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(54) **METHOD, SYSTEM AND DEVICE FOR CONTROLLING A HEATING AND COOLING SYSTEM OF A COMMERCIAL OR INDUSTRIAL ENTITY**

(57) Method for controlling the distribution of thermal energy in a commercial or industrial entity having a waste heat producing circuit connected to a primary side of a heat exchanger whose secondary side is connected to a heat recovery unit (HRU). To the heat sink side of the HRU a heat consuming circuit is connected. The method determines a first temperature range at which the waste heat producing circuit is operable at its optimal Energy Efficiency Ratio. Determines a second temperature range between a predetermined upper limit temperature and a predetermined lower limit temperature using the first temperature range and the heat exchange capacities of the heat exchanger and the HRU such that the waste heat producing circuit can be stably operated at its optimal Energy Efficiency Ratio (EER). And controls the fluid temperature in the return line by means of controlling one or more flow valves installed at the least at one or more heat energy consumer such that the temperature in the return line does not exceed the predetermined upper limit temperature neither fall below the predetermined lower limit temperature.

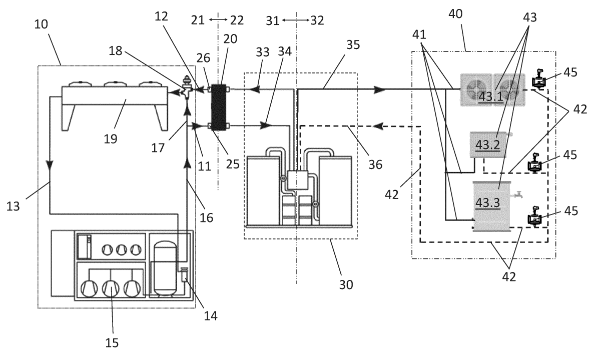

Figure 1

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Description

[0001] The invention relates to a method, a system and a device for controlling a heat energy distribution system of a commercial or industrial entity. The invention in particular refers to a method for optimizing the distribution of energy, especially the thermal energy distribution during service and non-service hours of a commercial or industrial entity, e.g., a supermarket, large-scale warehouses for the chilled or frozen storage of foods or any other buildings in which waste heat is produced by means of a thermodynamic cycle process. The invention preferable uses a heat recovery unit (HRU) for collecting, forwarding and/or transferring the arising/produced waste heat for use in a heat consumption circuit, e.g., a Heating, Ventilation and Air Conditioning (HVAC) system, and/or a hydronic system using water as energy transporting medium. However, the invention covers also heating systems which use other types of heat transporting media, like gas or air, etc. Further, the invention is not limited to one waste heat producing circuit in a commercial or industrial entity. As known and obvious to a person skilled in the relevant art, a plurality of such heat producing circuits can be connected to one HRU. Preferred, but not limited to, waste heat producing circuit(s) of the vapor-compression refrigeration type are used. However, other types of cycle process can be connected to the heat source side of the HRU also, like a distillation process or the like.

[0002] It is known from the art to transfer waste energy, e.g., from cooling or refrigeration systems, like refrigerated counters or frozen food compartments in supermarkets or similar, to a HRU and to transfer the waste heat further on to a heat consumption system for the climatization and/or heating of buildings, e.g. to a HVAC system of the supermarket in which the refrigerated counters or frozen food compartments are installed. The waste heat from the waste heat producing systems/circuits is usually taken from the hot gas/vapor after the refrigerant compression step of the cycle process and before the compressed gas/vapor enters a cooler or condenser. Gas-to-liquid heat exchangers are used for transferring the thermal energy of the hot gas/vapor as waste heat from the cycle process to a liquid energy transport medium used in the HRU, commonly water. From the HRU the heat is forwarded - usually via liquid-to-liquid heat exchangers to a heat consumption circuit, e.g., a HVAC-system for internal heating, for domestic hot water preparation, for charging heat storage tanks and/or for providing heat energy to surrounding buildings or a district heating network.

[0003] Supermarkets as mentioned before are only one of a multitude of examples for commercial sites or entities the invention can be applied to. Other locations as fabrics, office buildings, sports facilities, event facilities, etc., are included by the invention as well, as in all these entities waste heat producers are installed for a multitude of imaginable functions, like Air-Conditioners, machinery, any kind of cooling or refrigeration systems and so on. For illustration purposes only the invention is described thereinafter mainly by the help of a supermarket as one representative example for an entity to which the invention can be applied to.

[0004] In course of the further specification when it is referred to a vapor compression refrigeration system, this system is used as mere example for simplifying and illustrating the disclosure of the underlying idea of the invention. The same applies to the example of a HVAC-system preferably used as a representative and illustrative example for a heat consuming circuit at the heat sink side of an HRU. All these examples do not aim to limit the scope of the idea of the invention since aim to maintain the specification of the idea of the invention as simple as possible. A person skilled in the relevant art will find a multitude of other examples for waste heat producing and waste heat consuming circuits, which can be connected together via a heat recovery unit (HRU). Thereby using preferably a gas-to-liquid heat exchanger for connecting a vapor-compression cycle process to the heat source side of the HRU.

[0005] As known in the art waste heat is often accumulated or stored in HRUs for further use elsewhere, e.g., in a HVAC system or circuit. Frequently the HVAC system and the waste heat producing circuit are driven and controlled independently and separately depending on their individual demands. Consequently, the produced waste heat energy is not used effectively as the waste heat producing circuit, in particular, a cooling or refrigeration system, should be operated at its optimum Energy Efficiency Ratio (EER). As these waste heat producing circuits serve for refrigerated counters or frozen food compartments in supermarkets it is of primary importance to maintain the temperature in these compartments at the specified temperature in order to not endanger the food quality. On the other side heat consuming circuits, like HVAC systems, often use heating systems which should be operated as well in an efficient way, preferably at their optimal Coefficients of Performance (COP) to keep the ambient/room temperature in the entity, e.g. a supermarket, comfortable for clients and staff. In this context, in the art the term Energy Efficiency Ratio (EER) is usually used for cooling or refrigeration systems and the term Coefficients of Performance (COP) is used for heating systems, however sometimes these terms are used vice versa.

[0006] CA 2551268 A1 describes a heat energy distribution system of a restaurant kitchen having a heat recovery unit to which at the heat source side via a heat exchanger a waste heat producing circuit is connected and to which heat sink side a heat consuming circuit is connected with at least one or more heat energy consumer(s) for providing heat energy to the restaurant kitchen, wherein one or more temperature controlled flow valves are installed and controlled by a control unit.

[0007] Hence, it is an objective of the invention to provide an improved method for heat distribution and a heat energy distribution system for a commercial or industrial entity which overcomes the disadvantages of the art and provides for a more effective use of the thermal energy produced in the entity. The invention should lower the overall energy consumption of an entity having a HRU whose both sides - a waste heat producing side and a heat demand side - are controllable and operable in such a coordinated way that electric, thermal and/or mechanical energy supplied externally to heat distribution system of the entity is used optimal and such that at least for a heat waste producing circuit within the heat energy system, especially for a refrigeration or cooling system for food, can be operated at its optimum Energy Efficiency Ratio (EER). Simultaneously, the method should be simple in application and implementation as well as in monitoring the heat energy distribution system during operation. Preferably, the method of the invention can be installed to already existing heat energy distribution systems in a cost effective manner. At the same time the method according to the invention should be capable to use the arising waste heat energy at its maximum and in a cost effective way for the whole energy consumption of the commercial or industrial entity, wherein the arrangement/installation of devices and means to realize the inventive method should be simple and cost effective at the same time.

[0008] The objective of the invention is solved by the method specified by independent claim 1. Preferred embodiments are given by the subclaims depending on claim 1. The objective is also solved by a heat energy distribution system specified in the independent system claim, preferred embodiments of which are described in the subclaims directly or indirectly depending on the independent system claim. The problem of the invention is solved further by a flow valve claimed by a further independent apparatus claim. Preferred embodiments of the flow valve are provided in the subclaims directly or indirectly depending on the independent apparatus claim.

[0009] The method according to the invention controls the distribution of thermal energy in a commercial or industrial entity having a waste heat producing circuit connected to a primary side of a heat exchanger. Connected to the secondary side of the heat exchanger is a heat recovery unit with its heat source side (short in the following also: HRU). Connected to the heat sink side of the HRU is a heat consuming circuit - for instance a heating ventilation air conditioning (HVAC)-circuit - comprising at least one heat energy consumer.

[0010] The inventive method determines in a first step for the medium/fluid of the waste heat producing circuit a first temperature range at the outlet of the primary side of the heat exchanger at which temperature range the waste heat producing circuit is operable at its optimal Energy Efficiency Ratio (EER). In general, in a thermodynamic process waste heat is dissipated after a compressing step of the cycle process using a gaseous fluid/refrigerant. Hence an optimal fluid temperature at the output of the heat exchanger is reached, when, after the fluid has passed the heat exchanger, a further cooling step for the fluid for the waste heat producing circuit is not needed, as the temperature of the fluid leaving the heat exchanger is at the temperature optimal for the expansion step of the cycle process. To this temperature a cooler or condenser would have been brought down the fluid temperature in order to operate the waste heat producing circuit at its optimal Energy Efficiency Ratio (EER) when a heat exchanger is not used. Hence this temperature forms the lower end of the first temperature range and usually is defined in the design phase of the waste heat producing circuit or in case of a purchasable unit or installation this temperature is provided in the technical data sheet.

[0011] The upper temperature of the first temperature range is given by the cooling capacity of the condensing step, i.e. by the capacity of the cooler or condenser in order to provide the optimum fluid temperature for the expansion step. Adding this temperature difference achievable by the compression step to the temperature optimal for entering the expansion step provides the upper end of the first temperature range.

[0012] As already mentioned before the temperature optimal for entering the expansion step is provided by the cycle process used as waste heat producing circuit. Obvious to a person skilled in the relevant art is that the most effective use of waste heat is given when the cooling or condensing step is not used, i.e. no additional energy has to be supplied to the cool down the fluid of the waste heat producing circuit after leaving the outlet at the primary side of the heat exchanger. As the heat demand on the heat sink side of the HRU or the thermal heat energy consumption is not stable the fluid temperature at the second side of the heat exchanger connected to the HRU will also not be stable, hence a cooler or condensing in the waste heat producing circuit will be still necessary to adjust the fluid temperature of the waste heat producing circuit fluid to the optimum expansion temperature.

[0013] As the cooling capacity of a cooler or condenser is usually defined in the design phase of an apparatus used in a commercial or industrial entity, a person skilled in the relevant art is able to determine the first temperature range for the waste heat producing circuit fluid without any problem. Frequently the used apparatuses are a kind of standard equipment for which the cooling capacity is provided in the technical data sheet. So, for identifying the first temperature range at the outlet of the heat exchanger to be optimal for a waste heat producing circuit, a person skilled in the relevant art has to look up only the technical specification of the waste heat producing apparatus, where input temperature of the expansion step provides him the lower end of the first temperature range. Adding to this temperature the temperature difference achievable by the cooling/condensing step provides him the upper end of the first temperature range.

[0014] The next step of the method according to the invention uses the specification and technical data of the selected heat exchanger and the selected HRU to determine by calculation from the first temperature range the second temperature range for the fluid in the return line of the heat consuming circuit. Here, basically the first temperature range and the heat transfer capacities of both units - the heat exchanger and the HRU - enable the person skilled in the relevant art to determine this second temperature range for the fluid return temperature of the heat consuming circuit. So, when the technical specifications of the heat exchanger at the heat sink side of the used heat recovery unit (HRU) and the technical specifications of the HRU itself are known, a person skilled in the relevant art can derive from the first temperature range the second temperature range at an inlet of the heat sink side of the HRU. This second temperature range provides him a predetermined upper limit temperature (Tmax) and a predetermined lower limit temperature (Tmin) within which the waste heat producing circuit (10) on the other side of the HRU can be operated stably at its optimal Energy Efficiency Ratio (EER);

[0015] Accordingly, when the temperature of the fluid in the return flow of the heat consuming circuit is maintained within the second temperature range the fluid temperature at the outlet of the heat exchanger at the heat source side of the HRU is within the first temperature range within which the waste heat producing circuit can be operated at the optimal Energy Efficiency Ratio (EER). In the most preferable case the temperature achieved at the outlet of the heat exchanger is the entrance temperature for the expansion step of the waste heat producing circuit. In this case external energy to operate a condenser or cooler is not necessary and the overall energy balance for the commercial or industrial entity can be reduced.

[0016] In a last step the method of the invention controls the fluid temperature and/or the return flow rate in the return line of the heat consuming circuit by means of controlling one or more flow valves installed at the at least one heat energy consumer such that the temperature in the heat consuming circuit return line to the HRU does not exceed the predetermined upper limit temperature (T_{max}) neither falls below the predetermined lower limit temperature (T_{min}) both together defining the second temperature range. Thus, as long as the temperature in the return line of heat consuming circuit is hold within this second temperature range, the waste heat producing circuit can be stably operated around its optimal Energy Efficiency Ratio (EER) or coefficient of performance (COP) in case of a heating system at the heat source side of the heat recovery unit HRU.

[0017] Additionally, to control the temperature to be within the predetermined upper limit temperature (T_{max}) and the predetermined lower limit temperature (T_{min}) of the second temperature range, the flow rate through the return line can be monitored and controlled. As in the heat energy consuming circuit a variety of consumers of different type can and will be installed, the fluid temperature at the inlet of the HRU at the heat sink side will be a mixed temperature of the different return lines of a variety of consumers. So, by means of monitoring and controlling the flow rate in the return lines of the consumers, the fluid temperature entering the HRU at the heat sink side can be influenced. Monitoring of the fluid temperature entering the HRU at the heat sink side can be done, e.g. by an additional temperature sensor providing this temperature signal to one or more consumers or to a superordinated or supervising unit being capable to send a corresponding signal/command to the one or more flow valves. Thus, changing the flow rate can be used as an additional optimization to achieve an optimum temperature at the primary outlet of the heat exchanger in the thermal energy distribution installation of a commercial or industrial entity in order to operate at all times the waste heat producing circuit at the optimal Energy Efficiency Ratio (EER).

[0018] In other embodiments the control of the temperature in the return line and/or the control of the flow rate in the return line can be used to permit changing heat demands in the heat consumer circuit, wherein the temperature in the return line towards the HRU can stay within the pre-determined temperature range. So, the method according to the invention preferably controls whether the temperature exceeds the predetermined upper limit temperature (T_{max}) or falls below the predetermined lower limit temperature (T_{min}) in the return line and only commands to open or close a flow valve, respectively a flow passage, at a consumer in the heat consuming circuit in order to hold the temperature within the second temperature range in case the fluid temperature leaves the second temperature range. E.g., if the temperature in the return line of heat consuming circuit reaches T_{max} - the upper limit temperature - the method commands a flow valve at the return line of at least one heat consumer to close the return line and to reduce the consumer return flow - provided that the fluid temperature in the return line of the heat consumer is higher than T_{max}. Accordingly, the flow valve can be commanded to open and to increase the flow rate through the consumer return line when the fluid temperature at the consumer return is lower than T_{max}.

[0019] In the other case when the temperature in the return line of the heat consuming circuit reaches T_{min} - the lower limit temperature - the method commands a flow valve at the return line of the at least one heat consumer to open the return line and to increase the consumer return flow - provided that the fluid temperature in the return line of the heat consumer is higher than T_{min}. Accordingly, the flow valve will be commanded to close the flow passage to reduce the flow rate through the consumer return line when the fluid temperature at the consumer return is lower than T_{min}.

[0020] As already indicated above the priority of the method according to the invention is to provide optimum fluid temperature conditions for the waste heat producing circuit at the primary outlet of the heat exchanger connected to the heat source side of the HRU. This preferably at a temperature which is does not require the need to use a cooler or condenser in the waste heat producing circuit, i.e. to provide a refrigerant temperature at the primary outlet which is optimum for expansion to achieve optimal Energy Efficiency Ratio (EER) for the waste heat producing circuit. Expressed in other words, as all waste energy is aimed to be transferred to HRU via the heat exchanger - preferably a gas-to-liquid heat exchanger - this amount of waste heat can be used flexible within the HRU and in particular in the heat consuming circuit. There it can be used, e.g., to heat the interior of the commercial or industrial entity, or to heat water in a storage tank for (domestic) tap water, to evaporate refrigerant of an air-conditioning or a chiller. Here a person skilled in the relevant art will find a lot of other possibilities for which the waste heat can be used, including to provide an excess of energy to an external heating grid.

[0021] Preferably at the heat source side of the HRU a Heating Ventilation and Air Conditioning (HVAC) system for the commercial or industrial entity to which the method of the invention can be applied, is installed comprising a plurality and variety of different heat energy consumers each of which is equipped - as it is standard in the relevant art - with an individual flow valve. Thus, the method according to the invention can be applied to each and every flow valve individually or by grouping the flow valves in order to achieve the required fluid temperature in the return line of the heat consuming circuit within the predetermined temperature range.

[0022] In other cases when it is not possible to transfer all waste energy or waste heat to the HRU the refrigerant of the waste heat producing circuit will comprise at the outlet of the heat exchanger a temperature higher than the optimum temperature for expansion, such that a cooler or condenser is needed to bring the temperature of the refrigerant (further) down. Such a situation which, e.g., probably can occur at hot summer days when one or a plurality of vapor-compression cycles used as the waste heat producing circuit(s) are installed at a supermarket running all at high performance and on the other side of the HRU - the heat consuming side of the HRU - shows only a low demand of heat energy, as, for instance, only air-conditioning is required but no ambient heating nor hot tap water. In this exemplary case the capacity of the heat consuming circuit to assume all waste energy is not sufficient to fulfil the duty for the method according to the invention is to hold the temperature in the heat consuming circuit return line within the predetermined temperature range - in order to run the waste heat producing circuit at its optimal Energy Efficiency Ratio (EER). However, if this situation occurs the temperature at the outlet of the heat exchanger will be too high for the expansion step and must be cooled by means of a cooler or condenser dissipating heat energy to the ambient. This does not only result in loss of heat energy since also means supplying additional (electrical) energy to the cooler/condenser to reduce the temperature in the fluid before expansion. Here probably one can think about the connection of more consumers or more heat storage capacity at the heat consuming circuit in order to avoid energy loss.

[0023] Another case which can occur is that the energy demand at the heat consuming circuit is too high so that the temperature in return line falls below the predetermined lower temperature limit T_{min} and at the same time the energy consumption in the heat consuming circuit cannot be reduced reasonably. Here, the method of the invention provides for a bypass line bypassing the heat exchanger for all or part of the fluid and mixing it again with the outlet flow from the heat exchanger before entering the expansion step by means of a 3-way valve. Here, frequently a cooling step is not required as the two flows can be mixed at the optimal temperature for the expansion step. Such a situation is not a preferred point of operation of the method of the invention, because the invention aims to transfer all waste energy to the heat sink side of the HRU, i.e. to the heat consuming circuit. Thus, the bypass step should be omitted, meaning that a bypass line to the heat exchanger should be kept closed during normal operation of the heat distribution system according to the invention. In this case one can think about energy consumption reduction measures at the heat consuming circuit like improving isolation or to reduce, e.g., room temperature in the commercial or industrial entity or to reduce tap water temperature, and so on. Alternatively, to the heat consuming circuit an external heating can be installed such that the temperature in the return line can be increased again at least to T_{min} - the predetermined lower temperature limit. Another measure would be to reduce the amount of produced waste energy (heat) if possible, e.g. by improving the isolation of food cooling compartments. In case of food refrigerant or cooling compartments in the waste heat producing circuit a raise in temperature is not an available alternative as it would endanger the food quality.

[0024] The problem according to the invention to improve the thermal energy distribution in a commercial or industrial entity is solved also by a heat energy distribution system installed to a commercial or industrial entity having a heat recovery unit (HRU) to which at the heat source side via a heat exchanger a waste heat producing circuit is connected. To the heat sink side of the HRU a heat consuming circuit is connected with at least one or more heat energy consumer for providing heat energy to the commercial or industrial entity. In each return line of the least one or more heat energy consumer one temperature controlled flow valves is installed. Each flow valve comprises a control unit and a temperature sensor for monitoring the temperature in the return line. Each control unit is capable to command an actuator of the flow valve to open or close the corresponding flow valve passage such that the temperature in the return line of the consumer does not exceed a predetermined upper limit temperature (Tmax) neither fall below a predetermined lower limit temperature (Tmin).

[0025] As described above such a configured heat energy distribution system is capable to perform the underlying idea of the invention. Especially by arranging controllable flow valves in the return lines of the consumers enables the heat energy distribution system of the invention to hold the temperature of the fluid in the joint return line of the heat consuming circuit to the HRU in a temperature range which is preferred to operate the waste heat producing circuit at the other side of the HRU at the optimal Energy Efficiency Ratio (EER). As for an installed- or still only designed - heat energy distribution system the heat transfer capacities of all involved heat exchangers in the HRU and for the one between the HRU and the waste heat producing circuit are known, and the fluid temperature range for the fluid of the waste heat producing circuit for entering a cooler or condenser is also known, the temperature range with which the fluid of the heat consuming circuit should enter the HRU can be determined without big efforts. By means of the control units at the flow valves of the individual consumers this temperature range can be controlled, and the temperature in the joint return line can be maintained within the pre-determined temperature range, eventually by the (additional) help of a temperature sensor at the heat sink side inlet of the HRU.

[0026] In a preferred embodiment of the invention the upper predetermined temperature limit (T_{max}) and lower predetermined temperature limit (T_{min}) of this calculated temperature range at the heat consumption side can be set at the individual control units in dependency that the waste heat producing circuit is operatable at its optimal Energy Efficiency Ratio (EER). Here different temperature ranges can be set at different consumers or groups of consumers. Finally, the inlet temperature to the HRU has to be kept within the calculated temperature range for assuring that the waste heat producing circuit at the other side of the HRU is operable at the optimum Energy Efficiency Ratio (EER).

[0027] In another embodiment of the invention the flow valves at the return lines of the consumer are pressure independent or pressure dependent flow valves, which are controlled, e.g., in an on/off manner or in a modulated manner. The actuation of the flow valves respectively their actuators can be analogically controlled via a 0-10 V / 0-20 mA current or can be digitally controlled via any communication protocol. This can be realized by solenoids or other electric drives known in the art. Preferably the control unit of the flow valve generates a corresponding command with which the actuator movement can be performed in an adequate manner in order to enable, disable, restrict, open or close the flow valve passage in dependency of the temperature in return line measured by a temperature sensor of the associate flow valve or provided by a temperature range set signal received, for example from a Building Management System or another temperature sensor, e.g. from one installed close to the inlet in the return line to the HRU.

[0028] In another preferred embodiment of the Heat energy system according to invention the waste heat producing circuit is a refrigeration circuit using CO_2 or any other gas as refrigerant. Here a person skilled in the relevant art can think of a plurality of possible cycle processes which can be used in implementation of the invention, which are not necessarily vapor-compression cycle processes since also a Carnot process working with steam whose remaining heat after the expansion phase can be used according to the invention as waste heat, while the Carnot process is optimized by augmenting the temperature difference at which the Carnot process is operated.

[0029] On the other side of the HRU the heat consuming circuit preferably is a heating, ventilation air conditioning (HVAC)-circuit with all possible heat consumers a person skilled in the relevant art is aware of. Here the individual fluid temperatures in the return lines of different consumers or consumer groups can differ from each other, as they can be mixed in the joint return line of the HVAC-circuit to fulfil the criteria that the inlet fluid temperature at the heat sink side of the HRU is within the pre-determined required temperature range, such that the cycle process on the heat source of the HRU is operable at the optimal Energy Efficiency Ratio (EER) or optimal Coefficient of Performance (COP).

[0030] For this, according to the invention, flow valves are used preferably which comprise an electro-mechanical operable actuator configured to open and close a flow passage through the flow valve, which further comprise a temperature sensor for monitoring a medium temperature in the fluid line. A control unit of the flow valve is configured to set a predetermined upper limit temperature (T_{max}) and a predetermined lower limit temperature (T_{min}) and to command the actuator of the flow valve to open or close the flow passage. A microcontroller in the control unit is capable to receive a temperature signal from the temperature sensor and to determine whether the temperature signal indicates a fluid/medium temperature within, below or above a pre-set temperature range. The microcontroller in the control unit of the flow valve is configured to create an open valve command to the actuator of the flow valve in case the temperature signal indicates a fluid/medium temperature is below the temperature range, or to create a close valve command to the actuator in case the temperature signal indicates a medium temperature above the temperature range. In the case the temperature sensor of the flow valve detects the fluid temperature to be within the pre-set/pre-determined temperature range no command is generated and the flow rate through the flow valve is maintained as long as the sensed temperature does not leave the predetermined temperature range.

[0031] As mentioned above for each consumer return line in a heat distribution system of the invention an individual flow valve is provided. Preferably at each flow valve an individual temperature range can be set, wherein flow valves of a group of consumers may set to same pre-determined temperature range. For this the control unit of the flow valve further comprises a digital interface capable to receive wire-based or wireless an external temperature range set command, or temperature or command signal, in order to be capable to monitor and control the fluid temperature in the associated return line. The digital interface of the control unit may further be capable to receive the predetermined upper limit temperature (T_{max}) and the predetermined lower limit temperature (T_{min}) from a superordinated or supervisory control system, wherein the superordinated or supervisory control system can be a Building Management System (BMS). In this embodiment the flow valve according to the invention can be part of a Building Management System wherein the flow valve comprises its own intelligence to decide whether a flow rate through the flow valve should stay as it is or should be lowered or increased depending on the measured temperature of the temperature sensor belonging to the flow valve.

[0032] Even though the invention was described above by the help of only one waste heat producing circuit a person skilled in the relevant art will detect easily that a plurality of waste heat producing circuits can be connected to one HRU which transfers the heat to one or more heat consuming circuits not necessarily being HVAC systems. However it is preferred that to the heat sink side of the HRU a HVAC system of the commercial or industrial entity is connected.

[0033] With the help of the enclosed drawings preferred embodiments of the heat distribution method according to the invention are explained in more detail in order to enhance the understanding of the underlying idea of the invention and to illustrate embodiments, alternatives, modifications and changes which can be made to the underlying idea of the invention without leaving the scope of the idea. Thereby the illustrated embodiments do not limit the scope of the idea of the invention, but only represent possible design alternatives, to which within the knowledge of a person with skills in the relevant art modifications can be made without leaving the scope of the invention. Therefore, all those embodiments, alternatives, modifications and changes are covered by the claimed invention. In the drawings it is shown in:

Figure 1 schematically a heat energy distribution system according to the invention;

Figure 2 a temperature over time diagram according to the invention ;

Figure 3 schematically a flow valve according to the invention

[0034] Figure 1 shows schematically an embodiment of a heat energy distribution system according to the invention. In Figure 1 on the left side a waste heat producing circuit 10 is depicted and framed with a dotted line. The cycle process of the waste heat producing circuit 10 runs counterclockwise and represents only exemplarily a vapor/gas-compression refrigeration system. As known by a person skilled in the relevant art these processes can use different fluids/mediums as refrigerant which can be present in liquid and/or gaseous form during one cycle. As cycle refrigeration processes are known to a person skilled in the relevant art further detailing of these processes is omitted at this point.

[0035] As usual in a cyclic waste heat producing circuit 10 a compressor 15 pressurize the refrigerant after - where appropriate - an evaporation step, whereby the refrigerant is heated up and guided towards a cooler or condenser 19. According to heat energy distribution system of the invention the hot refrigerant is cooled down first, before entering the cooler or condenser 19 at a primary side 21 of a heat exchanger 20 whose secondary side 22 is connected to a HRU (heat recovery unit) 30. The hot refrigerant enters the heat exchanger 20 at the primary side 21 at an inlet 25 and leaves the heat exchanger 20 at an outlet 26 on the same primary side of the heat exchanger 20, however with a lower temperature, because a cooler HRU-refrigerant flows through the secondary side 22 of the heat exchanger 20. The HRU-refrigerant - regularly a liquid refrigerant, e.g. water - is capable to receive the (waste) heat from the (gaseous) refrigerant of the waste heat producing circuit 10 and transports/transfers it further via other heat exchangers - usually liquid/liquid heat exchangers - to a heat consuming circuit 40.

[0036] In the heat consuming circuit 40 connected to the heat sink side oft HRU 30 at least one heat consumer 43 is arranged for dissipating or storing heat. This at least one heat energy consumer can be selected from a multitude of possible heat energy consumers for which in Figure 1 three examples are shown: an air conditioning or ventilation system 43.1, a hydronic heating 43.2, domestic hot water (tank) 43.3. Here a person skilled in the relevant art will find a plurality of other consumers 43.n using heat energy, like (floor) heating, de-icing, evaporator solutions, which all may be grouped under the term Heating, Ventilation and Air Conditioning (HVAC) system. Hence all these possibilities are covered by the idea of the invention. In the end it is the waste heat produced in the waste heat producing circuit 10, which can be used ambient friendly at the heat sink side of the HRU by a multitude of consumers 43.n, wherein "n" indicates that one device/element can be present n-times, wherein equal numbering indicates a group of associated parts.

[0037] According to the method of the invention the temperature T in the return line 42 to the HRU 30 is controlled and hold in a temperature range such that the waste heat producing circuit 10 at the heat source side of the HRU 30 is capable to operate at its optimal Energy Efficiency Ratio (EER). For this the method according to the invention defines in a first step a first temperature range for the refrigerant of the waste heat producing circuit 10 at the outlet 26 of the heat exchanger 20. This temperature range follows from the optimal temperature with which the refrigerant should enter an expansion valve 14 in the waste heat producing circuit 10, and which temperature should be constant for operation of the waste heat producing circuit 10 at the optimal Energy Efficiency Ratio (EER) and ensuring a constant compartment freezing or cooling temperature in case of a vapor compression cooling circuit, as shown exemplarily with Figure 1. In the case where the refrigerant entering the heat exchanger 20 at inlet 25 and leaving it at outlet 26 can be cooled in the heat exchanger 20 to the temperature optimal for the expansion step, no additional cooling by a cooler/condenser 19 is necessary. Hence this temperature optimal for the expansion step determines the lower end of the first temperature range for the refrigerant temperature at outlet 26. The upper end of the first temperature range is given by the cooling capacity of the cooler/condenser 19. So, the temperature delta/temperature difference the cooler/condenser is capable to achieve, can be added to the optimal expansion temperature and provides therewith the upper end of the first temperature range.

[0038] As the method according to the invention aims to control the temperature T in the return line 42 to the HRU at the heat source side, the first temperature range at the outlet 26 of the heat exchanger has to be converted to a second temperature range for the heat transporting medium in the return line 42 of the heat consuming circuit 40 - also usually water. This conversion can be done according to the invention, e.g., by using the temperature deltas achievable at the secondary side of the heat exchanger 20 as well as the temperature deltas achievable at the heat source and the heat sink side of the HRU 30. So, e.g. by simple arithmetic the first temperature range can be converted to the second temperature range for the heat transport medium in the return line 42 respectively the feed line 36 of the HRU 30 on the heat sink side.

[0039] In this before mentioned simplified example it is not considered that heat can be stored in the HRU itself, which leads to modified heat transfer rates of the involved heat exchangers in the HRU 30. However, as the HRU is usually monitored with regard to his occupied storage capacity, it costs another little effort to a person skilled in the relevant art to adapt the temperature in the return line 42 to the circumstances in the HRU. Hence the determination of the second temperature range must not be fixed over the course of time since frequently undergoes changes, for instance as the heat storage level in the HRU 30 changes. In any case it is object of the method of the invention to assure that the refrigerant temperature at the inlet of the expansion step is always on the same temperature such that the waste heat producing circuit 10 can run at optimal Energy Efficiency Ratio (EER).

[0040] As stated already at the beginning and in course of the description of the invention, it is priority for the method according to the invention that the waste heat producing circuit 10 is operatable at its optimal Energy Efficiency Ratio (EER). Additionally, as long as the temperature of the heat transport medium in return line 42 is within the pre-determined second temperature range, the refrigerant of the waste heat producing circuit 10 at the outlet 26 is according to the invention within the first temperature range too. However, in case where a heat demand at the heat consuming circuit 40, i.e. at the heat sink side of the HRU 30, is greater than the amount of heat which can be transferred via the heat exchanger 20 from the waste heat producing circuit 10 to the HRU 30, the temperature in the return line 42 could fall below the lower predetermined temperature limit of the second temperature range such that the temperature at the outlet 26 of the heat exchanger 20 would be too low for an optimal operation of the waste heat producing circuit 10.

[0041] To prevent a too low refrigerant temperature at the inlet of the cooler/condenser 19 the invention provides for a bypass line 17 bypassing the inlet 25 with the outlet 26 and therewith the heat exchangers 20 primary side 21. A feed line 12 connects the outlet 26 with a 3-way valve 18 and comprises as second inlet the bypass line 17. The outlet of 3-way valve 18 is connected to the cooler/condenser 19. According to the invention the 3-way valve 18 closes the bypass line 17 as long as the temperature in return line 42 stays within the pre-determined upper and the lower temperature limits. If the temperature of the heat transport medium in the return line 42 falls below the pre-determined lower limit temperature and therewith the temperature of the refrigerant at outlet 26 would fall also below the lower end of the first temperature range, the 3-way valve 18 opens the bypass line 17 at least partially such that hot refrigerant can be mixed with the refrigerant below pre-determined lower limit temperature, which having passed the primary side 21 of the heat exchanger 20. Thus, by means of the arrangement of the 3-way valve 18 and the bypass line 17 the refrigerant temperature can be adjusted to an optimum temperature for the expansion step.

[0042] In another case where the temperature of the heat transport medium in the return line 42 exceeds the pre-determined upper limit temperature, which means that the heat demand in the heat consumption circuit is lower than the waste heat provided and transferred over the heat exchanger 20, the storage capacity of the HRU 30 can be used to assume the surplus of heat energy until the storage(s) is completely charged. If too much waste heat energy is still produced, heat has to be dissipated to the ambient either at the heat source or the heat sink side of the HRU 30. In this case a person skilled in the relevant art also could think about connecting the heat distribution system, e.g. the one shown in Figure 1, to an external heating grid or to increase the thermal energy consumption at the heat sink side, for instance, by rising the room temperature in the commercial or industrial entity or to rise the storage temperature for domestic hot water or hydronic heating.

[0043] With Figure 2 two temperature curves are shown, indicating with the continuous curve exemplarily a high level waste heat consumption at the heat consuming circuit 40 and with the dotted curve a low level heat consumption at the heat consuming circuit 40. From the continuous temperature curve it can be derived that when the temperature of the heat transport medium in return line 42 reaches pre-determined lower limit temperature T_{min}, the method according to the invention raises the temperature to prevent that the heat transport medium temperature falls below pre-determined lower limit temperature T_{min}. From the solid curve it can also be derived that the method according to the invention permits that the temperature in the return line 42 remains at the pre-determined lower limit temperature T_{min}, as this is the condition for maximum use of waste heat produced by the waste heat producing circuit 10 at optimal Energy Efficiency Ratio (EER).

[0044] From the dotted line it can be derived that the method according to the invention intends to prevent that the temperature of heat transport medium in return line 42 exceeds the pre-determined upper limit temperature T_{max}. At this pre-determined upper limit temperature T_{max} the waste heat producing circuit 10 operates at is optimal Energy Efficiency Ratio (EER), however the cooler/condenser 19 has to be driven in order to reduce the temperature of the refrigerant leaving the outlet 26 of the heat exchanger 20. See explaination above with regards to the determination by calculation of the pre-determined upper limit temperature T_{max} and the pre-determined lower limit temperature T_{min}. Hence, the method according to the invention preferably intends to lower the temperature of the heat transport medium in return line 42 within the pre-determined temperature range T_R. The closer the temperature of the heat transport medium in return line 42 is to the pre-determined upper limit temperature T_{max}, the more additional (mechanical and/or electrical) energy has to be provided to the cooler/condenser 19 in order to lower the refrigerant temperature at outlet 26 to the optimum temperature for the expansion step. From this it can be derived also that it is preferred to follow, e.g., the solid curve which is closer to T_{min} - the pre-determined lower limit temperature. As at T_{min} the cooler/condenser 19 can be or kept switched-off and does not consume additional work/energy, which means that the overall energy balance for the heat energy distribution system according to the invention is balanced, as all produced waste energy is consumed at the heat consuming circuit 40.

[0045] For holding the temperature and/or the flow rate of the heat transport medium in return line 42 within the temperature range T_R, the method according to the invention preferably uses a flow valve 45 installed at the return lines 42 of each consumer connected in the heat consuming circuit 40. The flow valve 45 according to the invention comprises an electro-mechanical operable actuator 46 which is configured to open and close a flow passage 44 through the flow valve 45 and therewith through the associated return line 42 (see Figure 1). As best can be seen in Figure 3 a temperature sensor 47 of the flow valve 45 is prepared for monitoring the temperature of heat transfer medium in the fluid line 42. A control unit 48 of the flow valve 45 is configured to set a predetermined upper limit temperature T_{max} and a predetermined lower limit temperature T_{min} and to command the actuator 46 to open or close the flow passage 44 of the flow valve 45. A microcontroller in the control unit 48 is capable to receive a temperature signal from the temperature sensor 47 and to determine whether the temperature signal indicates that the heat transfer medium temperature is within, below or above a pre-set temperature range T_R. The microcontroller creates an open valve command to the actuator 46 in case the temperature signal indicates that the heat transport medium temperature is below the temperature range T_R or creates a close valve command to the actuator 46 in case the temperature signal indicates the heat transport medium temperature is above the temperature range T_R.

[0046] The flow valve 45 according to the invention is configured to autonomously detect the temperature of heat transport medium in the associated return line 42.n of the consumer 43.n. The flow valve 45 is installed downstream of consumer 43.n in the return line 42.n. In the further the indexing ".n" is used for "n" possible consumers 43 each having one flow valve 45.n mounted to the return line 42.n downstream of the consumer 43.n. Thereby "n" is a natural number starting with "1". In the example for a heat energy distribution system of Figure 1 "n" is equal to three.

[0047] Each control unit 48.n of the flow valves 45.n of the invention is configured to receive a temperature signal from his own temperature sensor 47.n, e.g., periodically, and decides whether the belonging actuator 46.n has to open or close the flow passage 44.n in order to modify the flow rate through the flow valve 45.n. As long as the temperature of the heat transport medium is within the second temperature range T_R there is no need to change the flow rate. In this case no command of the control unit 48.n to the actuator 46.n is generated and the set flow rate through the flow passage remains constant. In case the heat transport medium temperature is outside the temperature range T_R the flow rate through the flow valve has to be adapted. This is decided by the control unit 48.n, e.g. by the help of the microcontroller arranged within the control unit 48.

[0048] If the temperature of the heat transport medium in the associated return line 42.n exceeds the pre-determined upper limit temperature the flow rate through the passage of the flow valve 45.n has to be reduced in order to bring the temperature in the associated return line 42.n back within the temperature range T_R. In this case the control unit 48.n creates and sends a corresponding close passage 44.n command to the actuator 46.n of the flow valve 45.n in order to reduce the flow passage 44.n or even close it completely. If the temperature of the heat transport medium in the associated return line 42.n falls below the pre-determined lower limit temperature the flow rate through the passage 44.n of the flow valve 45.n has to be increased in order to bring the temperature in the associated return line 42.n back within the temperature range T_R. In this case the control unit 48.n creates and sends a corresponding open passage 44.n command to the actuator 46.n of the flow valve 45.n in order to increase the flow passage 44.n or even open it completely.

[0049] Hence, as to each consumer 43.n a flow valve 45.n is associated, each consumer 43.n can be controlled individually. This enables a separate setting for each consumer associated flow valve 45.n. E.g., consumers 43.n with a higher temperature in the return line 42.n however with a lower flow rate can be set to a temperature T_R whose temperature level as a whole is higher than, e.g. another consumer 43.n+1 having a high flow rate in the return line 42.n+1 but at a lower temperature. These temperature ranges T_R can be set manually at each flow valve 45.n individually or alternatively set by a superordinated or supervising control system, e.g. a Building Management System (BMS). Such a BMS may, e.g., monitor the temperature of the joint return line 42 of the heat consuming circuit 40 and send a temperature range modification signal to one or more control units 48.n at the flow valves 45.n such that they can change their temperature range setting in order to fulfil the required second temperature range T_R for the temperature of the heat transport medium at the inlet of the HRU 30. Therewith it would be not necessary for each and every consumer 43.n to fulfil the second temperature range T_R itself, because only the mixed return flows of the plurality of consumers 43.n have to fulfil this criteria for comprising a temperature within the second temperature range T_R in order to comply the implementation of the idea according to the invention. For receiving such control or change setting signals, the flow valve 45 according to the invention comprise a digital interface 49 with which the flow valves 45.n can be connected to each other by a bus, LAN, or WLAN network.

[0050] Summarizing, the present invention provides for simple control method for a heat energy distribution system which uses the temperature control at the heat sink side of the HRU in order to provide sufficient heat absorption capacity to a waste heat producing circuit such that preferably all arising waste heat in a waste heat producing circuit can be transferred to the heat consuming circuit and used there effectively for satisfying heat energy demands. Finally, it should be noted that the presented embodiments show concepts of the present invention. Definitions of shapes, forms, connections, or numbers are only exemplary and may vary for different applications. However, all modifications within the knowledge of a person skilled in the relevant art are covered as long as the concepts of the invention are still implemented.

Reference List

[0051]

10	Waste heat producing circuit			
11	Return line	40	Heat consuming circuit / HVAC-circuit	
12	Feed line			
13	Fluid line (cold gas)	41	Feed line	
14	Expansion valve	42	Return line	
15	Cooler/compressor	43	Consumer	
16	Return line		43.1	Ventilation system
17	Bypass line		43.2	Heating system
18	3-way valve		43.3	Hot domestic water
19	Cooler / Condenser	44	Flow passage	
		45	Flow valve	
20	Heat exchanger	46	Actuator	
21	Primary side	47	Temperature sensor	
22	Secondary side	48	Control unit	
23		49	Interface	
24				
25	Inlet primary side			
26	Outlet primary side	T	Temperature	
		T_{max}	Upper limit temperature	
30	Heat recovery unit (HRU)	T_{min}	Lower limit temperature	
31	Heat source side	T_R	Temperature range	
32	Heat sink side	EER	Energy Efficiency Ratio	
33	Return line - heat source side	COP	Coefficient of performance	
34	Feed line - heat source side	BMS	Building Management System	
35	Return line - heat sink side			
36	Feed line - heat sink side			

Claims

1. Method for controlling the distribution of thermal energy in a commercial or industrial entity having a waste heat producing circuit (10) connected to a primary side (21) of a heat exchanger (20) whose secondary side (22) is connected to a heat recovery unit (HRU) (30) at its heat source side (31), wherein to the heat sink side (32) of the HRU (30) a heat consuming circuit (40), particularly a heating ventilation air conditioning (HVAC)-circuit, comprising at least one heat energy consumer (43) is connected, wherein the method:

A) determines for the fluid of the waste heat producing circuit (10) at an outlet (26) of the primary side (21) of the heat exchanger (20) a first temperature range at which the waste heat producing circuit (10) is operable at its optimal Energy Efficiency Ratio (EER);
B) determines by calculation for the fluid of the heat consuming circuit (40) in a return line (42) to the HRU a second temperature range (T_R) between a predetermined upper limit temperature (T_{max}) and a predetermined lower limit temperature (T_{min}) using the first temperature range and the heat exchange capacities of the heat exchanger (20) and the HRU (30) such that the waste heat producing circuit (10) can be stably operated at its optimal Energy Efficiency Ratio (EER);
C) controls the fluid temperature (T) in the return line (42) and/or the return fluid flow rate by means of controlling one or more flow valves (45) installed at the least one or more heat energy consumer (43) such that the temperature in the return line (42) to the HRU (30) does not exceed the predetermined upper limit temperature (T_{max}) neither fall below the predetermined lower limit temperature (T_{min}).

2. Method according to claim 1, wherein as long as the temperature (T) in the return line (42) stays within the temperature range (T_R):

- the temperature or the flow rate through the return line (42) remains unchanged and/or
- the flow rate through the primary side (21) of the heat exchanger (20) can be adjusted in function of the heat energy demand of the heat consuming circuit (40).

3. Method according to any of claims 1, wherein the flow rate through the return line (42) is increased when the temperature (T) in the return line (42) reaches or falls below the predetermined lower limit temperature (T_{min} and/or wherein the flow rate through the return line (42) is decreased when the temperature in the return line (42) reaches or exceeds the predetermined upper limit temperature (T_{max}).

4. Method according to any of claims 1 to 3, wherein the temperature at the inlet (25) of the heat exchanger (20) can be adjusted primary in function of the stable operation of the waste heat producing circuit (10) at the optimal Energy Efficiency Ratio (EER) and secondary to a heat demand of the heat consuming circuit (40).

5. Method according to any of claims 1 to 4, wherein the temperature at the secondary side (22) of the heat exchanger (20) is adjusted primary in function of the stable operation of the waste heat producing circuit (10) at its optimal Energy Efficiency Ratio (EER) and secondary to a heat demand of the heat consuming circuit (40).

6. Method according to any of claims 1 to 5, wherein the waste heat producing circuit (10) comprises a bypass line (17) bypassing the inlet (25) and the outlet (26) of the heat exchanger (10), wherein a 3-way valve (18) combines the flows from the outlet (26) and the bypass line (17) such that the temperature in the waste heat producing circuit (10) downstream the 3-way valve (18) stays within the first temperature range wherein preferably the 3-way valve (18) opens the bypass line (17) when the temperature of the waste heat producing circuit medium at the outlet (26) falls below the minimum temperature of the first temperature range.

7. Method according to any of claims 1 to 6, wherein the waste heat producing circuit (10) comprises a cooler downstream of the outlet (26), which is activated when the temperature of the waste heat producing circuit medium at the outlet (26) exceeds the maximum temperature of the first temperature range.

8. Heat energy distribution system of a commercial or industrial entity having a heat recovery unit (HRU) (30) to which at the heat source side (31) via a heat exchanger (20) a waste heat producing circuit (10), particularly a refrigeration circuit using CO_2 or any other gas as refrigerant, is connected and to which heat sink side (32) a heat consuming circuit (40), particularly a heating ventilation air conditioning (HVAC)-circuit,. is connected with at least one or more heat energy consumer (43) for providing heat energy to the commercial or industrial entity, **characterized in that** one or more temperature controlled flow valves (45) are installed in a return line (42) of the least one or more heat energy consumer (43) wherein each flow valve (45) comprises a control unit (48) and a temperature sensor (47) for monitoring the temperature in the return line (42), wherein each control unit (48) is capable to command an actuator (46) of the flow valve (45) configured to open or close the corresponding flow valve (45) such that the temperature in the return line (42) does not exceed a predetermined upper limit temperature (T_{max}) neither fall below a predetermined lower limit temperature (T_{min}).

9. Heat energy distribution system according to claim 8, wherein the upper predetermined temperature limit (T_{max}) and lower predetermined temperature limit (T_{min}) can be set at the control unit (48) in dependency that the waste heat producing circuit (10) is operatable at its optimal Energy Efficiency Ratio (EER).

10. Heat energy distribution system according to claim 8 or 9, wherein the flow valve (45) is a pressure independent or a pressure dependent flow valve and/or the flow valve (45) is controlled in an on/off manner or in a modulated manner, and wherein the actuation of the flow valve (45) is analogically controlled via 0-10 V / 0-20 mA current or is digitally controlled via any communication protocol.

11. Heat energy distribution system according to any of claims 8 to 10, wherein the one or more control units (48) receive the temperature limit values from a Building Management System (BMS).

12. Heat energy distribution system according to any of claims 8 to 11, wherein the waste heat producing circuit (10) comprises a bypass line (17) bypassing an inlet (25) and an outlet (26), the outlet (26) at the primary side (21) of the heat exchanger (10), wherein a 3-way valve (18) combines the flows from the outlet (26) and the bypass line (17) to the waste heat producing circuit (10) such that waste heat producing circuit (10) is operatable at its optimal Energy

Efficiency Ratio (EER).

13. Flow valve (45) for adjusting the flow rate through a fluid line (42), comprising:

- the flow valve, of the heat energy distribution system, is configured to be in the return line of the heat energy consumer,
- an electro-mechanical operable actuator (46) configured to open and close a flow passage through the flow valve (45);
- a temperature sensor (47) for monitoring a medium temperature in the fluid line (42);
- a control unit (48) configured to set a predetermined upper limit temperature (T_{max}) and a predetermined lower limit temperature (T_{min}) and to command the actuator (46) to open or close the flow passage;
- a microcontroller in the control unit (48) capable:

  • to receive a temperature signal from the temperature sensor (47);
  • to determine whether the temperature signal indicates a medium temperature within, below or above a pre-set temperature range (T_R);
  • to create an open valve command to the actuator (46) in case the temperature signal indicates a medium temperature below the temperature range (T_R), or
  • to create a close valve command to the actuator (46) in case the temperature signal indicates a medium temperature above the temperature range (T_R).

14. Flow valve (45) according to claim 13, wherein the control unit (48) further comprises a digital interface capable to receive wire-based or wireless an external temperature range set, temperature or command signal.

15. Flow valve (45) according to claim 13, wherein the digital interface of the control unit (48) is further capable to receive the predetermined upper limit temperature (T_{max}) and the predetermined lower limit temperature (T_{min}) values from a superordinated or supervisory control system, particularly from a Building Management System BMS.

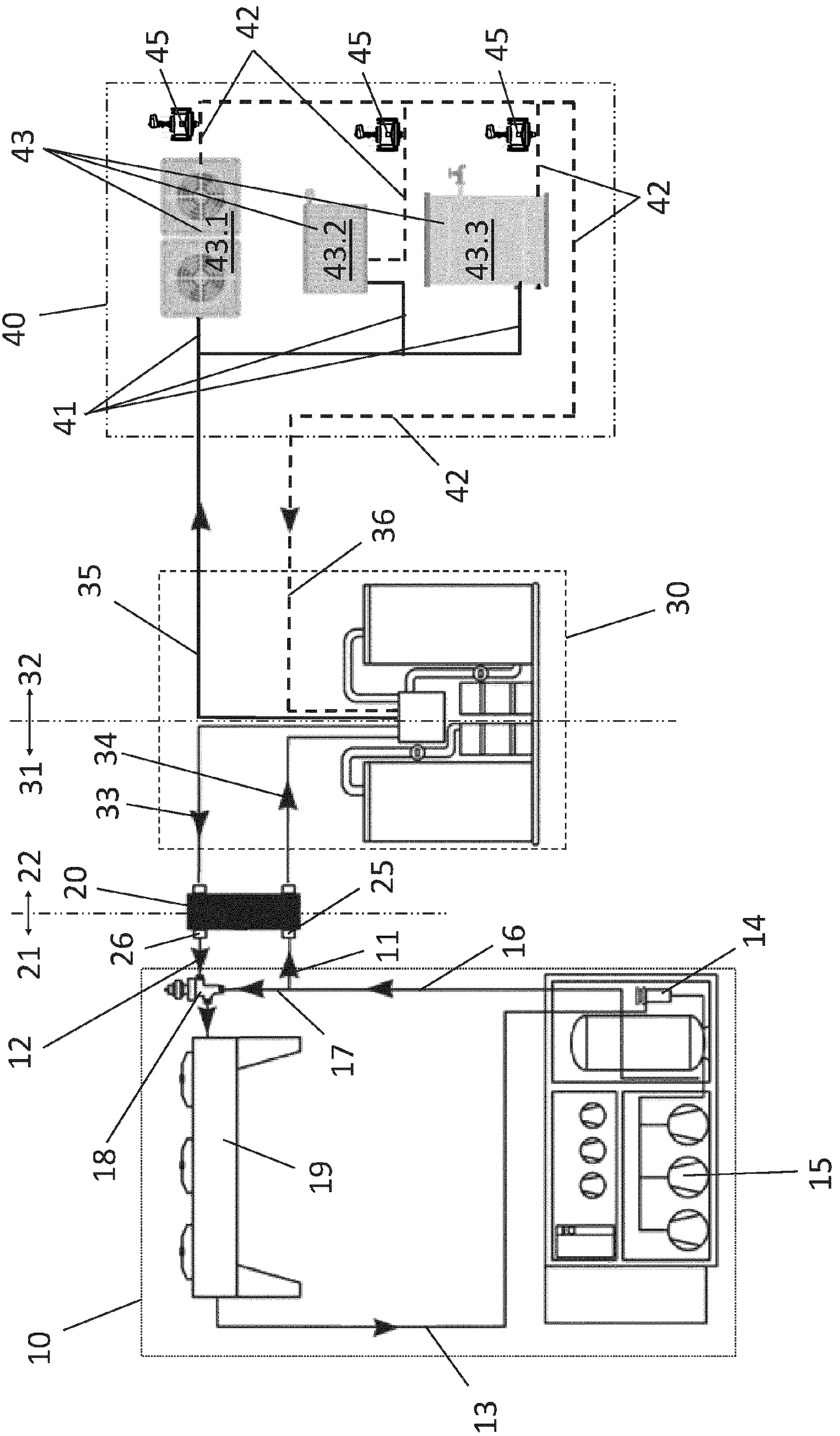
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Figure 1

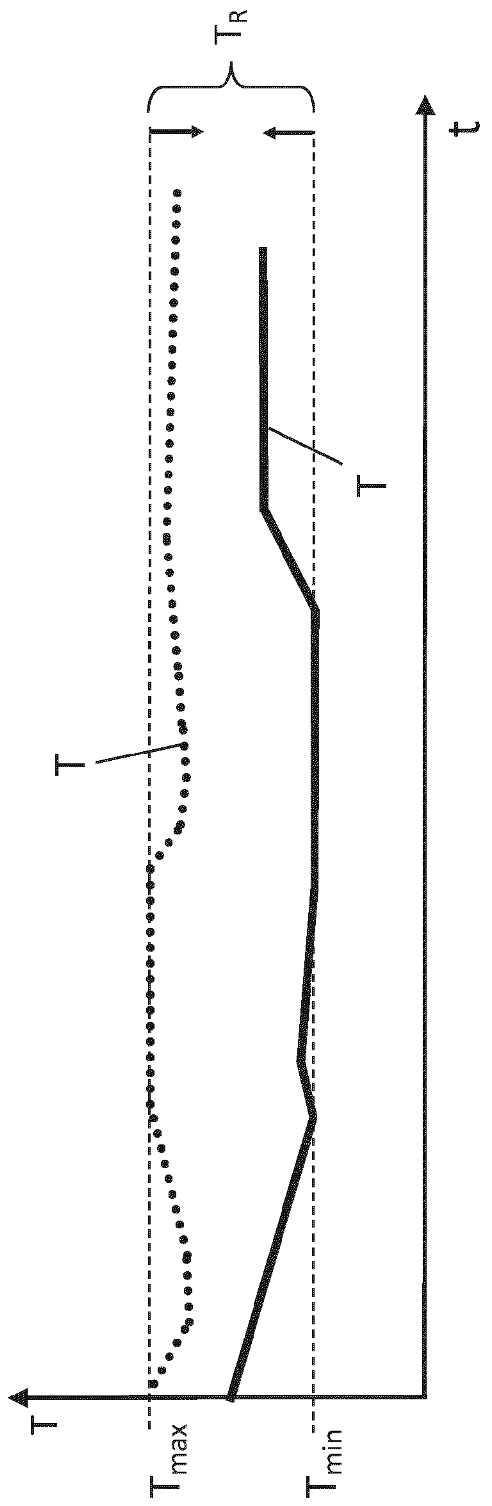

Figure 2

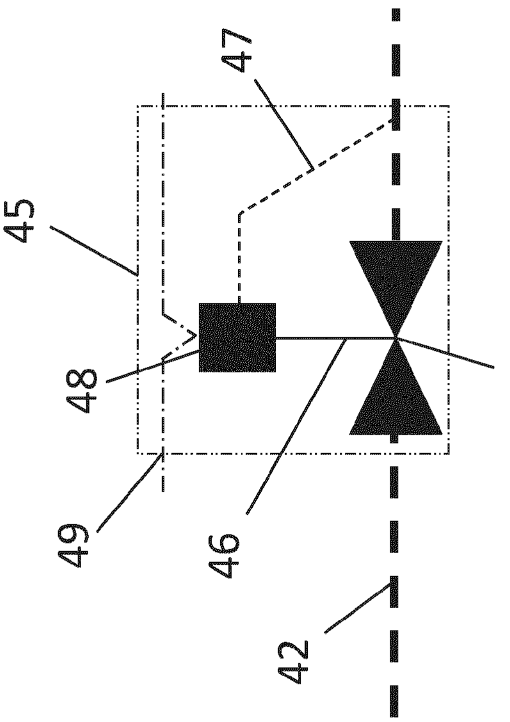

Figure 3

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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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