Energy Saver Device and Method for Cooling and Heating Apparatus.

Field of the Invention

The present invention relates to cooling and heating systems such as air-conditioners, chillers/refrigeration systems and boilers. In particular the invention relates to an energy saving device for cooling and heating apparatus and to an energy efficient method of controlling cooling and heating apparatus

Background to the Invention

Air-conditioning and refrigeration systems are typically designed to deliver required cooling under the most demanding of anticipated climate conditions. As an example, an air-conditioning system might be designed to maintain a room full of people at the lowest required temperature on the hottest day of the year and the compressor – the main energy consuming component – is sized to provide cooling under this extreme condition. Clearly, when operating in this situation and at a maximum design limit there is little or no opportunity to reduce energy consumption. However, because air-conditioning and refrigeration systems rarely operate at their maximum design limit, most of the time they are therefore oversized for the job at hand and actually consume more energy than is required.

Figure 1 is a schematic of a typical air-conditioning or refrigeration system. In this, a compressor and associated condenser 1 is used to generate a 'reservoir' of high-pressure liquid refrigerant on a high pressure circuit comprising a receiver/dryer 2 and connecting pipe work 3. The compressor 1 converts low pressure refrigerant vapour into high-pressure liquid refrigerant that can be used for cooling. In this compression of vapour a very large amount of heat is generated and this heat is dissipated external to the space that will be cooled allowing the refrigerant vapour to condense into a liquid at high pressure. The high pressure pipe work 3 carries the high-pressure liquid refrigerant into the space that will be cooled where it passing through a needle valve 5 that is usually part of an indoor heat exchanger (or evaporator) 6, but is shown separate for clarity. Passing though

the needle valve 5 the high-pressure liquid explosively decompresses back to a vapour at low pressure in the indoor heat exchanger 6. In this process a large amount of heat is absorbed from the air passing through the heat exchanger 6 resulting in a stream of very cold supply air into the room or area being cooled. A fan 7 moves air though the heat exchanger 6 to provide a stream of cold supply air 8. The low-pressure refrigerant is returned to the compressor 1 via a low pressure circuit comprising pipe work 4 to be compressed and returned to the high pressure side again.

Most air-conditioning and refrigeration systems today make use of simple ON/OFF temperature control with a thermostat 19 9 being used to control the compressor 1 which accounts for over 85% of the energy consumed. In operation with such systems, the thermostat 19 will keep the compressor running continuously while the room temperature is above a desired set point. On reaching a desired set point the thermostat 19 will then turn off the compressor until the temperature has risen by a small amount at which time the compressor is restarted. Except in situations where the compressor is running at or near its design limit this method of control presents a significant opportunity for energy reduction. In fact, continuing to run a compressor once it has generated a full 'reservoir' of high-pressure refrigerant is actually wasteful of energy.

More recently, a new class of air-conditioning and refrigeration systems has been introduced with compressors that make use of inverter drives. These drives continuously operate compressors which are sped up or slowed down depending on the loading on the system. While these units obviously save energy, the level of energy reduction is not as significant as that achievable by intelligently stopping compressor operations.

Summary of the Invention

According to a first aspect of the invention there is provided an energy saver device intended for use with a heating or cooling system having an apparatus for changing the temperature of a working medium, the device comprising contacts for providing an on/off signal to the apparatus, a timer having an adjustable timer value and providing a signal for opening or closing the contacts, a temperature sensor for measuring temperature the

working medium, and a controller arranged to adjust the adjustable timer value in response to changes in temperature of the working medium.

Preferably the energy saver device is intended for use with an air-conditioner or refrigeration system having a compressor for compressing a supply of a refrigerant and an evaporator in which the compressed refrigerant expands for cooling a stream of cold supply air, the controller comprising contacts for providing an on/off signal to the compressor, a timer having an adjustable timer value and providing a signal for opening or closing the contacts, a temperature sensor for measuring the cold supply air, and a controller arranged to adjust the adjustable timer value in response to a measured cold supply air temperature.

Preferably, the timer is arranged to open the contacts and the controller is arranged to activate the time and to closes the contacts.

Preferably, the controller comprises a microprocessor or electronic circuit adapted to detect signals from the temperature sensor representing a minimum cold supply air temperature and a high cold supply air temperature.

According to a second aspect of the invention there is provided an heating or cooling system, comprising a apparatus for changing the temperature of a working medium, a temperature sensor located to measure temperature of the working medium and a controller for turning the apparatus on and off in response to a sensed temperature of the working medium.

Preferably, the heating or cooling system is an air-conditioner or refrigeration system, comprising a compressor for compressing a supply of a refrigerant, an evaporator in which the compressed refrigerant expands for cooling a stream of cold supply air, a temperature sensor located to measure temperature of the cold supply air and a controller for turning the compressor on and off in response to a sensed temperature of the cold supply air.

Preferably, the controller comprises a timer having an adjustable timer value, the timer provided to turn the apparatus off at the end of the adjustable timer value.

Preferably, the controller comprises a microprocessor or electronic circuit adapted to detect signals from the temperature sensor representing a maximum temperature and a minimum temperature and to calculate a timer value.

Preferably, the system further comprises a second temperature sensor located to measure ambient temperature of a space to be heated or cooled such that the apparatus can also be turned on and off in response to a sensed temperature of the space.

According to a third aspect of the invention there is provided a method of controlling a heating or cooling system having an apparatus for changing the temperature of a working medium, the method comprising:

providing a temperature sensor for measuring a temperature of the working medium,

determining when the temperature reaches a steady state value and stopping the apparatus after a delay time T,

determining when the temperature reaches a threshold value and staring the apparatus,

determining a loading on the hearing or cooling system, and

calculating a new delay time T based on the loading.

Preferably, the method controls the compressor of an air-conditioner or refrigeration system having a compressor for compressing a supply of a refrigerant and an evaporator in which the compressed refrigerant expands for cooling a stream of cold supply air, the method comprising:

providing a temperature sensor for measuring a temperature of the stream of cold supply air,

determining when the temperature of the stream of cold supply air reaches a desired minimum value and stopping the compressor after a delay time T,

determining when the temperature of the stream of cold supply air reaches a desired maximum value and staring the compressor,

determining a loading on the air-conditioner or refrigeration system, and

calculating a new delay time T based on the loading.

Preferably, the desired minimum value of the stream of cold supply air temperature is a minimum steady state temperature.

Preferably, the desired maximum value of the stream of cold supply air temperature is lower than a desired ambient room temperature.

Preferably, determining a loading on the system comprises measuring an overshoot of the temperature past the threshold value.

Preferably, calculating a new delay time T based on the overshoot comprises increasing the delay time T if the overshoot exceeds a desired overshoot value and reducing the delay time T if the overshoot is less than a desired overshoot value.

Preferably, determining a loading on the system comprises measuring a rate of change in the temperature.

Further aspects of the invention are defined in the appended claims, or will become apparent from the following description which is given by way of example only.

Brief Description of the Drawings

The invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a schematic of a typical prior art air-conditioning or refrigeration system,

Figure 2 is a schematic diagram of an air-conditioning or refrigeration system according to one embodiment of the invention,

Figure 3 is a schematic of the typical room temperature and supply air temperature profiles and 'event points' used by the air-conditioning and refrigeration system according to the invention,

Figure 4 is a flow diagram of a microprocessor or software control scheme for operation of the air-conditioning and refrigeration system according to one embodiment of the invention,

Figure 5 is a schematic diagram of the energy save device,

Figure 6 is a schematic diagram of boiler system according to another embodiment of the invention, and

Figure 7 is a schematic of the typical hot supply water temperature profile,

Description of the Preferred Embodiments

Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The invention will be described as used in air-conditioning for example, but it is understood that it has application in heating and cooling systems generally.

In one embodiment the present invention is used to reduce the energy consumption in air-conditioning and refrigeration systems by controlling on and off states of the compressor

to make full use of the delivered 'reservoir' of high-pressure refrigerant, or latent cooling, and by continuously matching the delivered cooling to the actual load presented to the air-conditioning or refrigeration system.

In a preferred embodiment the invention provides an air-conditioning or refrigeration system and a method for control of an air-conditioning system that makes use of a temperature sensor to monitor the cold supply air temperature produced when high-pressure liquid refrigerant is allowed to explosively decompress in an evaporator unit. With the compressor operating, this cold supply air temperature continues to reduce while the room or enclosure being cooled is being cooled down. The detection of a minimum cold supply air temperature indicates stable room temperature conditions and that a full 'reservoir' of high-pressure liquid refrigerant (or latent cooling) has been established. The minimum cold supply air condition can be detected by monitoring the cold supply air temperature over successive intervals until it reached a constant or stead state temperature indicating that it has reached a minimum. At this point, and following a dynamically variable time delay, the compressor is stopped. On turning off the compressor the temperature sensor continues to monitor the cold supply air temperature until, at a point when the high-pressure liquid refrigerant has been used up, the supply air temperature will start to increase. To maintain comfort levels the supply air temperature is then allowed to increase to a suitable point below the minimum anticipated room temperature setting. On reaching this point the compressor is restarted. On restarting the compressor, an artificial intelligence designed algorithm can be used to calculate the actual loading on the air-conditioning system by monitoring the temperature 'overshoot', or supply air temperature rise shortly after recommencing compressor operation. The results of this calculation are then used to either extend or reduce dynamically variable time delay used to stop the compressor after the minimum supply air temperature point is reached in the next compressor operating cycle. In this way the control system works to continuously match the delivered cooling to the actual load presented to the air-conditioning system. The control system works in the same circuit as the room thermostat 19, thereby allowing the room thermostat 19 to define a desired room temperature set point while a separate energy controller works to optimise energy consumption. The main benefit of the invention is a continuously variable but significant reduction in energy consumption in

air-conditioning and refrigeration systems that are consistent with the need to retain comfort levels. A secondary benefit is a significantly reduced compressor start-up torque due to the depletion of high-pressure liquid refrigerant prior to restarting the compressor.

The invention will now be described as practiced in a domestic type air-conditioning system. This is not meant to limit the scope of use or functionality of the invention. The skilled addressee will appreciate that the invention applies equally to both domestic and commercial air-conditioning and refrigeration systems and to hearting and cooling systems generally. Referring to Figure 2, an air-conditioning system according to the invention may be a split-type air-conditioner in which an air-conditioning compressor and evaporator unit 10 (hereinafter the compressor unit 10) is located in a first, typically external, space A and an air-conditioner evaporator and fan unit 11 (hereinafter the evaporator unit 11) is located in a second, typically indoor, space B which is to be cooled. The two spaces A and B are separated by a wall 12. A high pressure refrigerant circuit comprises a receiver/dryer 13 located in proximity to the compressor unit 10 and pipe work 14 for carrying high pressure liquid refrigerant from the compressor unit 10 and receiver/dryer 13 through the wall 12 into the second space B and to a needle valve 15 which is located in the evaporator unit 11. In the schematic diagram of Figure 2 the needle valve 15 and evaporator are shown as separate and distinct components for clarity. A low pressure refrigerant circuit 16 leads from the indoor evaporator unit 11 through wall 12 to the outdoor compressor unit 10. In operation, the compressor unit 10 compresses a refrigerant gas to a high pressure liquid which circulates through the high pressure circuit 14. The high pressure refrigerant passes through needle valve 15 where it is permitted to expand in the evaporator unit 11 and in doing so absorbs heat from air passing through the evaporator unit 11. A fan 17 forces air through the evaporator unit 11 creating a continuous stream of cold air 18. An air-conditioning/refrigeration circuit of this type is well known in the art and can be readily understood by the skilled addressee.

In the preferred embodiment the air-conditioning system has two compressor control means connected in series for starting and stopping the compressor/condenser 10. The first control means is a typical room thermostat 19 which may be of a mechanical or electronic type both of which are well-known in the art. The room thermostat 19 has a

temperature sensitive element and a pair of contacts which open and close in response to movement or signals from the temperature sensitive element when the ambient room temperature moves in and out of a set temperature threshold. In the case of an air-conditioning or refrigeration system the contacts are arranged to open for stopping the compressor when the room temperature sensed by the temperature sensitive element falls below a room temperature set point. When the room temperature rises above the set point, plus some temperature differential to prevent excess of cycling of the contacts, the contacts will close for starting the compressor again. The second compressor control means is an energy saver controller 20. The energy saver controller 20 has a second temperature sensitive element 21 located in or near the evaporator unit 11 for sensing the temperature of the supply air stream 18 passing through or exiting the evaporator unit 11. The energy saver controller also has a second pair of contacts 22 and an electronic circuit or microprocessor 23 that includes a variable delay timer 24. The timer 24 could be an integrated timer of the microprocessor 23 or a separate discrete timer controlled (e.g. started, stopped and reset) by the microprocessor 23 or electronic circuit. The electronic circuit or microprocessor 23 dynamically adjusts the delay of the timer and operates the contacts in response to signals from the second temperature sensitive element 21 to stop and start the compressor unit 10. With the energy saver controller 20 and the room thermostat 19 being in series the compressor is stopped when the contacts in either of the energy saver controller 20 or the room thermostat 19 are opened and the compressor is started only when the contacts of both the energy saver controller 20 and room thermostat 19 are closed. Thus, as will be seen in the following description when either the ambient room temperature or the cold air stream 18 temperature falls below a respective threshold temperature operation of the compressor is stopped.

A preferred operation of the energy saver controller 20 will be described with referring to Figures 3, in which the cold supply air stream 18 temperature is indicated as line C, the room temperature is indicated as line D and the compressor on/off state is indicated by line E. The energy controller 20 may be implemented at an electronic circuit or as a microprocessor. A flow diagram of microprocessor control is illustrated in Figure 4. On powering up of the air-conditioning system at time 0 the room temperature is high and so the room thermostat 19 contacts are closed. The energy saver controller 20 starts the

compressor unit 10 within 10-15 seconds by de-energising its relay and closing its set of contacts that are in series with the room thermostat 19 contacts. Following compressor unit 10 startup the energy controller 20 makes use of its temperature sensor 21 to monitor the temperature of the cold supply air stream 18 and turn the compressor on and off in response to changes in the cold supply air stream 18. The cold air stream temperature C will continue to reduce as the ambient room temperature D continues on a downward track. At time 1 the temperature of cold air stream 18 reaches a minimum steady state temperature. When the energy saver controller detects that the supply air temperature has reached a steady state, which it can do by determining a difference in temperature between two successive intervals, it triggers the variable delay timer which in turn turns off the compressor at time 2 after a delay interval T. In the preferred embodiment the delay interval T is initially 2 minutes and is varied dynamically during successive on/off cycles of the compressor in response to a determined "load" on the air-conditioning system. In the preferred embodiment the delay timer settings is increased in, say, three-minute increments or reduced in, say, one minute increments depending on the supply air 18 temperature 'overshoot' level detected 30 second after the compressor is turned back on.

With the compressor unit 10 off the supply air temperature 18 will remain at its steady state minimum until the 'reservoir' of high-pressure liquid refrigerant in the receiver/dryer 13 and high-pressure pipe work 14 has been used up. This occurs at time 3 in Figure 3. The cold air stream 18 temperature C will then start to rise at a rate proportional to the loading on the air-conditioning system. This cold air stream 18 temperature C is allowed to rise until it reaches a defined 'switching point' at time 4 that in the preferred embodiment is 2°C below the minimum thermostat 19 defined room temperature likely to be encountered. As an example, for data centre operations requiring an operating temperature of 18°C the 'switching temperature' will be 16°C and for normal 22°C room temperature operation the 'switching temperature' will be 20°C etc. On reaching the defined 'switching temperature' at time 4 the energy controller 20 de energises its internal relay to restart the compressor unit 10. Following compressor start-up, and for every on/off compressor cycle, an algorithm is used to determine the actual loading on the air-conditioning or refrigeration system. In the preferred embodiment the

loading is inferred from the amount of supply air temperature 'overshoot', indicated by F in Figure 3, once the compressor has restarted. In the preferred embodiment the cold air stream 18 temperature 'overshoot' is measured at time 5, which in the preferred embodiment is 30 seconds after the compressor has been restarted at time 4. If this temperature 'overshoot' exceeds the minimum thermostat 19 defined room temperature likely to be encountered, in this case 2°C higher than the switching temperature, then the value T of the variable delay timer is increased. In the preferred embodiment a three-minute delay will be added to the timer to hold the compressor on for a greater length of time after the cold air stream 18 reaches a minimum temperature again at time 6. If this temperature 'overshoot' does not exceed the minimum thermostat 19 defined room temperature likely to be encountered, in this case 2°C higher than the switching temperature, then the value T of the variable delay timer is decreased. In the preferred embodiment T is decreased by 1 second to hold the compressor on for less after the cold air stream 18 reaches a minimum temperature again at time 6. The cycle repeats itself. In practice, as the loading on the air-conditioning or refrigeration system increases, additional three minutes delays are added in successive compressor cycles to maintain comfort levels while reducing energy savings. The delay timer settings is increased in three-minute increments or reduced in one minute increments depending on the temperature 'overshoot' level detected 30 second after the compressor is turned back on. In this way and on a cycle by cycle basis the continuous control system dynamically adjusts energy reduction levels in a way that assures set points and required comfort levels.

In the preferred embodiment described above a known air-conditioning system may be retrofitted according to the invention by wiring the energy controller 20 in series with their existing room thermostat 19. Many modern air-conditioning systems have IR or wireless remote controls for setting the room temperature set point and other functions. In an alternative embodiment that does not require fitting by a qualified electrician a battery-powered temperature sensor and energy control system that uses wireless or infrared communication to adjust the set point of an air-conditioning system via its remote control input. In this embodiment, on detection of a minimum supply air temperature and following a suitable time delay the compressor is turned off by the

temperature sensor/ control system combination which instructs the remote control system to adjust its set point to a maximum setting. In a similar fashion to the previous embodiment, once the 'reservoir' of high-pressure liquid refrigerant has been used up the supply air temperature will increase to a predefined switching point at which time the control system will use wireless or infrared communication to restart compressor operations by returning the remote-control unit's set point to its original value. Alternatively an air-conditioning system made in accordance with the invention may have a single controller having two temperature sensing elements, one for ambient room temperature and one for evaporate cold air supply temperature. Although the preferred embodiment described above is a split type air-conditioner the invention can equally be applied to single unit air-conditioners such as window type air-conditioners, and to refrigeration systems.

In the preferred embodiment the air-conditioning system loading is inferred from the amount of supply air temperature 'overshoot', indicated by F in Figure 3, once the compressor has restarted. In alternative embodiments the air-conditioning system loading could be inferred from the rate of supply air temperature rise once the liquid refrigerant has been used up, or a combination of the rate of supply air temperature rise and the amount of supply air temperature 'overshoot'. If rate of supply air temperature rise is used then time value T can be increased of the rate of rise exceeds a first threshold and decreased if it is below a second threshold.

One embodiment of a system and method for continuous control of energy consumption in air-conditioning and refrigeration systems has been described. The described embodiment operates on an individual air-conditioning or refrigeration installation using hardware and/or software components. Depending on the instantaneous system loading, the control system serves to reduce significantly the energy consumption in air-conditioning and refrigeration systems while maintaining comfort levels and temperatures at thermostat 19 defined set points. Each air-conditioning or refrigeration installation will include a plurality of components including compressors/condensers and refrigeration

media, as well as thermostat 19s and evaporators, fan coils or air handling units that are used by the described continuous control system.

The described control system and method uses a temperature sensor to continuously monitor the performance of a cold stream of supply air delivered by the air-conditioning or refrigeration system's evaporator, fan coil or air handling unit. Using an artificial intelligence designed algorithm and appropriate software, the minute by minute temperature of this supply air is used to infer the actual loading on the main energy consuming components of an air-conditioning or refrigeration system. The described control system works with the air-conditioning or refrigeration system's thermostat 19 to turn on/off a compressor or open/close a water valve, thereby optimising energy consumption consistent with actual system loading.

Figure 6 shows an alternative use of an energy saver according to the invention and a boiler heating system. The illustrated system is a heating system for a domestic or commercial property comprising a water heater or boiler 30 and a room radiator 31. Hot water is circulated from the boiler 30 to the radiator 31 by a hot water circuit 32 and is returned from the radiator to the boiler via a return water circuit 33. A wall thermostat 34 is provided, as is known in the art, for setting a desired temperature of a room or space heated by the radiator 31. In this embodiment the energy saving device 35 measures the supplied hot water temperature via a thermostat 36 in the hot water supply line 32. The hot water supply temperature shall be measured at or is close to the radiator 31 as possible. Referring to the graph of Figure 7, when the water heater or boiler 30 is turned on the water temperature in the hot water supply pipe 32 begins to rise. When the energy saving device 35 detects that the hot water temperature has reached a steady state maximum, which might typically be 70-80°C, the boiler is switched off after a time delay T although the water circulation pump is left running to continue circulating the hot water. The hot water temperature begins to fall and when it reaches a set point threshold, which is for example a few degrees above nominal room temperature the boiler is turned on again. The water temperature begins to rise and when it reaches its steady state maximum temperature the boiler is switched off again and the cycle repeats. The time

delay T is adjusted as described in the above examples based on an overshoot F of the threshold.

Aspects of the invention may be generalized as, but not limited to, an energy saver device intended for use with a heating or cooling system having an apparatus for changing the temperature of a working medium, the device comprising contacts for providing an on/off signal to the apparatus, a timer having an adjustable timer value and providing a signal for opening or closing the contacts, a temperature sensor for measuring temperature the working medium, and a controller arranged to adjust the adjustable timer value in response to changes in temperature of the working medium. A heating or cooling system, comprising a apparatus for changing the temperature of a working medium, a temperature sensor located to measure temperature of the working medium and a controller for turning the apparatus on and off in response to a sensed temperature of the working medium. And, a method of controlling a heating or cooling system comprising providing a temperature sensor for measuring a temperature of the working medium, determining when the temperature reaches a steady state value and stopping the apparatus after a delay time T, determining when the temperature reaches a threshold value and staring the apparatus, determining a loading on the hearing or cooling system, and calculating a new delay time T based on the loading.

Claims:

1. A method of controlling a heating or cooling system having an apparatus for changing the temperature of a working medium, the method comprising:

providing a temperature sensor for measuring a temperature of the working medium,

determining when the temperature reaches a steady state value and stopping the apparatus after a delay time T,

determining when the temperature reaches a threshold value and staring the apparatus,

determining a loading on the hearing or cooling system, and

calculating a new delay time T based on the loading.

2. A method of controlling the compressor of an air-conditioner or refrigeration system having a compressor for compressing a supply of a refrigerant and an evaporator in which the compressed refrigerant expands for cooling a stream of cold supply air, comprising:

providing a temperature sensor for measuring a temperature of the stream of cold supply air,

determining when the temperature of the stream of cold supply air reaches a desired minimum value and stopping the compressor after a delay time T,

determining when the temperature of the stream of cold supply air reaches a desired maximum threshold value and staring the compressor,

determining a loading on the air-conditioner or refrigeration system, and

calculating a new delay time T based on the loading.

3. The method of claim 2 wherein the desired minimum value of the stream of cold supply air temperature is a minimum steady state temperature.

4. The method of claim 2 wherein the desired maximum value of the stream of cold supply air temperature is lower than a desired ambient room temperature.

5. The method of claims 1 or 2 wherein determining a loading on the system comprises measuring an overshoot of the temperature past the threshold value.

6. The method of claim 4 wherein calculating a new delay time T based on the overshoot comprises increasing the delay time T if the overshoot exceeds a desired overshoot value and reducing the delay time T if the overshoot is less than a desired overshoot value.

7. The method of claims 1 or 2 wherein determining a loading on the system comprises measuring a rate of change in the temperature.