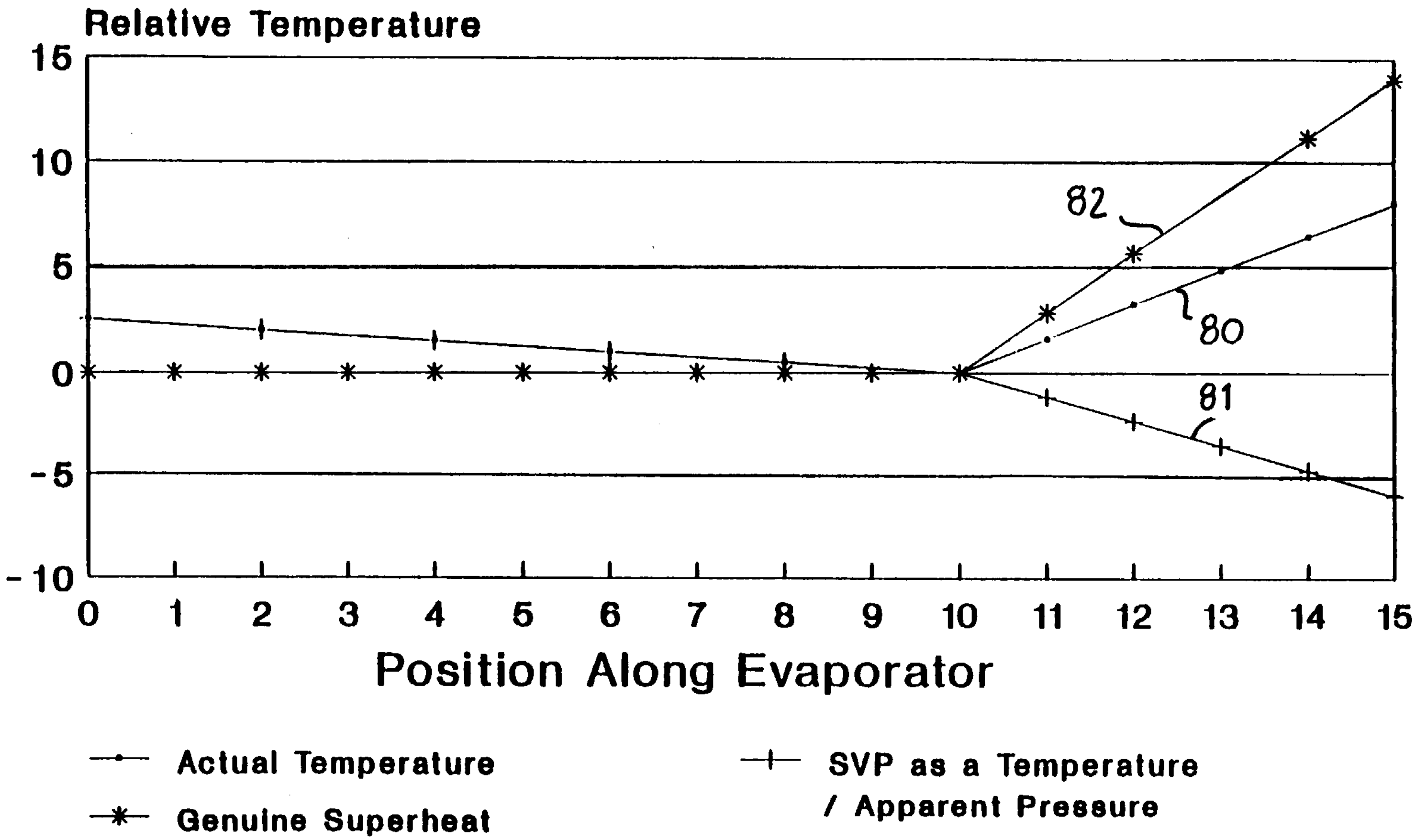
Relative Temperature
15
10
5
0
-5
-10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Position Along Evaporator
82
80
81
Actual Temperature
Genuine Superheat
SVP as a Temperature / Apparent Pressure

Fig. 8

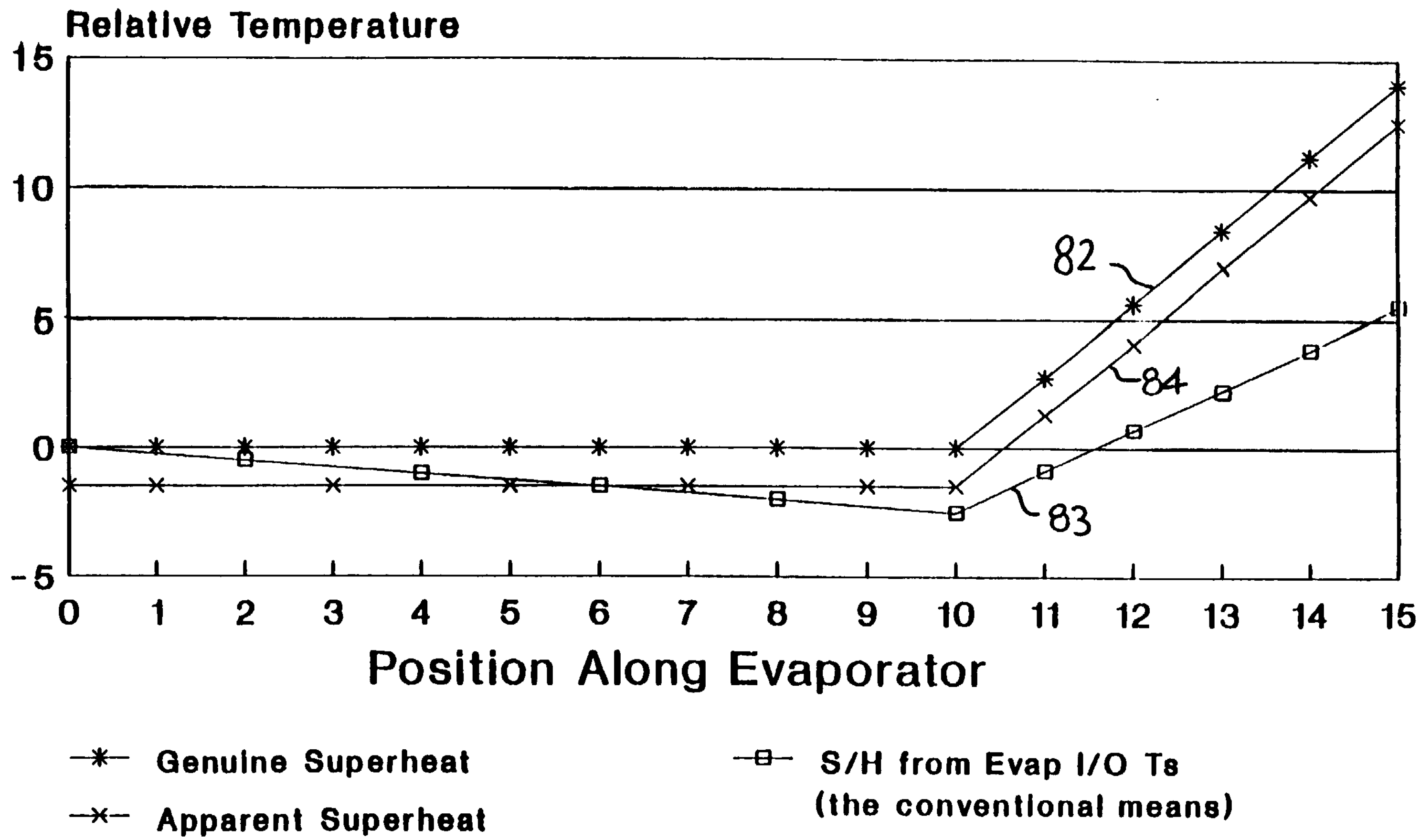
Relative Temperature
15
10
5
0
-5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Position Along Evaporator
82
84
83
Genuine Superheat
Apparent Superheat
S/H from Evap I/O Ts
(the conventional means)

Fig. 9

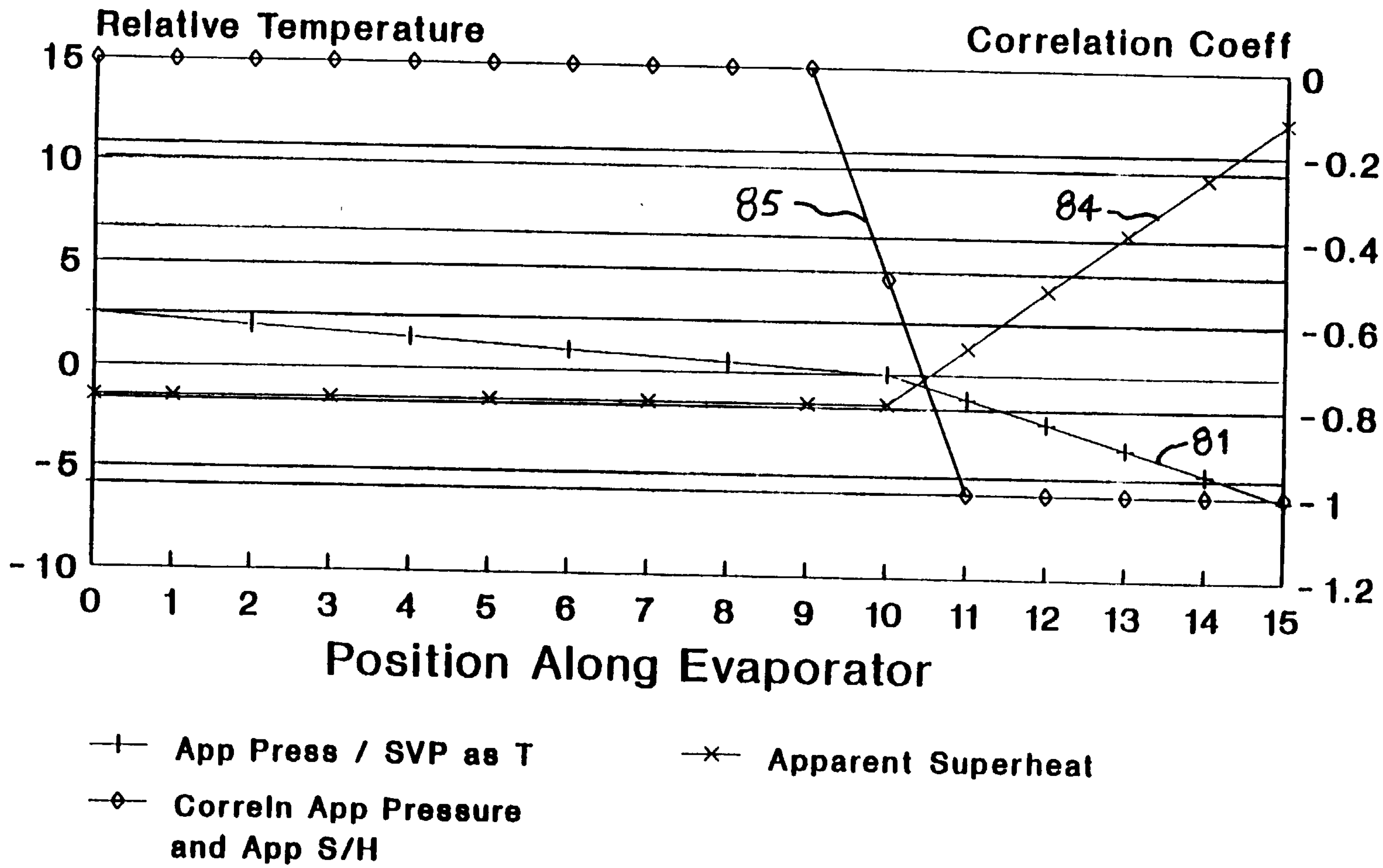
Relative Temperature
Correlation Coeff
15
10
5
0
-5
-10
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Position Along Evaporator
85
84
81
App Press / SVP as T
Correln App Pressure and App S/H
Apparent Superheat

Fig. 10

HEAT TRANSFER SYSTEM

This invention relates generally to a heat transfer system, and more specifically to such a system in which a fluid is passed through an evaporator and takes up heat from a medium to be cooled, using the latent heat of evaporation. The invention will be described in detail, by way of example only, in relation to a commercial refrigeration cabinet such as is used in supermarkets and other stores to maintain food items at a temperature within a predetermined range. However, the invention embraces other embodiments of a heat transfer system which uses an evaporator, including a blast chiller or blast freezer intended for cooling a product as compared with holding it at a particular temperature, cold room equipment, and air conditioning systems. This invention also embraces a heat transfer system in which the medium to be cooled by the evaporator is a coolant circulated in a secondary circuit.

Commercial refrigeration systems use the vapour compression cycle, in which the removal of heat relies on evaporation. A liquid refrigerant turns into gas in a component known as an evaporator, and in the process of doing so absorbs heat. The gas turns back into liquid in a component known as a condenser, and in the process of doing so releases heat in a location removed from that of the evaporator. The basic system configuration is show in Figure 1, in which the evaporator is referenced 1 and the condenser is referenced 2.

Referring to Figure 1, the refrigerant fluid is pumped around a circuit connecting the evaporator and the condenser by a compressor 3, which is a motor-driven pump. An expansion valve 4 serves to control or meter the rate at which the liquid refrigerant enters the evaporator 1. As shown in Figure 1, the system has a low pressure side LP and a high pressure side HP. The gas coming out of the evaporator 1 and entering the compressor 3 is at a relatively low pressure, whereas the gas coming out of the compressor 3 and entering the condenser 2 is at a relatively high pressure. The liquid coming out of the condenser is at the same high pressure. Thus, a pressure difference exists across the compressor 4 and also across the expansion valve 4.

The efficiency of the system is dependent upon the amount of work done by the compressor, which itself is related to the size of the pressure difference between the high pressure side and the lower pressure side of the system. In order to optimise the efficiency, the condensing pressure should be as low as possible and the evaporating pressure should be as high as possible. This is because the smaller is the pressure difference across the compressor, the greater is the amount of fluid pumped by the compressor per unit time. Thus, the difference in pressure between the high pressure side and the low pressure side of the system should be minimized.

For effective use of the evaporator, the proportion of the total length of the evaporator pipe in which the liquid is present so that evaporation can occur, should be as large as possible. However, the refrigerant at the outlet normally needs to be kept totally gaseous, since if liquid or mist enters the compressor damage is likely to result. The amount by which the fluid output of the evaporator is hotter than necessary to be gaseous is known as the superheat. This can be defined as the temperature of the gas at the evaporator outlet minus the saturated vapour temperature corresponding to the gas pressure at the outlet. In other words, the superheat is the amount by which the temperature of the gas exceeds the boiling point of the liquid at the particular pressure.

Ideally, the superheat should be maintained at practically zero degrees, but normally it is controlled within a small range of values having a predetermined minimum level a few degrees above zero. The superheat is controlled by means of the expansion valve at the evaporator inlet. If there is no superheat, the rate of liquid flow into the evaporator should be reduced. If there is too much superheat, the rate can be increased.

A variety of control techniques are known in the art for achieving the desired temperature control whilst maintaining as far as possible an effective use of the evaporator. For the type of refrigeration cabinet mentioned previously, the configuration which is long-established and most commonly in use today is illustrated in Figure 2, where the part of the circuit including the condenser is omitted for simplicity.

Referring to Figure 2, this configuration uses what is known as a thermostatic expansion valve 4a. The valve 4a consists of a needle 5 linked to a diaphragm 6. The linear position of the needle 5 (in the up/down direction in the figure) determines the degree of opening of the valve and thereby the rate at which liquid refrigerant enters the evaporator. The position of the needle 5 is determined by a balance of pressures on opposite sides of the diaphragm 6. The upper side of the diaphragm is coupled by a capillary tube 7 to a bulb 8 containing a quantity of the same type of refrigerant as the main circuit. The bulb is arranged to be in good thermal contact with the outlet of the evaporator. As a result, the upper side of the diaphragm receives a pressure P_{out} of the liquid/vapour mixture which corresponds to the outlet temperature of the evaporator. The other, lower side of the diaphragm is subjected to the evaporating pressure P_e of the liquid refrigerant at the evaporator inlet, plus a bias pressure P_s provided by a spring 9 within the valve 4a.

The state of the valve may be expressed as follows:

if $P_{out} > P_e + P_s$ the valve opens,

if $P_{out} < P_e + P_s$ the valve closes.

Thus, the superheat provided is related to the spring pressure. However, the spring pressure does not remain constant across the valve movement, it increases as the valve opens. As a result, this type of system configuration has the undesirable characteristic of using the evaporator less effectively when it is needed most; that is, the proportion of the length of the evaporator which contains the liquid/gas mixture 10 is reduced while the remaining proportion containing only the gas 11 becomes larger.

A further and significant drawback, affecting the efficiency of the system, is the reliance of the operation of the expansion valve on the pressure of the liquid from the condenser. For this type of expansion valve a relatively high pressure difference across the valve is required. This makes greater the amount of work that needs to be done by the compressor, to the cost of the user in terms of electricity consumption and to the cost of us all in terms of the resultant effect on the environment.

In the type of system described above with reference to Figure 2, temperature control of the load is realised by a simple on/off regime using a magnetic valve (not shown) to interrupt the supply of liquid refrigerant to the expansion valve when the temperature has been reduced to the desired level. Thus, the system provides a relatively fixed amount of superheat when the magnetic valve is open, while it is practically shut down when that valve is closed. This mode of operation is considered by those skilled in the art to be less preferable than one in which the refrigerant is circulated in a continuous, variable flow.

More recently, it has been proposed to replace the traditional thermostatic expansion valve with an electrically-controlled one. Apart from the selfevident difference of being controlled by an electrical signal rather than a gas pressure, the electronic expansion valve provides a relatively unimpeded passage for the fluid flow when the valve is in its open condition. The rate of flow of liquid refrigerant into the evaporator is determined by the relative time periods for which the valve is open and closed within a continuously repeated cycle. The cycle is typically one of six or eight seconds' duration, the valve being pulsed open once in each cycle for a period determined by the required flow rate.

The use of such electrically-actuated expansion valves has a number of attractions. Perhaps the greatest is the potential for energy savings. As compared with the thermostatic version, the electric expansion valve requires only a small pressure drop across it to operate. This means that a lower condensing pressure and temperature can be adopted, enabling the compressor to pump a greater quantity of refrigerant per unit of electricity used, and thereby to operate more efficiently. It is estimated that the available reduction in energy consumption will be of the order of 25% or more. Considering the extensive use of refrigeration equipment throughout the world, the potential benefit to our environment cannot be overstated. Secondly, the electric expansion valve offers greater flexibility in the choice of control regime in that the number of control inputs to the valve is not limited, as it is in the case of the thermostatic valve. Thirdly, the electric expansion valve may replace not only the thermostatic expansion valve, but also the associated magnetic valve, since the electronic valve can be operated so as to be closed for the complete cycle when required.

Despite these potential benefits, refrigeration systems incorporating electronic control of the refrigerant flow have gained only a limited share of the market to-date. One important reason, other than a resistance to change from a well-tried mechanical valve notwithstanding the prospect of energy savings, is that technical problems remain to be solved in the method of sensing superheat. These problems will be discussed in relation to a known system configuration shown in Figure 3.

Referring to Figure 3, the system includes an electrically-controlled expansion valve 4b for controlling the flow of refrigerant into the evaporator 1. The valve 4b comprises the valve mechanism itself and an actuator for controlling the state of the valve. The actuator receives an electrical control signal on line 13 from a control circuit 12. The signal takes the form of a periodic pulse whose duration is varied to adjust the flow rate. For the length of the pulse the actuator holds the valve open, otherwise the valve is closed. Thus, the flow rate is determined by the mark/space ratio of the pulse within the periodic cycle. This ratio is set according to the control input(s) to the circuit 12.

The system is designed to maintain a fixed amount of superheat, such that the major part of the evaporator is filled with the liquid/gas mixture 10, the remaining part near the output containing only the gas 11. The actual superheat at the output of the evaporator is continuously or regularly measured and compared in the control circuit 12 with a desired value input at a reference terminal 16. The control signal for the valve 4b is adjusted accordingly; that is, if the measured superheat exceeds the reference value, the mark/space ratio is increased, whereby the valve is open for a longer time in each cycle and more liquid enters the evaporator. This moves the point 17 in the evaporator at which the fluid becomes gas only, closer to the outlet of the evaporator. On the other hand, if the measured superheat is too low, the mark/space ratio is reduced, so that the flow rate of refrigerant into the evaporator is diminished and the point 17 moved back.

The superheat is measured using two temperature sensors 14 and 15 respectively disposed at the inlet and outlet of the evaporator, where they pick up the temperature of the refrigerant vapour. The control circuit 12 calculates the superheat by subtracting the inlet temperature from the outlet temperature. This method of determining the superheat contains two inherent and very serious drawbacks. First, the calculation makes two assumptions: that the vapour at the evaporator inlet is saturated and that the vapour pressure is the same at both the inlet and the outlet. Whereas the former assumption is generally valid, the latter one is not. In fact, there is a pressure drop along the evaporator from inlet to outlet. Moreover, the size of the pressure difference is dependent on the flow rate through the evaporator. Thus, the inlet temperature requires a complex correction. Secondly, the measurement cannot distinguish between an evaporator full of liquid and one full of gas; in each case, there is no temperature difference between inlet and outlet, and therefore apparently no superheat. Obviously, this is not true when the evaporator is full of gas.

Designers have sought to overcome these problems by adopting complicated control algorithms and/or running the system with an excessive amount of superheat (which compromises effective use of the evaporator). Despite these precautions, it is a common experience that systems controlled in this way operate with liquid coming out of the evaporator, with the consequent risk of damaging the compressor.

Accordingly, there is a need for improved methods and devices for sensing superheat, or its absence. Meeting this need will enable the benefits of very considerable energy savings and/or being able to prevent flooding of a compressor, to be reaped. Such methods and devices will also offer advantages in other types of system and in different control regimes than those which have just been specifically described.

This invention is defined by the claims. It will be seen in the following that this invention provides not just superiority over the prior art, but also major benefits to manufacturers, users and the environment alike.

In one aspect, the invention provides a heat transfer system such as a refrigeration system or an air conditioning system wherein the flow of liquid refrigerant or coolant into the evaporator is varied according to the system load. In the case of a refrigeration cabinet for storing food items, if the calculated product temperature rises above a preset temperature, the expansion valve is operated to increase the input flow, whereas if the calculated product temperature falls below a preset temperature, the input flow is reduced or interrupted. In an air conditioning system the or each reference temperature defines the required air temperature. Thus, the amount of superheat is varied continually in dependence upon the load conditions. This principal control regime is subject to an overriding control mechanism which monitors the superheat in the fluid coming out of the evaporator, and reduces or interrupts the input flow when it is detected that the superheat has fallen below a preset amount or there is an absence of superheat. This system provides a continuous flow of fluid adapted to the requirements of the load, whilst ensuring that the output fluid does not become wet and thereby damage the compressor. A continuous-flow system has for a long time been seen as desirable by designers. In refrigeration, one advantage of a continuous flow of refrigerant is a lesser amount of frosting, which is good for efficiency in general and shortens the time or interval for the defrosting process.

In another aspect, the invention provides a number of methods suitable for monitoring the fluid at the outlet of an evaporator. Although these methods may be suitably employed in the refrigeration system according to the first aspect of the invention, they are not limited to such an application.

A first method is used to warn of the absence of superheat by detecting the presence of liquid in the output fluid. In one embodiment, this is achieved by disposing two temperature sensors in the path of the fluid flow, one of the temperature sensors being deliberately heated above the surrounding gas temperature, and monitoring a difference in the temperatures sensed by the two temperature sensors. When liquid appears the added heat is consumed, as the latent heat of evaporation, in converting the liquid to gas. This causes a sudden fall in the monitored temperature difference between the two sensors.

The method has been proven to provide an adequately quick response to the detection of liquid. It offers a simple, yet highly effective, way of preventing a wet fluid output from damaging a compressor. Moreover, the size of the temperature change is dependent on the amount of liquid. This provides the significant advantage over conventional superheat detection methods, of being able to determine not just the absence of superheat in the fluid output but also its degree of wetness. A small amount of liquid at the evaporator outlet may be tolerable by virtue of the length of the suction pipe connecting the evaporator to a compressor. Thus, a threshold may be set for taking action when the amount of liquid exceeds the tolerable or a desirable upper limit. The invention also provides a sensor device which employs this first method.

A second method provides for measurement of the actual amount of superheat, the method comprising measuring the displacement of a movable member having two, mutually opposite surfaces, one of which receives vapour pressure originating from the fluid at the outlet and the other of which receives vapour pressure originating from a contained quantity of liquid which is physically isolated from said fluid but acquires substantially the same temperature as the fluid, and converting the measured displacement into an electrical signal. The electrical signal is related to the amount of superheat and it will be appreciated that this method adopts part of the mode of operation of the conventional thermostatic expansion valve. However, the new method breaks the inherent link in the traditional valve between the displacement of the diaphragm and the state of opening of the valve. Now, an electrically-actuated expansion valve can be controlled according to not just a superheat signal, but also, or alternatively, another control signal such as one relating to the load temperature. Thus, a much greater flexibility in the choice of control regime is available. The invention also provides a sensor device which employs this second method.

In a third method for monitoring the fluid at the outlet of the evaporator a precise measurement of the actual amount of superheat is not crucial, provided a trend, i.e. whether the superheat is increasing or diminishing in the output fluid, can be reliably sensed. This third method comprises making a series of measurements of the temperature and pressure of the fluid at said outlet, calculating a value of superheat for each pair of a temperature and a pressure measurement, and determining whether a relationship indicating the existence of superheat is established between the variation of the superheat measurements with time and the variation of the pressure measurements with time.

The invention is more fully explained and illustrated, although not limited, by the following description with reference to the accompanying drawings, in which:

Figure 1 is a schematic, simplified drawing of a refrigeration system;

Figure 2 illustrates particularly the use of a thermostatic expansion valve in a conventional system;

Figure 3 illustrates particularly the use of an electric expansion valve in another conventional system;

Figure 4 is a schematic, simplified drawing of a refrigeration system according to a first and second embodiment of the invention;

Figure 5 shows a sensor device employed in the first embodiment;

Figure 6 shows a sensor device employed in the second embodiment;

Figure 7 is a schematic, simplified drawing of a refrigeration system according to a third embodiment of the invention; and

Figures 8 to 10 are graphs for explaining the principles of operation of the third embodiment.

It is noted here that throughout the description and drawings, like components are denoted by the same reference numeral.

Referring to Figures 4 and 5, a refrigeration system and sensor device according to a first embodiment of the invention will be described. The refrigeration system represents one example of a heat transfer system. The system has the basic configuration shown in Figure 1 (the part of the circuit including the condenser 2 with which this invention is not concerned, being omitted in Figure 4), and takes the form of a refrigeration cabinet for storing food items (which term includes cold drinks) at a predetermined temperature or within a predetermined range of temperature. Here, the medium to be cooled using the evaporator 1 is the air which flows over the evaporator and circulates around the products. In order to monitor and control the refrigeration operation, one or more temperature sensors 20 is arranged to sense the air temperature in the vicinity of the evaporator and an estimated product temperature is calculated therefrom in a manner known to those skilled in the art. The temperature sensor 20 may measure one of the "air on" and the "air off" temperatures, that is the temperature of air circulating towards and of air leaving the evaporator, respectively, and supply the measurement as a signal on line 21. The product temperature is calculated as a function of the measured temperature, or both temperatures if two sensors are employed. The calculated product temperature constitutes one control input used by the control circuit 12.

A second control input used by the control circuit 12 is derived from the output of a sensor device 18 on line 19. The sensor device 18 is arranged at the outlet of the evaporator 1 and detects the presence of any liquid in the normally gaseous output fluid. The sensor device 18 is suitably mounted in the suction pipe 22 connecting the evaporator to the compressor 3, and the pipe 22 may be expanded or include an expanded vessel to receive the device for this purpose. However, the location of the sensor device is not especially critical, provided it comes into contact with the fluid flow; references herein to the outlet of the evaporator should be interpreted accordingly.

The flow of liquid refrigerant into the evaporator is controlled by an electrically-actuated expansion valve 4b, of the type described already with reference to Figure 3. The valve 4b includes an actuator which receives on line 13 a control signal generated by the control circuit 12, which determines the opening time of the valve in each operating cycle.

Before describing in detail the sensor device 18, an explanation of the control regime will be given. The first control input derived from the temperature sensor(s) 20 is principal. In basic operation, the control circuit 12 will set the mark/space ratio of the signal on line 13, determining the opening/closing time of the valve 4b, according to how the calculated product temperature relates to a desired temperature or range of temperature preset or programmed in the circuitry 12. Thus, the system operates continuously (excepting any defrost) with a variable amount of superheat, higher if the product is adequately cool or lower if further cooling is required. The second control input indicating the detection of liquid in the fluid coming out of the evaporator, overrides the basic control according to the first control input by causing the input refrigerant flow to be reduced or, if necessary, interrupted irrespective of the demand determined by the first control input. The control according to the first control input may be resumed as soon as the second control input has ceased, or a predetermined delay thereafter which ensures full recovery and thereby more stable operation. Therefore, it can be seen that this system is highly responsive to any change in the load condition, uses a preferred continuous flow of fluid, and prevents damage to the compressor by immediately reacting to the fluid output by the evaporator becoming wet. It also offers the potential significant energy savings associated with using an electric expansion valve.

The sensor device 18 will now be described with reference to Figure 5. The device comprises a body consisting principally of two thermally-conductive members 40, 41 in the form of hollow cylindrical housings mounted end-to-end. The member 40 includes at one end a tapered cylindrical block threaded at the surface 43 so as to permit the device to be mounted in a fluid-sealing manner in the wall 22′ of the suction pipe 22 (Figure 4) or of a vessel provided in that pipe. The two housings 40, 41 are held together by means of a bolt 44 which extends through the housings, including an axial hole in the block 42, and a nut 45 secured on a threaded end of the bolt which emerges from the hole in the block. The housings are thermally isolated from each other, both directly and via the bolt, by thermally-insulative elements in the form of washers 46, 47. The washer 46 is sandwiched between the two housings, whereas the washer 47 is sandwiched between the housing 41 and the bolt head. Each washer constitutes a thermal barrier which ensures that the temperature of each housing remains largely independent of that of the other housing.

A temperature sensor 48 is mounted on the inside of the housing 40 in good thermal contact therewith. The sensor 48 takes the form of a temperature-dependent resistor, specifically in this embodiment a thermistor. The output lead of the thermistor (not shown) is routed externally of the device via an axial hole 51 in the block 42. Another temperature sensor 49 is similarly mounted in the housing 41, where additionally an electrical heating element 50, specifically in this embodiment an electrical resistor, is mounted adjacent the sensor 49. The sensor 49 and the heating element 50 are arranged such that the element 50 raises the temperature of the housing 41, and the sensor 49 is responsive to the temperature of the housing 41. It is preferable although not essential that the two components 49, 50 are mounted adjacent each other. Alternatively, the heater and the associated temperature sensor may be integrated or consist of a single component such as a self-heating thermistor. The wiring (not shown) to the thermistor 49 and the resistor 50 is routed externally of the device via axial holes 52 and 53 in the washer 46 and the block 42, respectively. The heater is powered continuously. In a prototype sensor, a heater power of 2.5 W was used. However, a lower power is likely to be suitable in practice.

The internal cavity of the body is sealed from the fluid flow and contains air at the ambient, atmospheric pressure existing outside the suction pipe 22. Thus, the electrical components 48, 49, 50 mounted in the cavity do not require special protection. The materials of the housings 40, 41, the washers 46, 47 and the bolt 44, on the other hand, must be able to survive for a reasonable period of service the physical (temperature, pressure) and chemical environment of the refrigerant fluid flow. For this purpose the housings and bolt are suitably metallic, for example brass in the case of an HFC refrigerant or stainless steel for one such as ammonia. The optimum material to be selected for the washers will also depend, to some extent, on the chemical composition of the particular refrigerant being used, but it is likely to be a thermoplastic and/or polymer.

The operation of the sensor device 18 is described in the following. Both of the temperature sensors 48, 49 are responsive to the temperature of the fluid flowing past the device. In a wholly gaseous fluid, the member 40 will acquire substantially the gas temperature and this temperature is sensed by the sensor 48. The member 41 will acquire a temperature higher than the gas temperature due to the heating effect of the heating element 50, and this higher temperature is sensed by the sensor 49. Since the washer 46 provides a thermal barrier between the members 40, 41 and a gas is a poor conductor of heat, the higher temperature of the member 41 will not cause the member 40 to be heated significantly above the gas temperature. This is further ensured in this embodiment by virtue of the relative dispositions of the members 40, 41 with respect to the dominant direction of the fluid flow.

Thus, when the fluid is totally gaseous and contains no liquid component, there will exist a definite difference between the temperatures sensed by the sensors 48, 49, the difference being determined practically by the magnitude of the current supplied to the heating resistor 50. The difference between the two sensed temperatures is of the order of a few degrees Celsius. In this embodiment, the temperature difference is monitored by a comparator. This may be incorporated in the sensor device itself, but it is more conveniently provided in the control circuitry 12.

When liquid appears in the fluid output of the evaporator, indicating an absence of superheat, the liquid comes into contact with the heated member 41 of a temperature exceeding that of the fluid. The effect of this contact is that the liquid immediately vaporises, the heated member 41 providing the necessary latent heat for the change of state. The vaporisation of the liquid is manifest by a rapid or sudden lowering of the temperature of the member 41, which is detected by the sensor 49. Thus, by monitoring the difference between the temperatures sensed by the sensors 48 and 49, the occurrence of liquid in the fluid flow can be quickly and reliably established by detecting the corresponding lowering of the temperature difference. For example, the detection may be achieved by setting a threshold for the output of the comparator; if the output level, corresponding to the temperature difference, falls below the threshold (for example, instantaneously or for a predetermined period), an output signal indicating liquid detection is generated. This output signal constitutes the aforementioned second control input of the circuit 12.

The size of the temperature difference is dependent on the amount of liquid, i.e. the ratio of liquid to gas, in the fluid being monitored. Thus, it is possible to set the threshold for detection at a level which corresponds to a particular degree of wetness which needs to be checked. This is a highly advantageous refinement to the known systems of superheat detection which cannot provide such a measure of fluid wetness.

This embodiment utilizes the difference between the temperatures sensed by two temperature sensors, the heating means associated with one of the sensors. However, it will be appreciated from the above explanation, that the operation relies essentially on the fall in the temperature detected by the heated sensor. Thus, the unheated sensor 48 may be dispensed with in an alternative embodiment. The presence of liquid may then be detected by differentiating the output of the one temperature sensor with respect to time. If the value of the differential exceeds a predetermined threshold, indicating a fall in temperature sufficiently rapid to be due to the consumption of the latent heat of evaporation, it is established that liquid is present and a control signal to that effect is generated.

The method and device employing two temperature sensors has the advantage that it is comparatively easy to monitor a difference in two temperatures, and the difference is virtually immune to external influences, which are cancelled out.

Although the sensor device 18 has been described in relation to its operation in the system of Figure 4, it will be appreciated that the device and the method it exploits have wider application. In fact, the device may be used in any situation in which a normally-gaseous fluid needs to be monitored for the intrusion of liquid. In the context of a heat transfer system, the sensor device may be fitted at the outlet of an evaporator as an additional safety component to an existing system as a safeguard against flooding of a compressor. The device may be used to generate a warning signal and/or a control signal for remedial/preventative action, when liquid or an excessive amount of liquid is detected. The system may be operating on the basis of a fixed superheat or range of superheat control, whether using a thermostatic expansion valve or an electrically-actuated one. In all these applications, the advantages of being able to detect liquid reliably and sufficiently quickly for action to be taken, and the independence of the operation with respect to the particular type of fluid in use, continue to be obtained.

Referring to Figures 4 and 6, a refrigeration system and sensor device according to a second embodiment of the invention will be described. This embodiment differs from the first embodiment particularly in the structure and operation of the sensor device 18′ at the evaporator outlet. Otherwise, the second embodiment is practically the same as the first embodiment, and, in the main, the description of the common features will not be repeated.

In the system of Figure 4, the sensor device 18′ is adapted to generate a signal representing the amount of superheat in the fluid at the outlet of the evaporator. The control circuit 12 operates the expansion valve 4b to adjust the flow of liquid refrigerant into the evaporator according to the temperature picked up by the sensor 20, in the same manner as for the first embodiment. The control according to this first control input derived from the sensor 20 is overridden when the superheat signal from the sensor device 18′ indicates that the superheat has fallen below a present minimum level, or that the superheat is zero. Thus, the system according to this second embodiment provides the same useful advantages of the first embodiment.

Referring to Figure 6, the sensor device 18′ will be described in detail. The device comprises a body 60 having a portion 61 which is threaded so as to permit the device to be mounted in a fluid-sealing manner in the wall 22′ of the suction pipe 22 (Figure 4) or a vessel provided in that pipe. The body 60 has an internal chamber 63 which is in open communication with the fluid flowing through the pipe 22 at the end having the threaded portion 61. A movable member in the form of a flexible diaphragm 62 is mounted within the chamber 63 on support elements 64 and 66.

The upperside of the diaphragm 62 in the drawing is in open communication with the fluid within the chamber 63, via respective apertures 65, 67 in the support elements 64, 66. This upperside of the diaphragm is thereby subject to the vapour pressure of the fluid at the outlet of the evaporator. The lower side of the diaphragm is isolated from the vapour pressure of the refrigerant fluid within the chamber 63, and is coupled instead to a container in the form of a phial 68 containing a quantity of liquid, as indicated by the horizontal shading in the drawing. The coupling forms a closed sub-chamber 69 containing a saturated vapour of the liquid within the phial. In this embodiment, the phial is fixed in its location with respect to the body of the sensor device and is disposed substantially externally of the body. Thus, the phial is surrounded by the refrigerant fluid flow, its liquid content acquires the temperature of that fluid, and a vapour pressure corresponding to that temperature is exerted on the lower side of the diaphragm by the vapour within the sub-chamber 69.

A difference in the respective vapour pressures exerted on the opposite, upper and lower surfaces of the diaphragm 62 determines a vertical displacement of the diaphragm which is related to the amount of superheat. A detector for the diaphragm displacement is housed in the support element 66. The detector comprises an elongate linearly-movable member 70 coupled to the diaphragm, and a position sensor 71 for sensing the position of the member 70. The position sensor 71 thus outputs an electrical signal related to the sensed superheat, the signal being led out at the top end of the body 60 through a fusite connector 72 which provides the necessary pressure seal. The output signal is supplied to the control circuitry 12 as the aforementioned second control input.

The liquid in the phial 68 preferably has a composition which is the same as, or very similar to, that of the refrigerant circulated through the evaporator. If the refrigerant is a mixture of substances having different boiling points, the liquid in the phial 68 should substantially match the least volatile component of the mixture, since that component will determine whether there is any superheat in the refrigerant. In both these cases, the vapour pressure exerted on the lower side of the diaphragm 62 will be that required for measuring the superheat. Alternatively, a known substance, different to the refrigerant, may be used for the phial liquid. In that case, a correction needs to be made to the electrical signal output by the position sensor 71. The correction is to allow for the relationship between the different vapour pressure-temperature characteristics of the liquid in the phial (which determines the vapour pressure in the sub-chamber 69) and the refrigerant in the evaporator (which determines the vapour pressure in the chamber 63).

Although the sensor device 18′ has been described in relation to its operation in the system of Figure 4, it will be appreciated that the device and the method it exploits have wider application. In fact, the device may be used in any situation in which it is desired to measure or monitor the superheat of a gaseous fluid. In the context of a heat transfer system, the device may be used, for example, in controlling the fluid flow at the inlet of an evaporator so as to maintain the superheat at the outlet above a minimum value and/or below a maximum value, each of which may be preset in the system or variable according to the operating conditions.

Referring to Figures 7 to 10, a refrigeration system according to a third embodiment of the invention will be described. This embodiment differs from the previous two embodiments in the way the superheat is monitored at the outlet of the evaporator. Otherwise, the third embodiment is practically the same as the first and second embodiments, and, in the main, the description of the common features will not be repeated.

In the system of Figure 7, the superheat in the fluid at the outlet of the evaporator is monitored using a pressure transducer 24 and a temperature sensor 26, which provide signals to the control circuit 12 on lines 23 and 25 respectively. The two sensors 24 and 26 are suitably coupled to the suction pipe 22. However, all that is important in terms of their locations is that they are exposed to the temperature and vapour pressure of the fluid leaving the evaporator. By applying a knowledge of the saturated vapour pressure/temperature characteristic of the particular fluid, the amount of superheat can be determined from a pair of measurements, one of temperature and one of pressure. However, this embodiment does not rely on precision in such an absolute determination of superheat. A different approach is taken, the background to which will be explained with reference to Figures 8 to 10.

The actual temperature along the evaporator falls progressively along the length of the evaporator until the point is reached where all the liquid has become gas; this occurs at point 10 on the horizontal scale of arbitrary unit in Figures 8 to 10. The reduction in temperature is the result of pressure drops affecting the saturated vapour temperature at the different points along the evaporator. Beyond the totally gas point, the temperature rises at a rapid rate. This profile of the actual temperature is shown by the plot 80 in Figure 8. The saturated vapour pressure expressed as a temperature is shown by the plot 81 in Figure 8. It declines in line with actual temperature up to the totally gas point 10. Thereafter, it declines at a more significant rate because the rate of pressure drop increases when the refrigerant is totally gas and therefore occupies a larger volume. The genuine superheat is the amount by which the temperature at each point along the evaporator exceeds the saturated vapour temperature at that point. Thus, it is the difference between the plots 80 and 81, as indicated by the plot 82 in Figure 8. As shown by the plot 82, the genuine superheat is zero through the part of the evaporator where liquid and gas co-exist, that is up to the point 10. Beyond this point, the superheat rises rapidly. For safe operation, in terms of eliminating or reducing to an acceptable level the risk of damaging the compressor, the outlet of the evaporator must be beyond the point 10.

The superheat measured in the conventional way described with reference to Figure 3, that is by taking as the superheat the difference between the temperature at the inlet to the evaporator and the temperature at the evaporator outlet, is shown by the plot 83 in Figure 9. In this example, the superheat measured using such a conventional method reaches a minimum at point 10 and then increases, reaching zero at about point 11.5. On the other hand, the apparent superheat, as calculated from the pressure and temperature measurements made by the sensors 24 and 26 in this embodiment is shown by the plot 84 in Figure 9. This apparent superheat corresponds to the genuine superheat except for a certain offset introduced by the particular pressure sensor in use. In Figure 9, the amount of this offset is -1.5°C. However, it could be any small amount in either direction.

Referring to Figure 10, the relationship between the variation of the vapour pressure along the evaporator, as shown by plot 81, and the corresponding variation of the apparent superheat, as shown by the plot 84, can be seen. Up to the point 10 where the fluid becomes totally gas, the apparent superheat shows a constant value along the evaporator, corresponding to the zero genuine superheat plus the aforementioned offset. Beyond the point 10, the apparent superheat rises and the apparent pressure falls in an inter-related and predictable manner. In statistical terms, the plots 81 and 84 will exhibit, in theory, a correlation coefficient of zero up to the point 10 and a correlation coefficient of minus 1 beyond the point 10. This is shown by the plot 85, which relates to an experimental result. The recognition that a relationship exists between the plots 81 and 84 when the fluid at the outlet of the evaporator exhibits superheat, yet disappears when liquid and gas co-exist enables the fluid flow through the evaporator to be appropriately controlled based on the measurements made by the sensors 24, 26, in a manner in which it is not critical to know the amount of the offset introduced by the pressure sensor 24.

In this embodiment, whether any relationship exists between the plots 81 and 84 in the fluid at the outlet of the evaporator is tested in the following way.

A series of measurements (in this embodiment numbering eight) is made repeatedly, each series within a predetermined short interval, using the pressure and temperature sensors 24 and 26. This process generates in each cycle eight measurements of pressure and eight corresponding measurements of temperature. The individual pairs of temperature and pressure measurements differ from one another because the conditions at the point at which the fluid flow is examined naturally fluctuate. The set of pressure measurements is first converted to a corresponding set of saturated vapour temperatures, using a look-up table which stores the characteristic for the refrigerant in use. Next, a set of eight superheat values is calculated by subtracting from each temperature measurement the corresponding calculated saturated vapour temperature.

Linear regression is performed on the set of superheat values so as to obtain the slope of the part of the plot 84 which has been measured at the monitoring point. The slope defines the per-unit time change in superheat for the series of measurements. The same process is performed for the pressure measurements, so as to obtain the slope of the same part of the plot 81. This slope defines the per-unit change in pressure for the series of measurements.

A control variable is generated by dividing the calculated slope of the superheat plot by the calculated slope of the pressure plot. This control variable will have a value of zero or a small negative value if liquid and gas co-exist in the monitor fluid, indicating an absence of superheat, whereas it will have a high negative value if the monitored fluid is totally gas, indicating the presence of superheat.

By comparing the value of the control variable with a predetermined threshold, a control signal is generated when the processing indicates that there is an absence of, or lack of sufficient, superheat in the fluid at the outlet of the evaporator. The control signal is applied to the expansion valve 4b on line 13. It acts to reduce the proportion of time within the predetermined cycle, in which the expansion valve is open. Alternatively, the control signal may be varied according to the actual magnitude of the control variable, thereby adjusting the opening time of the valve.

The above-described processes of sampling and processing the pressure and temperature measurements made by the sensors 24 and 26 and generating the control signal for the expansion valve, are performed by the control circuitry 12. The functions are suitable implemented by the programming of a microprocessor. The implementation is within the ordinary skill of the person skilled in the art.

In this embodiment, like the first and second embodiments, the flow of fluid through the evaporator is controlled principally in response to the output of the temperature sensor 20, the secondary control according to the monitoring of superheat at the outlet of the evaporator having an overriding function of limiting the input liquid flow to the evaporator to prevent the outlet fluid becoming wet. However, in all three embodiments the control based on the temperature sensed by the sensor 20 is by no means essential and other control principles will be apparent to those skilled in the art. It will also be appreciated that the method in which the fluid output is monitored in this third embodiment has wider application, including one of performing a safety check on the output fluid in a more conventional system, and generating a warning signal and/or a control signal for remedial/ preventative action when it is established that the fluid contains, or is likely to contain, a liquid component.

According to this invention, it is now possible to adopt the use of an electronically-controlled expansion valve without risk of damaging a compressor due to an erroneous detection of superheat. Therefore, the much higher efficiency and substantially lower power consumption associated with the use of this type of expansion valve and the concomitant adoption of a lower condensing pressure, may be realised. The method of monitoring fluid at the evaporator outlet according to the first embodiment has the unique advantage of being wholly independent of the composition of the fluid. This provides a wide suitability of the first embodiment to existing designs.

The invention has relevance to changes which have been occurring in recent years in the refrigeration industry. The 1986 Montreal Protocol, which seeks to bring to an end CFC production in order to protect the Earth's stratospheric ozone layer is forcing manufacturers to use new, ozone-friendly, HFC refrigerants. One problem presented by these new refrigerants is that they are not azeotropic mixtures; at any one pressure there is a range of boiling points corresponding to those of the different components of the mixture. This phenomenon is one further reason why the conventional method of superheat determination using the evaporator inlet and outlet temperatures is inappropriate, the temperature at the evaporator inlet providing an invalid baseline for the calculation of the superheat at the outlet.

However, it has been mentioned already that this invention is not limited to the field of refrigeration. The same principles may be adopted for example in an air conditioning system in which a coolant fluid is passed through an evaporator. In adapting the three embodiments to such an air conditioning system, the temperature monitored by the sensor(s) 20 would be the ambient air temperature. Otherwise, the operation is the same as far as the invention is concerned.

The invention may also be embodied in other forms and manners not specifically described herein without departing from the scope of the claims.

CLAIMS

1. A heat transfer system comprising an evaporator through which fluid is passed while taking up heat from a medium to be cooled using the latent heat of evaporation, valve means for controlling the flow of said fluid as a liquid at the inlet of the evaporator, first sensor means for monitoring said fluid at the outlet of the evaporator, and control means for operating the valve means to adjust the liquid flow in response to an output of said first sensor means, wherein the first sensor means comprises a temperature sensor, a heating means associated with the temperature sensor, and means for detecting change in the temperature sensed by the temperature sensor due to the appearance of liquid in the monitored fluid.

2. A heat transfer system comprising an evaporator through which fluid is passed while taking up heat from a medium to be cooled using the latent heat of evaporation, valve means for controlling the flow of said fluid as a liquid at the inlet of the evaporator, first sensor means for monitoring said fluid at the outlet of the evaporator, and control means for operating the valve means to adjust the

liquid flow in response to an output of said first sensor means, wherein the first sensor means comprises two temperature sensors responsive to the temperature of said fluid at the outlet of the evaporator, a heating means associated with one of the temperature sensors, and means for detecting change in a difference in the temperatures sensed by the two temperature sensors.

3. A heat transfer system according to claim 1 or claim 2, wherein the detecting means is adapted to generate an output signal upon the detection of a said change, said control means reducing said liquid flow in response to the output signal.

4. A heat transfer system comprising an evaporator through which fluid is passed while taking up heat from a medium to be cooled using the latent heat of evaporation, valve means for controlling the flow of said fluid as a liquid at the inlet of the evaporator, first sensor means for monitoring said fluid at the outlet of the evaporator, and control means for operating the valve means to adjust the liquid flow in response to an output of said first sensor means, wherein the first sensor means is adapted to generate a signal in dependence upon the

difference between, on the one hand, vapour pressure of a contained quantity of fluid held at the temperature of the fluid at the outlet of the evaporator and, on the other hand, vapour pressure of said fluid at the outlet of the evaporator.

5. A heat transfer system according to claim 4, wherein said first sensor means comprises a diaphragm which receives the first-mentioned vapour pressure on one side thereof and the second-mentioned vapour pressure on the other side thereof, and transducer means for converting displacement of the diaphragm in dependence upon the difference in pressures into a signal representing superheat.

6. A heat transfer system comprising an evaporator through which fluid is passed while taking up heat from a medium to be cooled using the latent heat of evaporation, valve means for controlling the flow of said fluid as a liquid at the inlet of the evaporator, first sensor means for monitoring said fluid at the outlet of the evaporator, and control means for operating the valve means to adjust the liquid flow in response to an output of said first sensor means, wherein the first sensor means comprises detection means responsive to the vapour pressure and

the superheat of said fluid at the outlet of the evaporator in a series of measurements in time, and means for testing for correlation between the superheat and the vapour pressure for the series of measurements.

7. A heat transfer system according to claim 6, wherein the detection means comprises a temperature sensor and a pressure sensor, and means for calculating the superheat from the sensed temperature and vapour pressure.

8. A heat transfer system according to any of claims 1 to 7, further comprising second sensor means responsive to the temperature of said medium to be cooled, wherein the control means operates the valve means to adjust said liquid flow in response to the output of the second sensor means.

9. A heat transfer system according to claim 8, wherein the control means normally operates the valve means in response to the output of the second sensor means, but operates the valve means in response to an output of the first sensor means which indicates that the superheat of the fluid at the outlet of the evaporator is substantially zero or is below a

predetermined minimum value.

10. A heat transfer system according to claim 8 or claim 9, wherein the second sensor means includes at least one temperature sensor arranged to sense the temperature of air cooled by the evaporator.

11. A heat transfer system according to any preceding claim, wherein the valve means is an electrically-actuated expansion valve.

12. A heat transfer system according to claim 1 or claim 2, or any claim as dependent on claim 1 or claim 2, wherein the first sensor means generates said output when the detected change in temperature indicates that a proportion of liquid in the monitored fluid exceeds a predetermined value.

13. A sensor device for monitoring fluid at the outlet of an evaporator, comprising first and second temperature sensors each mounted on a thermally-conductive member adapted to be disposed in the fluid flow, and a heating means associated with one of the temperature sensors.

14. A sensor device according to claim 13,

wherein each temperature sensor is mounted on a respective housing so as to be in thermal contact therewith.

15. A sensor device according to claim 14, wherein the two housings are disposed end-to-end sandwiching a thermally-insulative element therebetween.

16. A sensor device according to any of claims 13 to 15, wherein the heating means is a component having an electrical resistance.

17. A sensor device according to any of claims 13 to 16, wherein each temperature sensor is a component having an electrical resistance which is dependent on temperature.

18. A sensor device according to claim 17, wherein each temperature sensor is a thermistor.

19. A sensor device according to any of claims 13 to 18, wherein the temperature sensors and the heating means are disposed inside a body of the device, and the interior of the body is sealed from the fluid environment.

20. A sensor device according to claim 19, wherein the interior of the body contains gas at substantially atmospheric pressure.

21. A sensor device according to any of claims 13 to 20, wherein the device includes a thread adapted for coupling the device to a pipe or vessel through which said fluid flows.

22. A sensor device according to any of claims 13 to 21, further comprising detection means responsive to change in a difference in the temperatures sensed by the two temperature sensors.

23. A sensor device for monitoring fluid at the outlet of an evaporator, comprising a body, a movable member mounted within the body, the movable member having two, mutually opposite surfaces, the body providing open communication between said fluid and one surface of the movable member, the other surface of the movable member being in open communication with a container containing a quantity of liquid, wherein the container is disposed such that the liquid is physically isolated from said fluid but acquires substantially the same temperature as the fluid, and detection means responsive to displacement of the

movable member due to differing vapour pressures, originating from the fluid and the contained liquid, being exerted on the respective surfaces of the movable member.

24. A sensor device according to claim 23, wherein the location of said container is fixed with respect to said body.

25. A sensor device according to claim 24, wherein the container is disposed substantially externally of the body.

26. A sensor device according to any of claims 23 to 25, wherein an end of the body which provides said communication between the fluid and said one surface of the movable member, is threaded for coupling the device to a pipe or vessel through which said fluid flows.

27. A sensor device according to any of claims 23 to 26, wherein said detection means is adapted to convert said displacement into an electrical signal.

28. A sensor device according to any of claims 23 to 27, wherein the detection means comprises a

linearly-movable member coupled to the movable member, and a position sensor for sensing the position of the linearly-movable member.

29. A sensor device according to any of claims 23 to 28, wherein the movable member is a diaphragm.

30. A method of sensing the presence of liquid in a flow of fluid in a heat transfer system, the method comprising monitoring the temperature of a heat-conductive member which is heated by a heating means, said member being disposed in the fluid flow, and detecting a fall in the sensed temperature which occurs due to change of state of said liquid when it comes into contact with the heated member.

31. A method of sensing the presence of liquid in a flow of fluid in a heat transfer system, the method comprising disposing two temperature sensors in the path of the fluid flow, one of the temperature sensors having a heating means associated therewith, and monitoring a difference in the temperatures sensed by the two temperature sensors.

32. A method according to claim 31, wherein the monitoring step comprises detecting a change in said

difference which occurs when heat provided by the heating means causes the sensed liquid to vaporise.

33. A method according to claim 32, wherein the size of said change is used to gauge the proportion of liquid comprised in the fluid.

34. A method of measuring superheat in a flow of fluid at the outlet of an evaporator, the method comprising measuring the displacement of a movable member having two, mutually opposite surfaces, one of which receives vapour pressure originating from said fluid at the outlet and the other of which receives vapour pressure originating from a contained quantity of liquid which is physically isolated from said fluid but acquires substantially the same temperature as the fluid, and converting the measured displacement into an electrical signal.

35. A method of monitoring superheat in a flow of fluid at the outlet of an evaporator, the method comprising making a series of measurements of the temperature and pressure of the fluid at said outlet, calculating a value of superheat for each pair of a temperature and a pressure measurement, and determining whether a relationship indicating the

existence of superheat is established between the variation of the superheat measurements with time and the variation of the pressure measurements with time.

36. A method according to claim 35, further comprising the step of generating a control signal in dependence upon the result of the determination.

37. A method according to claim 36, wherein the control signal is used to vary the proportion of time, within a predetermined cycle, in which an expansion valve controlling the flow of said fluid as a liquid into said evaporator, is open.

38. A method according to any of claims 35 to 37, wherein the determination step comprises performing linear regression on the superheat measurements and the pressure measurements, respectively, to determine a per-unit time change in superheat and a per-unit time change in pressure, and calculating a ratio of the two per-unit time change amounts.

39. A heat transfer apparatus comprising an evaporator through which fluid is passed while taking up heat from a medium to be cooled using the latent

heat of evaporation, valve means for controlling the flow of said fluid as a liquid at the inlet of the evaporator, first sensor means responsive to superheating of the fluid at the outlet of the evaporator, second sensor means responsive to the temperature of said medium to be cooled, and control means for operating the valve means to adjust the liquid flow, wherein the control means operates the valve means to vary the flow of said liquid into the evaporator in response to the output of the second sensor means so as to maintain said medium at a predetermined temperature or within a predetermined range of temperature, subject to limiting or interrupting the input liquid flow if the first sensor means indicates that the superheat is substantially zero or is below a predetermined minimum value.

40. A refrigeration apparatus according to claim 39.

41. An air conditioning apparatus according to claim 39.

42. A heat transfer system substantially as hereinbefore described with reference to Figures 4 and 5, Figures 4 and 6, or Figures 7 to 10.

43. A sensor device substantially as hereinbefore described with reference to Figure 5 or Figure 6.

44. A method of monitoring fluid substantially as hereinbefore described with reference to Figures 4 and 5, Figures 4 and 6, or Figures 7 to 10.

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Examiner's report to the Comptroller under Section 17
(The Search report)

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GB 9513191.8

Relevant Technical Fields

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Search Examiner
M C MONK

Date of completion of Search
27 SEPTEMBER 1995

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant following a search in respect of Claims :-
1, 2, 30, 31 AT LEAST

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

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Category	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2157447 A (DANFOSS) consider whole document	1, 2, 30, 31 at least

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Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report) 2ND SEARCH**	Application number GB 9513191.8
Relevant Technical Fields (i) UK Cl (Ed.N) G1N (NADCX, NAEQ) F4H (HGXT1, HGXT2, HGXC, HGXG) (ii) Int Cl (Ed.6) F25B (41/04, 49/00, 49/02) G01N (7/00, 7/16, 19/10, 25/56)	Search Examiner M C MONK Date of completion of Search 6 NOVEMBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 13-22

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Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2157447 A	(DANFOSS) sensors 13, 14; Heating element 11	13, 16 at least
X	GB 1480349	(APV CO) Example of a level detector	13, 16-18 at least

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Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report) THIRD SEARCH**		Application number GB 9513191.8
Relevant Technical Fields		Search Examiner M C MONK
(i) UK Cl (Ed.N)	G1N (NADP, NACL, NACJ) F4H (HGXT1, HGXT2, HGXC, HGXG)	
(ii) Int Cl (Ed.6)	F25B (41/04, 49/00, 49/02) G01N 25/56	Date of completion of Search 7 NOVEMBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI		Documents considered relevant following a search in respect of Claims :- 4, 23, 34

Categories of documents

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&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

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