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(54) **Method for monitoring of refrigeration system**

(57) Method for using a sensor (11) and a receiver (12) for monitoring a refrigeration system which has a compressor (1) and a pipe (8) which comes from the compressor and which conveys refrigerant. According to the invention, a temperature detector (13) of the sensor is

disposed on top of the pipe in order to indirectly measure the temperature of the refrigerant, and a processor (17) of the sensor is used to calculate an operating state value, a cycle time and a load factor for the compressor based on the measured temperature, after which the sensor sends these values to the receiver.

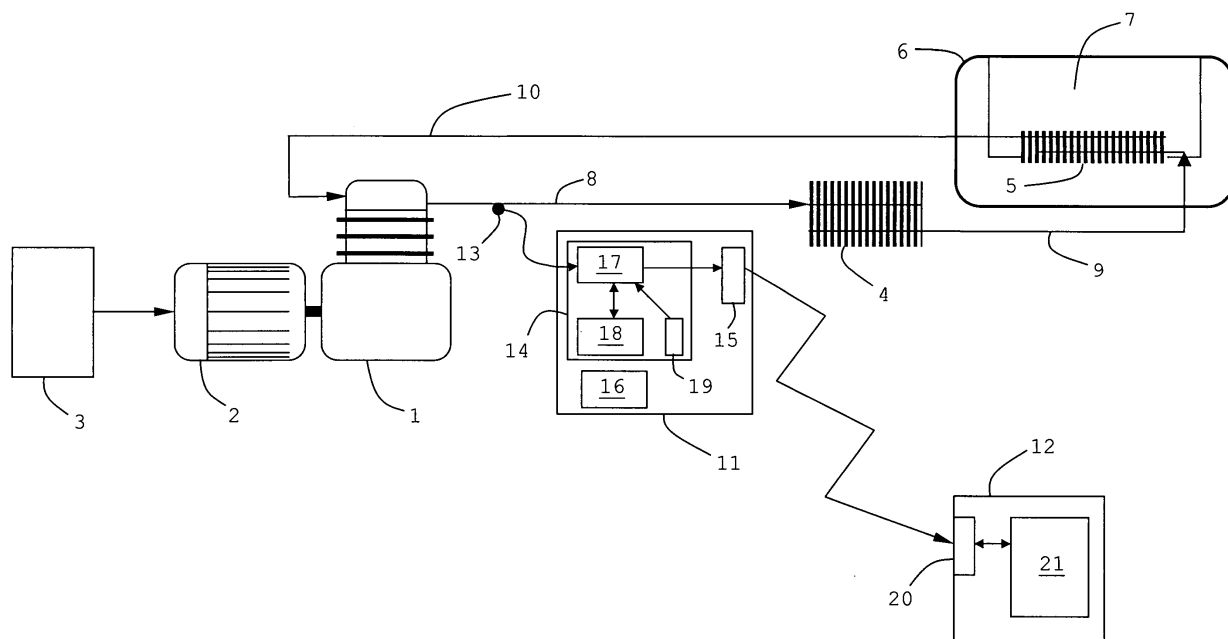


Fig. 1

Description

[0001] The present invention relates to a method for using a device including partly a sensor which itself comprises a temperature detector, a processor and a memory unit, and partly a receiver for receiving messages from the sensor, in order to monitor an existing refrigeration system comprising a pulse-regulated compressor and a pipe which comes from the compressor and which conveys a refrigerant.

[0002] The present invention relates particularly to a method for monitoring the temperature of refrigeration systems for chilled and frozen foods in food businesses, warehouses and restaurants, which refrigeration systems often have a pulse-regulated compressor. A compressor being pulse-regulated means here that the compressor has only two operating states. Either the compressor is operating at its full nominal power or it is at standstill. In other words, the compressor is either on or off. Pulse-regulated compressors are the commonest type of compressor in food refrigeration systems. If the refrigeration in such a refrigeration system is not sufficient, a thermostat initiates further refrigeration by causing the compressor to switch on and operate until the thermostat detects that the refrigeration is sufficient, whereupon the compressor switches off. A pulse-regulated compressor thus operates in cycles whereby periods when the compressor is at standstill alternate with periods when the compressor is operating at full nominal power. If the compressor is heavily loaded, the periods when it is operating are significantly longer than those when it is at standstill. The opposite situation applies when the compressor is lightly loaded.

[0003] Food refrigeration systems need monitoring of their performance. If the refrigeration system suddenly fails, this may lead to food representing a large value having to be discarded, and if a gradual deterioration in refrigeration performance is not detected in time, foods risk being stored at too high temperatures for long periods, leading to possible danger to human health.

[0004] There are currently in principle two ways of detecting a refrigeration system not functioning satisfactorily.

[0005] The first is based on measuring the temperature of foods and the time they are held at different temperatures while stored in refrigerating or freezing appliances. This method is directly related to the foods but its form in practice has to be such that large variations in both temperature and holding time are allowed. The temperature has in practice to be allowed to rise to a significantly higher value than the statutory temperature for frozen products, which may be -18°C , and the statutory temperature for chilled products, which may be $+4^{\circ}\text{C}$ or $+8^{\circ}\text{C}$ without an alarm occurring. This is because the refrigeration system has to be defrosted at regular intervals, which means that the refrigeration package of the refrigeration system is recurringly brought to a temperature above freezing point so that frozen condensate accumulated on the refrigeration package can melt and run off. Defrosting involves the refrigeration package maintaining a relatively high temperature for 90 to 120 minutes, which sets a practical time limit for alarm signals. Only after food has been at too high a temperature for more than that time can an alarm occur. This detection situation means that by the time both temperature and holding time are exceeded and an alarm finally occurs, the foods concerned are in practice close to being discardable. The net effect is that this type of detection with subsequent alarm is a kind of "panic alarm" system. This type of alarm must be attended to at any time of the day or night, because food representing a large value is often immediately at risk.

[0006] The other way of detecting a refrigeration system not operating satisfactorily is to use built-in sensors to monitor the actual refrigeration system. This is done, for example, by the operation of the compressor's electric motor being monitored and an alarm occurring if incorrect operating conditions of the electric motor's power supply are detected. Examples of such operating conditions are short-circuits, overcurrents or the loss of a phase. The monitoring system may also comprise various kinds of built-in pressure and temperature monitors which issue alarms in response to sudden pressure or temperature changes. However, such monitoring systems are designed to detect sudden and relatively large faults and are less suitable for detecting gradual deterioration of the refrigeration system's performance.

[0007] It is not possible on the basis of a momentary operating state of a pulse-regulated compressor to decide how heavily loaded the refrigeration system is. In food shops, which often have refrigeration systems comprising 3-15 compressors, it is impossible to assess the refrigeration system's operating situation by brief observation of the compressors, since it is usual for some compressors to be at standstill while others are operating.

[0008] It is undesirable for a compressor to operate for long periods close to its maximum capacity, partly because the refrigeration system would then be operating with no margin and no spare capacity and partly because the compressor would be subject to an unnecessarily large amount of wear. Therefore, such a situation needs to be detected quickly. However, a compressor operating close to its maximum capacity usually functions normally, from a purely mechanical and electrical point of view, but has to operate continuously or almost continuously if it is to provide the refrigeration demanded by the refrigeration system's thermostats. The refrigeration in refrigerating appliances may thus be quite normal despite the compressor being close to overload. Thus a compressor operating close to its maximum capacity is difficult to detect by either of the two forms of monitoring described above.

[0009] The refrigeration circuit in a refrigeration system is usually physically quite extensive, with a high-pressure side in which there is risk of the refrigeration system's refrigerant leaking out and a low-pressure side in which there is risk of air leaking into the refrigerant. Both forms of leakage lead to gradual deterioration of the refrigeration system's per-

formance. This type of fault is difficult to detect by either of the two forms of monitoring described above, since the thermostats of the refrigeration system will as long as possible compensate for the fault and conceal it by demanding more refrigeration. The ultimate result is that the compressor risks operating continuously during certain parts of the day and/or night. Since neither of the two monitoring systems described above detect or trigger alarms in this serious situation, the degradation may proceed further until the compressor, despite running continuously, is no longer able to maintain sufficient refrigeration, which is usually only revealed by rising food temperatures. Alternatively, the compressor may break down because of overload, which is only revealed when sensors built into the refrigeration system detect it and trigger alarms.

[0010] There are many refrigeration systems with pulse-regulated compressors of varying age and condition. A usual medium-large food business may for example have 3-15 large compressors and about ten smaller so-called plug-in compressors. With the state of the art it is difficult in an existing refrigeration facility to improve the monitoring of pulse-regulated compressors without major installing and restructuring costs.

[0011] There is therefore a need for a monitoring system which can easily be installed in an existing refrigeration system comprising a pulse-regulated compressor and is not only applicable without being connected into or acting upon the refrigeration circuit, the compressor or its drive or control systems but also makes it possible to detect the many different kinds of fault which may occur in such a refrigeration system, particularly those which result in gradual or sudden deterioration in refrigerating function despite the compressor itself functioning normally from a purely mechanical and electrical point of view.

[0012] The object of the present invention is to present a method for such a monitoring system.

[0013] The method according to the invention is characterised by features according to the characterising part of claim 1.

[0014] The invention is thus based on the at first sight contradictory principle that high temperature from the compressor indicates that a refrigerating function is being delivered by the refrigeration system. The invention is also based on it being possible for a deteriorated or failed refrigerating function to be detected early by analytical monitoring of variations in the temperature of the refrigerant on the refrigeration system's high-pressure side.

[0015] The invention makes it possible to set up effective monitoring of already installed refrigeration systems.

[0016] Installing the monitoring system according to the invention takes in practice only about 15-30 minutes. This is done without penetrating the existing refrigeration system and can therefore be carried out by a person with no heavy-current authorisation. Since there is no need for any penetration of the existing refrigeration system, neither the actual installing of the monitoring system nor the presence of its installed components will affect the functioning of the refrigeration system. This means that the original supplier of the refrigeration system cannot argue that any guarantee commitment is affected or no longer applicable.

[0017] Monitoring according to the invention is simple and effective, since analysis of a single parameter, viz. the delivery temperature of the refrigerant, provides an immediate picture of the functioning of the refrigeration system's central component, i.e. the compressor. The technical requirements for the components of the monitoring system are low, making it possible to use inexpensive standard components.

[0018] Unlike the state of the art, the monitoring system according to the invention makes it possible to detect the compressor's inability to provide refrigeration irrespective of whether the underlying cause is overdimensioning, underdimensioning, power failure, phase loss, faulty control and regulating equipment, faulty compressor, faulty refrigeration circuit or some other fault which makes it impossible for the compressor to provide refrigeration. In addition, the monitoring system enables early detection of inability of the refrigeration system to provide refrigeration, thereby enhancing the possibility of a successful response to save food from destruction. In the best case, unscheduled responses can be completely avoided by faults being detected in such good time that servicing during normal working hours can be arranged before the functioning of the facility has declined so much that refrigeration can no longer be maintained.

[0019] The invention is described in more detail below with reference to the attached drawings.

[0020] Fig. 1 depicts schematically an embodiment of a monitoring system according to the invention.

[0021] Fig. 2 depicts curves illustrating the calculation of operating state values of the monitoring system according to Fig. 1.

[0022] Figs. 3-5 illustrate the processing of temperature values of the monitoring system according to Fig. 1.

[0023] Fig. 1 depicts a conventional refrigeration system comprising a pulse-regulated compressor 1, a drive unit in the form of an electric motor 2 for driving the compressor 1, and a control unit 3 for controlling the electric motor 2. The compressor 1 being pulse-controlled means in this context that the compressor has only two operating states. Either the compressor 1 is operating at its full nominal power or it is at standstill. In other words, the compressor is either on or off, and the control unit 3 regulates the operation of the compressor 1 by varying the length of the periods of time when the compressor 1 is on.

[0024] The refrigeration system further comprises a condenser 4 and a refrigeration package 5 situated in a refrigeration unit 6. In the refrigeration unit 6, which may for example be a refrigerator, a freezer, a freezing cabinet or some other type of refrigerating appliance, there is a food storage space 7.

[0025] The compressor 1, the condenser 4 and the refrigeration package 5 are linked by pipes 8-10. The pipes 8-10,

the compressor 1, the condenser 4 and the refrigeration package 5 constitute in a conventional manner a refrigeration circuit for a refrigerant. The compressor 1 compresses the refrigerant, which is heated. The compressed refrigerant is led through the first pipe 8 to the condenser 4 where the refrigerant cools and condenses. The refrigerant is led thereafter via the second pipe 9 to the refrigeration package 5, in which the refrigerant cools the storage space 7 by absorbing heat from the storage space 7 and foods stored therein. Finally, the refrigerant is led through the third pipe 10 back to the compressor 1, in which the refrigerant is compressed again. The refrigeration circuit thus comprises a high-pressure side downstream of the compressor, in which the refrigerant flows through the pipe 8 at high pressure, and a low-pressure side upstream of the compressor, in which the refrigerant flows through the pipe 10 at low pressure.

[0026] The monitoring system according to the invention comprises a sensor 11 and a receiver 12.

[0027] The sensor 11 comprises a sensor element in the form of a temperature detector 13, a control unit 14, a transmitter unit 15 and an energy source in the form of a battery 16. The control unit 14 itself comprises a processor 17, a memory unit 18 and a clock 19. The control unit 14 is preferably a so-called single-chip processor, i.e. a chip which comprises a processor element, a memory element and a clock function. The sensor 11 is adapted to measuring temperature values via the temperature detector 13, processing the measured temperature values in the control unit 14 and sending the processed temperature values out wirelessly in the form of radio messages via the transmitter unit 15.

[0028] The receiver 12 comprises a receiver unit 20 for receiving radio messages from the sensor 11. The receiver also comprises a control unit 21 for further analysis and processing of the temperature values processed in the sensor.

[0029] The temperature detector 13, the control unit 14 and the transmitter unit 15 may constitute a unit. The temperature detector 13 may alternatively be connected to the control unit 14 by a short flexible signal line, thereby allowing more freedom in the positioning of the temperature detector 13.

[0030] Fitting the monitoring system entails disposing the temperature detector 13 on top of the shell surface of the first pipe 8 in order to measure the shell temperature of the pipe 8, which shell temperature is an indirect measure of the temperature of the refrigerant on the high-pressure side of the refrigeration system. The pipes of refrigerant circuits of refrigeration systems are almost without exception made of metal, thereby ensuring that a change in the temperature of the refrigerant is rapidly propagated to the surface of the pipe.

[0031] The temperature detector 13 is preferably disposed at a predetermined distance, e.g. about 10-100 cm, from the compressor 1. If the temperature detector 13 is situated too close to the compressor 1, the thermal inertia of the material of the compressor casing will disrupt the temperature measurement. If the temperature detector is situated too far from the compressor 1, the temperature of the refrigerant will no longer reflect the operating state of the compressor. A preferred position for the temperature detector 13 is about 50 cm from the compressor 1 along the pipe 8. It should be noted that the temperature detector 13 is disposed on top of the pipe 8 without penetrating the pipe 8 at all. The temperature detector 13 is preferably fastened on top of the pipe 8 by banding which is caused to surround the pipe and at the same time press the temperature detector 13 towards the shell surface of the pipe 8.

[0032] After the temperature detector 13 has been fitted, the sensor is activated, causing the temperature detector 13 to measure the temperature of the shell surface of the pipe 8 at a predetermined measuring rate, i.e. at regular intervals of time ... t_{n-2} , t_{n-1} , t_n ... and to send the measured temperature values ... T_{n-2} , T_{n-1} , T_n ... to the control unit 14. The time between two consecutive measurements t_{n-1} and t_n should preferably be not more than half of the shortest running or standstill time of the compressor which is to be monitored. For a compressor with nominal power of 3-10 kW, which is a usual nominal power of a compressor in a food refrigeration system, the shortest running and standstill periods are normally about 5 minutes, although shorter running and standstill periods may occur, e.g. due to too little hysteresis of the refrigeration system's thermostats. These short running and standstill periods are interesting from the monitoring point of view, since they result in heavy wear of the refrigeration system. Thus the time between two consecutive measurements should preferably be less than 2.5 minutes and most preferably be at most 1-2 minutes, which means that the measuring rate should be at least 24 measurements per hour and preferably at least 30-60 measurements per hour.

[0033] The processor 17 is programmed to compare each measured temperature value with a first temperature value $T_{\max}$ stored in the memory unit 18 and a second temperature value $T_{\min}$ stored in the memory unit 18. The first temperature value represents a maximum current temperature of the refrigerant, and the second temperature value a minimum current temperature of the refrigerant. When the sensor is activated, these first and second temperature values are preferably set at predetermined normally occurring temperature values, preferably about 30°C and about 70°C respectively. This makes it possible for the monitoring system to supply usable information directly from the facility. If the measured temperature value T_n exceeds the first temperature value $T_{\max}$, the processor 17 replaces the first temperature value $T_{\max}$ by the measured temperature value T_n , which thus becomes the new first temperature value stored in the memory unit 18. If the measured temperature value T_n is below the second temperature value $T_{\min}$, the processor replaces the second temperature value $T_{\min}$ by the measured temperature value T_n , which thus becomes the new second temperature value stored in the memory unit 18. The processor 17 is also programmed to reduce the first temperature value and increase the second temperature value by a predetermined amount of temperature, e.g. a temperature in the range 1°C-2°C, at regular intervals, e.g. once per 24 hours. The monitoring system thus has an ability to adapt to

individual refrigeration systems and to changing operating conditions even if the initial values of $T_{\max}$ and $T_{\min}$ are not quite correct. The automatic decrease and increase in $T_{\max}$ and $T_{\min}$ respectively also ensures that temporary extremely high or extremely low temperature values do not persist in the memory unit 18 for a long period of time after they have occurred.

[0034] For each measured temperature value, the processor 17 calculates an operating state value on the basis

$$(T_n - T_{n-1}) / (t_n - t_{n-1}) + (T_{n-1} - T_{\text{mean}}) / K$$

where T_n is the latest measured temperature value, T_{n-1} is the previous measured temperature value, t_n is the time of measurement of the latest measured temperature value, t_{n-1} is the time of measurement of the previous measured temperature value, K is a time constant within the range 2-30 minutes and T_{mean} is the mean of said first and second temperature values, i.e. $(T_{\max} + T_{\min})/2$.

[0035] If the interval between two consecutive measurements is short, e.g. less than 1 minute, T_n may with advantage be used instead of T_{n-1} in the second term, which means that the operating state value is instead calculated on the basis

$$(T_n - T_{n-1}) / (t_n - t_{n-1}) + (T_n - T_{\text{mean}}) / K$$

[0036] The calculated operating state value is in practice definitely positive on an operating compressor and definitely negative on a compressor at standstill, apart from a certain time delay which is in practice unavoidable but negligible relative to other time perspectives.

[0037] The first term of the operating state value, $(T_n - T_{n-1})/(t_n - t_{n-1})$, is a measure of how much the temperature changes between two consecutive measurements. In other words, this term is a temperature derivative. Theoretically this term is always positive so long as the compressor is operating, but after a certain running time of the compressor the measured temperature will in practice fluctuate about a relatively stable working temperature, with the result that the first term oscillates between being positive and negative.

[0038] The object of the second term, $(T_{n-1} - T_{\text{mean}})/K$ or $(T_n - T_{\text{mean}})/K$, is to compensate for this fluctuation so that the operating state value calculated as above does not falsely signal a compressor standstill when the compressor is still operating, or vice versa when the compressor is at standstill, i.e. to prevent the calculated operating state value being negative when the compressor is actually operating and positive when it is actually at standstill. In practice the highest temperature value measured is normally about 80°C and the lowest normally about 20°C, resulting in a T_{mean} value of about 50°C. However, this value may be allowed to vary $\pm 10\%$ without disrupting the result derivable from the operating state value. With a continuously operating compressor, the measured temperature T_{n-1} or T_n will most certainly be higher than T_{mean} , so the second term will make a positive contribution which compensates for any slight negative value of the first term. With a compressor continuously at standstill, the measured temperature T_{n-1} or T_n will most certainly be lower than T_{mean} , so the second term will make a negative contribution which compensates for any slight positive value of the first term.

[0039] The constant K causes the calculated operating state value to be relatively insensitive to temporary temperature fluctuations. Practical experience has shown that a K value within the range 2-30 minutes, and preferably about 8 minutes, is advantageous. The result of a value of 8 minutes is that sudden temperature fluctuations of up to 3.75°C per minute on a compressor which is continuously running or continuously at standstill do not lead to an incorrect operational indication. An increased K value gives a quicker operating state value response but also entails more risk of false values, i.e. of the operating state value being negative when the compressor is actually in operation, and vice versa.

[0040] When it has calculated the operating state value, the processor 17 thus establishes whether the value is positive or negative, a positive value being associated with the compressor 1 being in operation and a negative value with the compressor 1 being at standstill. This preferably leads to the current time of measurement being associated with the operating state 1 if the operating state value is positive and with the operating state 0 if the operating state value is negative. This operating state is thereafter stored in the memory unit 18.

[0041] Fig. 2 depicts curves illustrating the monitoring system's calculation of the operating state value, with the monitoring system's temperature detector disposed on top of a pipe of a refrigeration circuit such as described above, in this case about 50 cm downstream of the refrigeration system's compressor. The top curve, which should be read with the temperature scale on the left, shows how the temperature measured by the temperature detector varies over 24 hours. The temperature detector's measuring rate in this case is about 24 measurements per hour, which means that the period between two consecutive measurements is about 2.5 minutes. The middle curve, which should be read

with the temperature variation scale on the right, represents the operating state value calculated on the above $(T_n - T_{n-1}) / (t_n - t_{n-1}) + (T_{n-1} - T_{\text{mean}}) / K$ basis, with the time constant K set at 8 minutes. The bottom curve shows the result of the control unit's analysis of the calculated operating state value, whereby the value 1 indicates that the sign of the operating state value is positive and the compressor is therefore assessed as being in operation, and the value 0 indicates that the sign of the operating state value is negative and the compressor is therefore assessed as being at standstill.

[0042] Between 00.00 and 08.00 the compressor is in normal operation, with the thermostat periodically switching it on and off.

[0043] Between 08.00 and 10.00 the compressor is very heavily loaded and in continuous operation except for a few brief disconnections.

[0044] Between 10.00 and 18.30 the compressor is in continuous operation but overloaded, possibly because it is underdimensioned for the current load.

[0045] Between 18.30 and 19.30 the compressor is totally disconnected for defrosting.

[0046] Between 21.00 and 00.00 the compressor is again in operation, but heavily loaded with periodic thermostat-controlled running, mostly on.

[0047] As the middle curve shows, the operating state value is typically about $-6^\circ\text{C}/\text{minute}$ after the compressor has switched off and about $+10^\circ\text{C}/\text{minute}$ after the compressor has switched on. The upper and lower curves show a very good match between the compressor's actual operating state, i.e. whether it is off or on, and the sign of the operating state value.

[0048] When it has calculated the operating state value, the processor 17 establishes not only whether there has been a change in the compressor's operating state since the previous measurement but also the length of the latest completed period in which the operating state value is negative or positive, as the case may be. If the compressor's operating state is unchanged since the previous measurement, the processor 17 also determines the length of the uncompleted current period, irrespective of whether the operating state value is negative or positive during that period, i.e. irrespective of whether the compressor is operating or at standstill. This step is illustrated by examples in Figs. 3-5, where $\underline{a}$ denotes the length of the latest completed period in which the operating state value is negative, $\underline{b}$ the length of the latest completed period in which the operating state value is positive and $\underline{c}$ the length of the uncompleted current period.

[0049] Fig. 3 illustrates a situation in which the compressor's operating state has changed from 1 at t_{n-1} to 0 at t_n . The latest completed period $\underline{a}$, i.e. that in which the operating state value is negative, runs between t_{n-5} and t_{n-3} , and the length of that period is therefore $t_{n-3} - t_{n-5}$. The latest completed period $\underline{b}$, i.e. that in which the operating state value is positive, runs between t_{n-3} and t_n , and the length of that period is therefore $t_n - t_{n-3}$.

[0050] Fig. 4 illustrates a situation in which the compressor's operating state is an unchanged 1 at t_n . The latest completed period $\underline{a}$ runs in this case between t_{n-3} and t_{n-2} , and the length of that period is therefore $t_{n-2} - t_{n-3}$. The latest completed period $\underline{b}$ runs between t_{n-4} and t_{n-3} , and the length of that period is therefore $t_{n-3} - t_{n-4}$. The uncompleted current period $\underline{c}$ runs between t_{n-2} and t_n , and its length is therefore $t_n - t_{n-2}$.

[0051] Finally, Fig. 5 illustrates a situation in which the compressor's operating state is an unchanged 0 at t_n . The latest completed period $\underline{a}$ runs in this case between t_{n-5} and t_{n-4} , and the length of that period is therefore $t_{n-4} - t_{n-5}$. The latest completed period $\underline{b}$ runs between t_{n-4} and t_{n-2} , and the length of that period is therefore $t_{n-2} - t_{n-4}$. The uncompleted current period $\underline{c}$ runs between t_{n-2} and t_n , and its length is therefore $t_n - t_{n-2}$.

[0052] Thereafter the processor 17 calculates not only a current cycle time for the compressor on the basis:

$$\text{cycle time} = \text{running time} + \text{standstill time}$$

but also a current load factor for the compressor on the basis:

$$\text{load factor} = \text{running time} / \text{cycle time}$$

the running time being equal to the length of the latest completed period $\underline{b}$ in which the operating state value is positive or, if the compressor's operating state is an unchanged 1 at the time of measurement, to the length of the uncompleted current period $\underline{c}$ if greater than $\underline{b}$, and the standstill time being equal to the length of the latest completed period $\underline{a}$ in which the operating state value is negative or, if the compressor's operating state is an unchanged 0 at the time of measurement, to the length of the uncompleted current period $\underline{c}$ if greater than $\underline{a}$. The results in the examples illustrated in Figs. 2-4 will thus be in Fig. 3:

$$\begin{aligned}\text{cycle time} &= \underline{b} + \underline{a} \\ \text{load factor} &= \underline{b} / (\underline{b} + \underline{a}) = 3/5 = 0.60\end{aligned}$$

in Fig. 4 (since $\underline{c} > \underline{b}$) :

$$\begin{aligned}\text{cycle time} &= \underline{c} + \underline{a} \\ \text{load factor} &= \underline{c} / (\underline{c} + \underline{a}) = 2/3 \approx 0.67\end{aligned}$$

and in Fig. 5 (since $\underline{c} > \underline{a}$):

$$\begin{aligned}\text{cycle time} &= \underline{b} + \underline{c} \\ \text{load factor} &= \underline{b} / (\underline{b} + \underline{c}) = 2/4 = 0.50\end{aligned}$$

[0053] The load factor may thus assume a value between 0 and 1, low values denoting a lightly loaded and possibly poorly utilised compressor and high values a heavily loaded compressor. A load factor close to 1 denotes a continuously operating compressor under maximum load. For example, the load factor and the operating state may be related as follows:

0.0 = compressor at standstill
Up to 0.5 = compressor overdimensioned
0.5-0.7 = normal operation
Over 0.7 = compressor heavily loaded
Over 0.9 = compressor very heavily loaded
1.0 = compressor overloaded

[0054] When the processor 17 has calculated the load factor, the processor 17 sends to the receiver 12 via the transmitter unit 15 a radio message conveying measured temperature, current first and second temperature values ($T_{\max}$ and $T_{\min}$), running time, standstill time and load factor.

[0055] The control unit 21 in the receiver 12 analyses the radio message received and, on the basis of the information in the message, adopts suitable measures, e.g. possibly issuing some form of alarm.

[0056] If the standstill time exceeds a predetermined maximum permitted threshold value, e.g. a threshold value within the range 1-2 hours, the control unit 21 may for example assume that the compressor is at standstill longer than is normal for a defrosting period and may issue an alarm to that effect.

[0057] If the running time exceeds a predetermined maximum permitted threshold value, e.g. 5 hours, the control unit 21 may for example assume that the compressor is overloaded, resulting in an alarm to that effect.

[0058] If the cycle time is less than a predetermined minimum cycle time, e.g. 5 minutes, the control unit 21 may for example assume that the refrigeration system is operating at too low thermostat hysteresis, resulting in an alarm to that effect.

[0059] If the measured temperature exceeds a predetermined first permitted temperature value, which is preferably within the range 115-139°C, it is preferred that the control unit 21 sends out a low-priority alarm to that effect. If the measured temperature exceeds a predetermined second maximum permitted temperature value, which is preferably about 140°C, it is preferred that the control unit 21 sends out a high-priority alarm to that effect.

[0060] As well as pure alarms, the receiver may also issue opinions about the refrigeration system and its performance. For example, the load factor provides very good information about the construction and functioning of the facility. For example, low load factor values on a new refrigeration system indicate that the compressor is lightly loaded and the refrigeration system overdimensioned, whereas high load factor values indicate that the compressor is overloaded and the refrigeration system underdimensioned. Slowly rising load factor values may indicate that there is leakage of refrigerant.

erant or that air is leaking into the refrigeration circuit, thereby gradually impairing the functioning of the facility so that the compressor gradually becomes increasingly loaded.

[0061] The invention is described above with reference to a pair of specific embodiments. However, it should be appreciated that other embodiments and variants are possible within the scope of the invention. For example, messages between the sensor and the receiver may be sent by wire instead of wirelessly.

[0062] With advantage, the type of sensor and receiver described in European patent application No. 07018543.4 may be used with the present invention, in which case reactivation of the sensor will restart the calculation of T_{mean} .

Claims

1. A method for using a device including partly a sensor (11) which comprises a temperature detector (13), a processor (17) and a memory unit (18), and partly a receiver (12) for receiving messages from the sensor (11), in order to monitor an existing refrigeration system comprising a pulse-regulated compressor (1) and a pipe (8) which comes from the compressor (1) and which conveys a refrigerant, **characterised by** the steps:

- of the temperature detector (13) being disposed on top of the pipe (8) at a predetermined distance from the compressor (1) and being caused to measure the temperature of the shell surface of the pipe (8), and thereby indirectly the temperature of the refrigerant, at a predetermined measuring rate,
- of the processor (17) for the measured temperature values T_n :

- comparing T_n with a first temperature value T_{max} stored in the memory unit (18) and with a second temperature value T_{min} stored in the memory unit (18),
- replacing T_{max} by T_n in the memory unit (18) if T_n exceeds T_{max} replacing T_{min} by T_n in the memory unit (18) if T_n is less than T_{max} ,
- calculating an operating state value on the basis:

$$(T_n - T_{n-1}) / (t_n - t_{n-1}) + (T_{n-1} - T_{mean}) / K$$

where T_{n-1} is the previous measured temperature value, t_n is the time of the latest measured temperature value, t_{n-1} is the time of the previous measured temperature value, T_{mean} is the mean of said first and second stored temperature values and K is a constant within the range 2-30 minutes,

- determining whether the operating state value is positive or negative, associating a positive value with the compressor operating and a negative value with the compressor being at standstill,
- calculating the length (a) of the latest completed period in which the operating state value is negative and the length (b) of the latest completed period in which the operating state value is positive and, if the operating state of the compressor (1) is unchanged since the previous measurement, calculating the length (c) of the uncompleted period in the current operating state,
- calculating a current cycle time for the compressor (1) on the basis:

$$\text{cycle time} = \text{running time} + \text{standstill time}$$

and a current load factor for the compressor (1) on the basis:

$$\text{load factor} = \text{running time} / \text{cycle time},$$

the running time being equal to the length (b) of the latest completed period in which the operating state value is positive or, if the compressor's operating state is an unchanged positive at the time of measurement, to the length (c) of the uncompleted current period if greater, and the standstill time being equal to the length (a) of the latest completed period in which the operating state value is negative or, if the compressor's operating state is an unchanged negative at the time of measurement, to the length (c) of the uncompleted

current period if greater, and

- sending a message to the receiver (12) conveying measured temperature, running time, standstill time and load factor.

- 5 2. The method according to claim 1, **characterised in that** said predetermined distance between the compressor (1) and the temperature detector (13) is within the ranges 10-100 cm.
- 10 3. The method according to claim 2, **characterised in that** the distance between the compressor (1) and the temperature detector (13) is 50 cm.
- 15 4. The method according to any one of claims 1-3, **characterised in that** said predetermined measuring rate is at least 24 measurements per hour.
5. The method according to claim 4, **characterised in that** said predetermined measuring rate is at least 30-60 measurements per hour.
- 20 6. The method according to any one of claims 1-5, **characterised in that** $T_{\min}$ and $T_{\max}$ are initially set at 20°C and about 80°C respectively when the sensor is activated or reactivated.
7. The method according to any one of claims 1-6, **characterised in that** said constant K is equal to 8 minutes.
8. The method according to any one of claims 1-7, **characterised in that** said operating state value is calculated on the basis:

$$(T_n - T_{n-1}) / (t_n - t_{n-1}) + (T_n - T_{\text{mean}}) / K$$

instead of on the basis basis:

$$(T_n - T_{n-1}) / (t_n - t_{n-1}) + (T_{n-1} - T_{\text{mean}}) / K.$$

- 35 9. The method according to any one of claims 1-8, **characterised in that** said message also conveys $T_{\max}$ and $T_{\min}$.
- 40 10. The method according to any one of claims 1-9, **characterised in that** the processor (17) at regular intervals of time, preferably once per 24 hours, decreases $T_{\max}$ and $T_{\min}$ by a predetermined amount of temperature, preferably 1°C-2°C.
- 45 11. The method according to any one of claims 1-10, **characterised in that** said refrigeration system is for food.

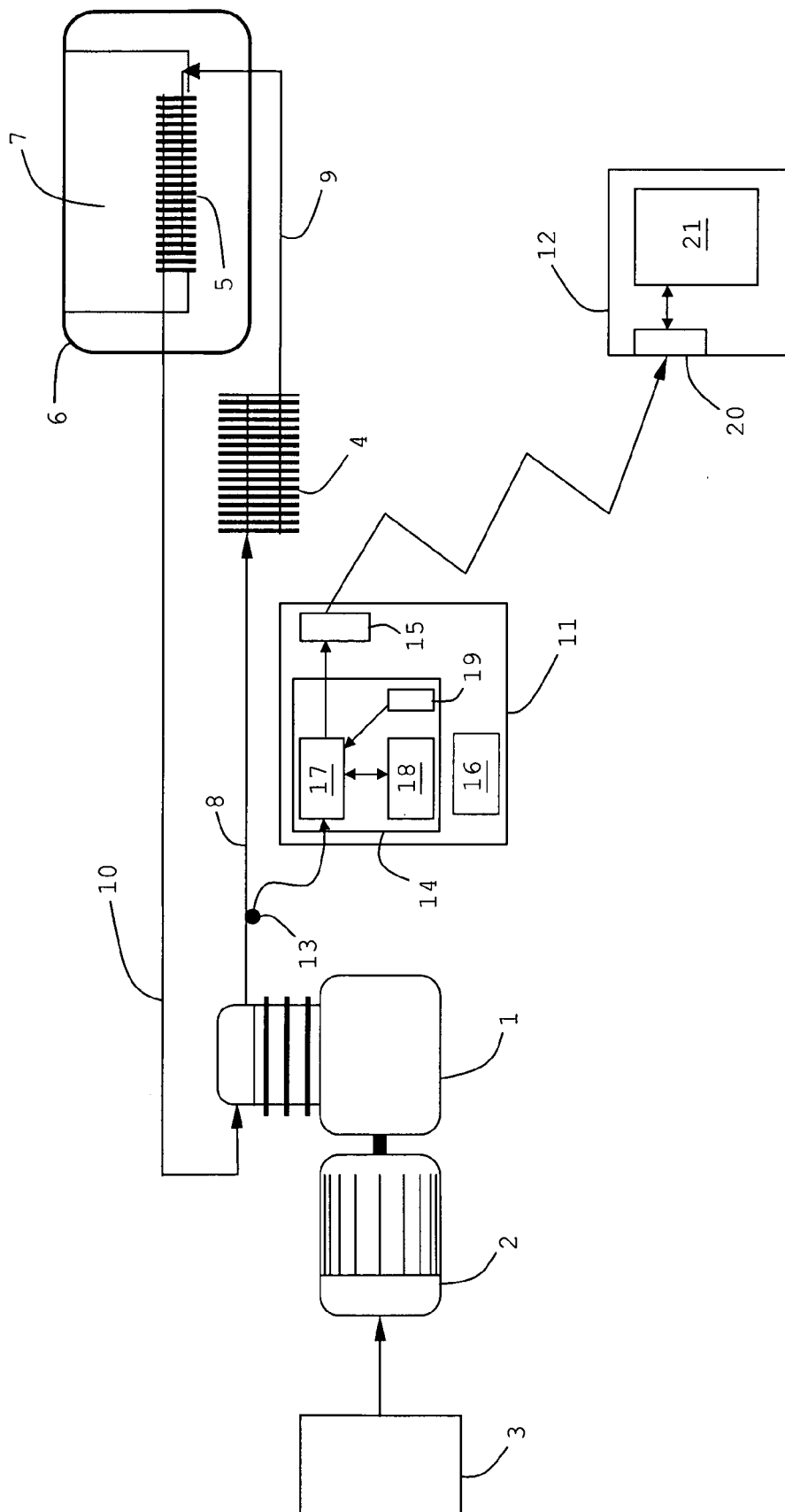


Fig. 1

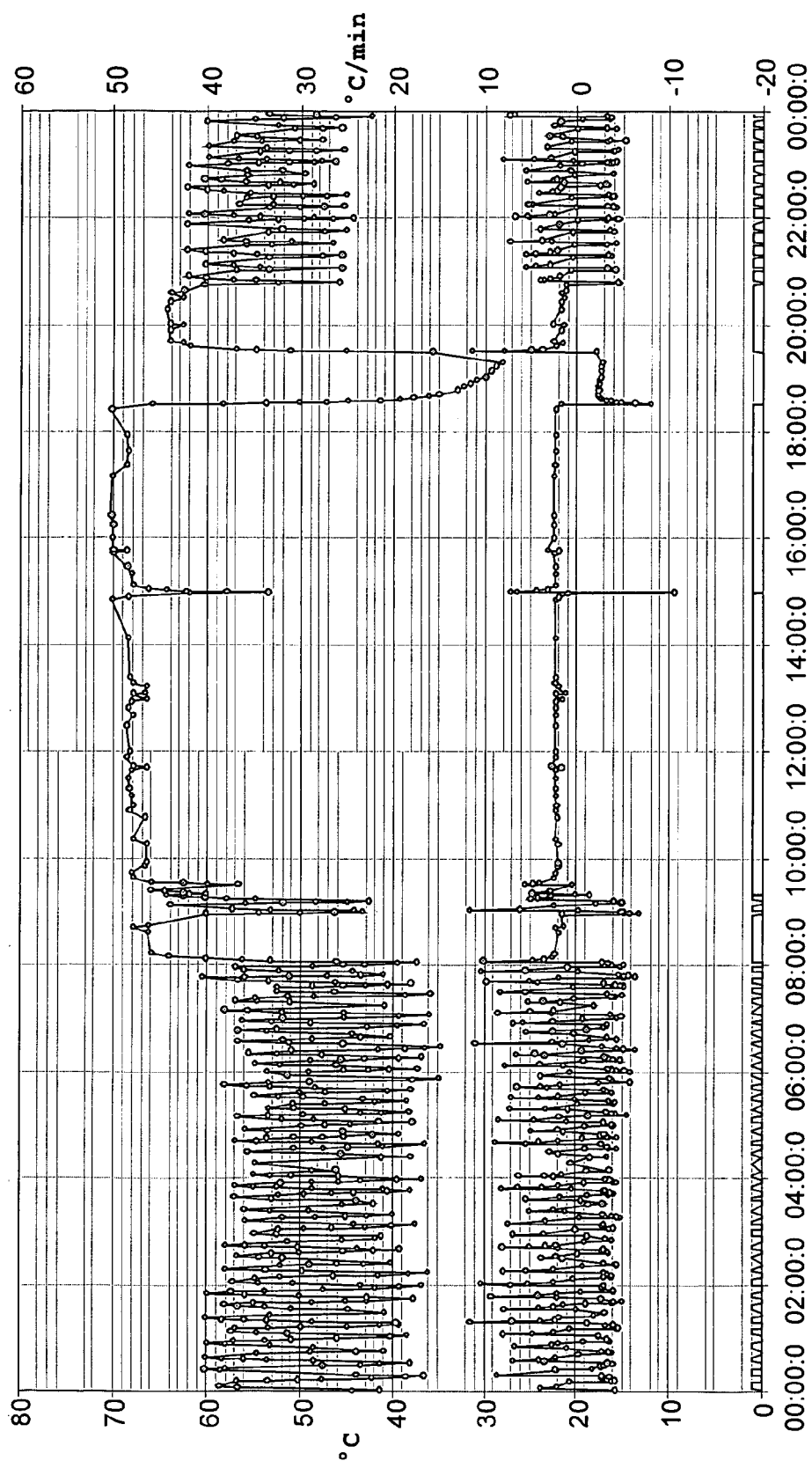


Fig. 2

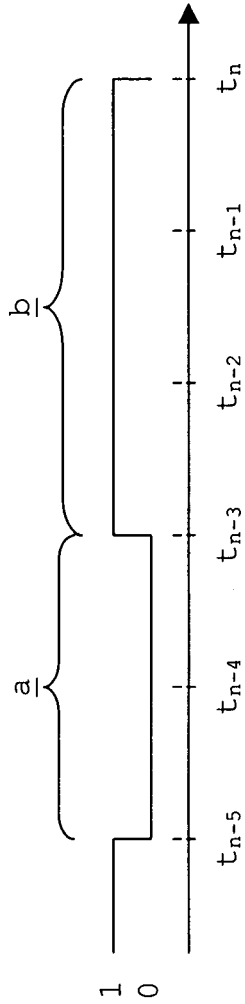


Fig. 3

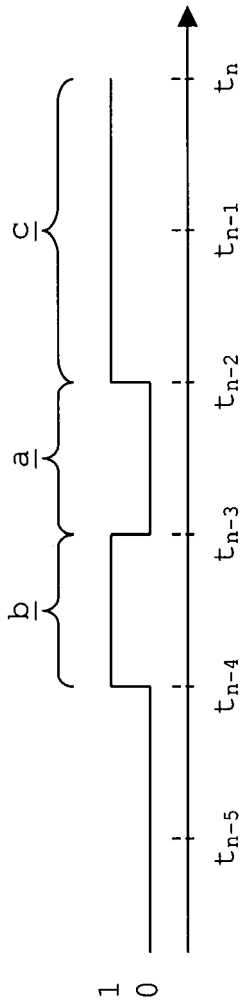


Fig. 4

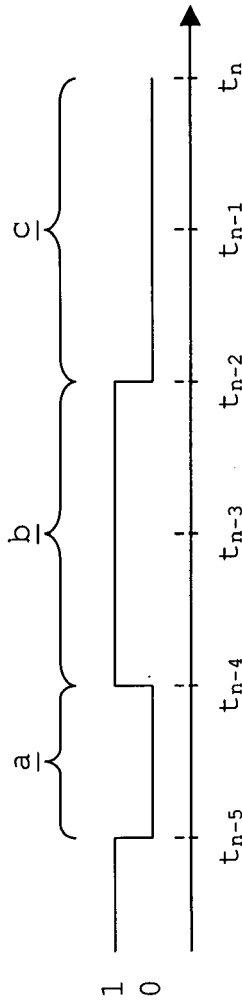


Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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