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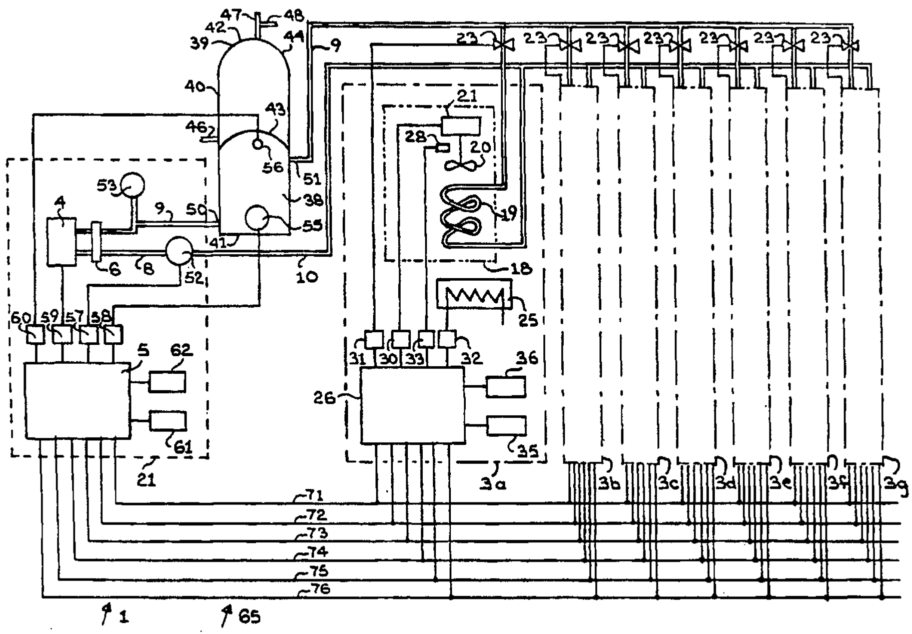

(57) Abstract

Space heating apparatus (1) comprises a central unit (2) which comprises a reversible heat pump circuit (4) which provides heating and cooling to a heat transfer medium circuit (8) through a main heat exchanger (6). Heated water in the circuit (8) is circulated through fan coil heat exchangers (18) in remote units (3) by a circulating pump (52). Water in the circuit (8) is stored and heated in a storage tank (38) during a heat storage period for use when the apparatus (1) is being operated with minimum power requirement. During the heat storage period, the water in the storage tank (38) is initialled heated by the heat pump to a temperature of 60 °C and is then raised to 85 °C by an immersion heater (55) in the storage tank (38).

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"Space heating apparatus"

The present invention relates to space heating apparatus, and in particular though not limited to space heating apparatus for heating a domestic dwelling. In particular, the invention relates to space heating apparatus of the type which comprises at least one secondary heat exchange means for space heating, a main heat exchange means for transferring heat to and from a heat transfer medium, a heat transfer medium circuit for communicating the main heat exchange means with each secondary heat exchange means for transferring heat between the main heat exchange means and the respective secondary heat exchange means by the heat transfer medium, a heat pump means for transferring heat to or from the main heat exchange means, a storage means in the heat transfer medium circuit for storing the heat transfer medium for storing heat for subsequent transfer to the secondary heat exchange means, a make-up heat source in the storage means for heating the heat transfer medium, a circulating means in the heat transfer medium circuit for circulating the heat transfer medium through the main heat exchange means, the secondary heat exchange means and the storage means, a cycle timing means for timing a cycle of the apparatus and for timing a heat storage period during which the apparatus is operated for storing heat in the heat transfer medium, and a minimum demand period during which the apparatus is operated for minimising power consumption of the apparatus, the minimum demand period being after the heat storage period, and a main control means for controlling the operation of the apparatus.

Such space heating apparatus is known, and in general, operates with limited efficiency, and in general, with limited control. Where a reasonable degree of control is required, relatively complex control systems and circuitry are required. Similarly, where such known space heating apparatus operates with a reasonable degree of efficiency, generally quite complex control systems are required. In general, known space heating apparatus are relatively inefficient in storing heat during offpeak demand periods of electricity supply utilities for subsequent use during an onpeak period, so that during the onpeak period the apparatus may be operated with minimum power demand.

PCT Specification No. WO 86/00976 discloses space heating apparatus in which the apparatus can be operated so that the power requirement of the space heating apparatus during onpeak periods of the electricity supply utilities is maintained relatively low. However, this is only achieved by the provision of a relatively complex apparatus and also with relatively complex controls. Indeed, even with the relative complexity of the apparatus the power requirement during onpeak periods is relatively high. Furthermore, while this apparatus stores heat during offpeak periods the apparatus is relatively inefficient when operating to store heat and the power requirement of the apparatus when storing heat is relatively high.

PCT Specification No. WO 87/07703 also discloses space heating apparatus, however, to maintain adequate space heating, an auxiliary power supply provided by a boiler is necessary. Additionally, the space heating apparatus disclosed in this PCT specification has no provision for controlling or regulating the power requirement of the apparatus such that the power requirement can be minimized during onpeak periods of an electricity supply utility.

German Patent Specification No. 2,402,703 discloses space heating apparatus which provides for storing heat during offpeak periods of electricity supply utilities which may be used during onpeak periods. However, because of the arrangement of the heat transfer medium circuitry of this space heating apparatus, its efficiency is relatively poor.

There is therefore a need for space heating apparatus which overcomes the problems of known space heating apparatus.

It is an object of the invention to provide such space heating apparatus in which the apparatus can be operated to store heat during offpeak periods and to operate with minimum power requirements during onpeak periods of an electricity supply utility. It is a particular object of the invention to provide such space heating apparatus which operates efficiently and in particular, which operates efficiently when storing heat, and also which operates efficiently when it is operating with minimum power demand. It is a further object of the invention to provide such space heating apparatus in which the control system of the apparatus is relatively simple to provide, install and operate.

According to the invention, there is provided space heating apparatus comprising at least one secondary heat exchange means for space heating, a main heat exchange means for transferring heat to and from a heat transfer medium, a heat transfer medium circuit for communicating the main heat exchange means with each secondary heat exchange means for transferring heat between the main heat exchange means and the respective secondary heat exchange means by the heat transfer medium, a heat pump means for transferring heat to the main heat exchange means, a storage means in the heat transfer medium circuit for storing the heat transfer medium for storing heat for subsequent transfer to the secondary heat exchange means, a make-up heat source in the storage means for heating the heat transfer medium, a circulating means in the heat transfer medium circuit for circulating the heat transfer medium through the main heat exchange means, each secondary heat exchange means and the storage means, a cycle timing means for timing a cycle of the apparatus and for timing a heat storage period during which the apparatus is operated for storing heat in the heat transfer medium, and a minimum demand period during which the apparatus is operated for minimising power consumption of the apparatus, the minimum demand period being after the heat storage period, and a main control means for controlling the operation of the apparatus, wherein the main control means is responsive to the cycle timing means for enabling the heat pump means to heat the heat transfer medium in the storage means during the heat storage period to a predetermined intermediate temperature, and for enabling the make-up heat source on the temperature of the heat transfer medium reaching the predetermined intermediate temperature for rising the temperature of the heat transfer medium in the storage means to a predetermined final temperature during the heat storage period.

By virtue of the fact that the heat transfer medium in the storage means is raised to a predetermined intermediate temperature by the heat pump means, and then subsequently raised to a final temperature by the make-up heat source, the operation of the space heating apparatus is particularly efficient during the heat storage period.

Preferably, the main control means is responsive to the cycle timing means for disabling the heat pump means during the minimum demand period for reducing the power requirements of the space heating apparatus to a minimum during the minimum demand period.

In one aspect of the invention, the minimum demand period follows immediately sequentially after the heat storage period, for further enhancing the efficiency of the heat storage apparatus.

Preferably, the predetermined intermediate temperature of the heat transfer medium is at least 40°C, and preferably, at least 45°C. Advantageously, the predetermined intermediate temperature of the heat transfer medium is at least 50°C, and preferably, at least 55°C, and in a preferred aspect of the invention, the predetermined intermediate temperature of the heat transfer medium is approximately 60°C. The nearer the predetermined intermediate temperature can be raised to 60°C by the heat pump means, it has been found the more efficient the space heating apparatus operates during the heat storage period.

In one aspect of the invention, the predetermined final temperature of the heat transfer medium is in the range of 75°C to 95°C, preferably, the predetermined final temperature of the heat transfer medium is in the range of 80°C to 90°C, and advantageously, the predetermined final temperature of the heat transfer medium is approximately 85°C. It has been found that the nearer the predetermined final temperature is maintained to 85°C, the more efficiently the space heating apparatus operates during the heat storage period and also during the minimum demand period.

In another aspect of the invention, each secondary heat exchange means is provided with an associated fan for transferring heat between the secondary heat exchange means and its associated environment.

Preferably, the main control means is responsive to the cycle timing means for disabling the associated fan of each secondary heat exchange means during the heat storage period, for improving the efficiency of operation of the space heating apparatus during the heat storage period.

In another aspect of the invention, each secondary heat exchange means is provided with an associated isolating means for isolating the secondary heat exchange means from the heat transfer medium circuit. Advantageously, the control means is responsive to the cycle timing means for disabling each isolating means during the heat storage period for further improving the efficiency of operation of the space heating apparatus during the heat storage period.

In a preferred embodiment of the invention, each secondary heat exchange means is provided with an associated secondary heat source, operable independently of the secondary heat exchange means, for heating the environment associated with the secondary heat exchange means during the heat storage period. Preferably, each secondary heat source comprises an electrically powered heat source. Advantageously, the control means is responsive to the cycle timing means for disabling each secondary heat source during the minimum demand period, for minimising the power demand of the space heating apparatus during the minimum demand period.

It is preferable that the heat pump means is reversible and is operable in a heating cycle and a cooling cycle for providing both heating and cooling to the secondary heat exchange means.

Preferably, the cycle timing means times a twenty-four hour cycle, and the cycle timing means may time a seven day cycle.

To facilitate the space heating apparatus operating with minimum power demand during periods of onpeak demand of an electricity supply utility, which normally occurs once per day, the space heating apparatus is operated under the control of the main control means with one heat storage period and one minimum demand period during each twenty-four hour cycle. Preferably, the minimum demand period of the space heating apparatus is of substantially similar length to the onpeak demand period of a mains electricity supply utility which powers the space heating apparatus, and the minimum demand period of the space heating apparatus co-incides with the onpeak demand period.

In one embodiment of the invention, a main temperature sensing means is provided in the storage means for monitoring the temperature of the heat transfer medium.

Preferably, a secondary temperature sensing means is provided associated with each secondary heat exchange means for monitoring the air temperature of the environment in which the respective secondary heat exchange means are located, and advantageously, each secondary temperature sensing means is located in the path of the return air being returned to the associated secondary heat exchange means.

In one aspect of the invention, the secondary heat source and the fan associated with each secondary heat exchange means is responsive to the associated secondary temperature sensing means.

In general, it is envisaged that a plurality of remotely located secondary heat exchange means are provided.

It is preferable that each secondary heat exchange means is provided with a secondary control means for controlling the secondary heat exchange means, the associated fan, secondary heat source and the isolating means, and preferably, a communicating means communicates each secondary control means with the main control means.

Advantageously, the communicating means communicates each secondary control means with the other secondary control means.

For simplicity, it is preferable that the communicating means comprises at least two wires, namely, a first wire and a second wire extending between the main control means and the secondary control means for enabling each secondary control means to communicate with the main control means and the other secondary control means, each of the two wires being operable in two states so that on a secondary heat exchange means requiring heating or cooling, the secondary control means of that secondary heat exchange means changes the state of the appropriate wire indicating the relevant demand to the main control means.

Preferably, a change in state of either of the first and second wires caused by a secondary control means causes the secondary control means of the other secondary heat exchange means to operate the isolating means for isolating the secondary heat exchange means from the heat transfer medium circuit of those secondary heat exchange means which are not making the same demand as that being made by the secondary control circuit which changed the state of the wire. This arrangement provides a particularly simple form of control of the space heating apparatus.

In one aspect of the invention, the first wire communicates a demand for heating and the second wire communicates demand for cooling.

To facilitate efficient operation of the space heating apparatus, the main control means controls the heat pump means for operating in a heating cycle until a demand for heating no longer exists or until a secondary control means changes the state of the second wire to indicate a demand for cooling.

To enhance communication between the main control means and the secondary control means, the communicating means comprises a third wire which is operable in three states, namely, a first state, a second state and a third state, the state of the third wire being determined by the main control means such that in the first state the secondary heat exchange means are allowed to operate under the control of their associated secondary control means, in the second state the secondary heat source associated with each secondary control means is disabled, and in the third state the isolating means associated with each secondary heat exchange means is closed.

Preferably, the third wire is operable in a fourth state, and in the fourth state some of the secondary heat exchange means are subject to the control of the main control means. Operating the third wire in a fourth state enables independent control of secondary heat exchange means through their respective secondary control means in different zones.

In one aspect of the invention, in the third state the fan and secondary heat source associated with each secondary heat exchange means may be disabled.

In another aspect of the invention, in the first state a continuous high signal is applied to the third wire, in the second state a continuous low signal is applied to the third wire, in the third state a pulsed signal of relatively low frequency is applied to the third wire, and in the fourth state a pulsed signal of relatively high frequency is applied to the third wire.

In a preferred embodiment of the invention, the communicating means comprises a fourth wire and a fifth wire for addressing the respective secondary control means in three respective zone, each of the fourth and fifth wires being operable in two states so that the secondary control means in the three different zones are addressed by different combinations of signals on the fourth and fifth wires.

Advantageously, the respective secondary control means are responsive to the signal on the third wire while being addressed by the fourth and fifth wires.

In one embodiment of the invention, the communicating means comprises a sixth wire which acts as a ground wire.

In one aspect of the invention, the storage means comprises an enclosed storage tank, and the storage tank is an elongated storage tank comprising a base and a side wall extending upwardly from the base and terminating in an upper wall closing the storage tank. Preferably, the upper wall is dome shaped. Advantageously, the upper wall is convex when viewed from above. Preferably, the side wall is of cylindrical construction.

To further enhance the efficiency of the space heating apparatus and to provide a domestic hot water supply efficiently, a domestic hot water supply tank is located on top of the storage tank for facilitating heat transfer from the storage tank to the domestic hot water supply tank. Preferably, the upper wall of the storage tank forms a base of the domestic hot water supply tank for facilitating heat transfer from the storage tank to the domestic hot water supply tank.

Additionally, the invention provides space heating apparatus comprising at least one secondary heat exchange means for space heating, a main heat exchange means for transferring heat to and from a heat transfer medium, a heat transfer medium circuit for communicating the main heat exchange means with each secondary heat exchange means for transferring heat between the main heat exchange means and the respective secondary heat exchange means by the heat transfer medium, a heat pump means for transferring heat to the main heat exchange means, a storage means in the heat transfer medium circuit for storing the heat transfer medium for storing heat for subsequent transfer to the secondary heat exchange means, a make-up heat source in the storage means for heating the heat transfer medium, a circulating means in the heat transfer medium circuit for circulating the heat transfer medium through the main heat exchange means, each secondary heat exchange means and the storage means, a cycle timing means for timing a cycle of the apparatus and for timing a heat storage period during which the apparatus is operated for storing heat in the heat transfer medium, and a minimum demand period during which the apparatus is operated for minimising power consumption of the apparatus the minimum demand period being after the heat storage period, and a main control means for controlling the operation of the apparatus, wherein each secondary heat exchange means is provided with a secondary control means and a communicating means communicates each secondary control means with the main control means.

Further, the invention provides space heating apparatus comprising at least one secondary heat exchange means for space heating, a main heat exchange means for transferring heat to and from a heat transfer medium, a heat transfer medium circuit for communicating the main heat exchange means with each secondary heat exchange means for transferring heat between the main heat exchange means and the respective secondary heat exchange means by the heat transfer medium, a heat pump means for transferring heat to the main heat exchange means, a storage means in the heat transfer medium circuit for storing the heat transfer medium for storing heat for subsequent transfer to the secondary heat exchange means, a make-up heat source in the storage means for heating the heat transfer medium, a circulating means in the heat transfer medium circuit for circulating the heat transfer medium through the main heat exchange means, each secondary heat exchange means and the storage means, a cycle timing means for timing a cycle of the apparatus and for timing a heat storage period during which the apparatus is operated for storing heat in the heat transfer medium, and a minimum demand period during which the apparatus is operated for minimising power consumption of the apparatus, the minimum demand period being after the heat storage period, and a main control means for controlling the operation of the apparatus, wherein the storage means co-operates with a domestic hot water supply tank for heat transfer from the storage means to the domestic hot water supply tank.

The invention will be more clearly understood from the following description of a preferred embodiment thereof which is given by way of example only with reference to the accompanying drawings, in which:

Fig. 1 is a schematic representation of space heating apparatus according to the invention,

Fig. 2 is a circuit diagram of the space heating apparatus of Fig. 1,

Fig. 3 is a flow chart of a computer programme which controls the operation of the space heating apparatus of Fig. 1,

Fig. 4 is a flow chart of a subroutine of the computer programme of Fig. 3,

Fig. 5 is a flow chart of another subroutine of the computer programme of Fig. 3, and

Fig. 6 is a flow chart of a further subroutine of the computer programme of Fig. 3.

Referring to the drawings, and initially to Figs. 1 and 2, there is illustrated space heating apparatus according to the invention indicated generally by the reference numeral 1. The apparatus 1 is particularly suitable for space heating a domestic dwelling house. The space heating apparatus 1 comprises a central unit 2 for providing heating and cooling to the apparatus 1 and a plurality of remote units 3, in this case seven remote units 3 which are located remotely from the central unit 2, and typically, one in each room of the domestic dwelling for heating or cooling the respective room of the dwelling. Only one of the remote units 3 is illustrated in detail in Fig. 2. For efficiency, as will be described below, the domestic dwelling is divided into three zones, namely, zone 1, zone 2 and zone 3. Zone 1 includes the bedrooms of the dwelling house, and the remote units 3a, 3b and 3c are located in zone 1. Zone 2 includes the living rooms, typically, a sitting room and dining room. The remote units 3d and 3e are located in these two rooms respectively. Zone 3 includes the kitchen, bathroom and toilet areas of the dwelling, and remote units 3f and 3g are located in these areas.

The central unit 2 comprises a heat pump means, namely, a heat pump circuit 4 which is illustrated in block representation. The heat pump circuit 4 is reversible so that it can be operated in a heating cycle or a cooling cycle. In a heating cycle, the heat pump circuit 4 supplies heat from the central unit 2 to the remote units 3 and in the cooling or refrigeration cycle the heat pump circuit 4 removes heat from the remote units 3, in other words cools the remote units 3 for cooling the rooms in which they are located. A main control means, namely, a main control circuit 5 controls the operation of the heat pump circuit 4 as well as the apparatus 1 as will be described in more detail below. The main control circuit 5 is illustrated in block representation in Fig. 2. A main heat exchange means, namely, a main heat exchanger 6 is located in the central unit 2 and exchanges heat between the heat pump circuit 4 and a heat transfer medium, which in this case is water for transferring heat to and from the remote units 3 through a heat transfer medium circuit 8. The heat transfer medium circuit 8 comprises a flow line 9 and a return line 10 of relatively small bore pipe which may be of plastics material, copper or other suitable material for receiving the heat exchange water from the main heat exchanger 5.

Each remote unit 3 comprises a housing 15 having an air inlet 16 and an air outlet 17. A secondary heat exchange means, namely, a fan coil heat exchanger 18 is located within each housing 15. The fan coil heat exchangers 18 each comprise a heat exchange coil 19 and a fan 20 driven by an electrical motor 21 for circulating air from the room over the heat exchange coil 19 from the air inlet 16 to the air outlet 17 for transferring heat between the heat exchange coil 19 and the air in the room. The heat exchange coil 19 of each remote unit 3 is connected to the flow and return lines 9 and 10 for receiving heat exchange medium from the heat transfer medium circuit 8. An isolating means, namely, a solenoid operated isolating valve 23 connects each heat exchange coil 19 to the flow line 9 for enabling the heat exchange coil 19 to be isolated from the heat transfer medium circuit 8 under certain conditions as will be described below. A secondary heat source comprising a secondary electrical resistive heater 25 is located in the housing 15 of each remote unit 3 for providing additional heat to the room should the heat exchange coil 19 be unable to supply the heat demand of the room, or during periods where the heat pump circuit 4 is disabled or is operating in a cooling cycle to satisfy a demand for cooling from another room or rooms, as will be described below. The fan 20 is arranged in the housing 15 to circulate air over the heater 25 for transferring heat therefrom to the room.

A secondary control means, namely, a secondary control circuit 26 which is illustrated in block representation in Fig. 2 is located in the housing 15 of each remote unit 3 and controls the operation of the fan 20, the isolating valve 23 and the heater 25 of that remote unit 3 under the partial control of the main control circuit 5, as will be described below. A secondary temperature sensing means, namely, a secondary temperature sensor 28 is located in the housing 15 of each remote unit 3 adjacent the air inlet 16 for monitoring the temperature of air from the room being returned to the remote unit 3. The secondary temperature sensor 28 is read by the secondary control circuit 26 for controlling the operation of the remote unit 3. This is described in more detail below. The motor 21, the isolating valve 23 and the heater 25 are controlled by the secondary control circuit 26 of each remote unit 3 through drivers 30 to 32, respectively. An analog to digital converter 33 converts the analog signal of the temperature monitored by the secondary temperature sensor 28 of each remote unit 3 to digital form for delivery to the secondary control circuit 26. A keypad 35 is connected to the secondary control circuit 26 of each remote unit 3 to enable a user to input desired upper and lower set point temperatures within which the room is to be maintained. A liquid crystal display 36 connected to the secondary control circuit of each remote unit 3 displays temperature.

A storage means is provided for storing heat transfer medium at a relatively high temperature in the heat transfer medium circuit 8 during a heat storage period for use during a minimum demand period during which the electrical power requirement of the apparatus 1 is minimized. The heat storage period and the minimum demand period are described below. The storage means comprises a storage tank 38 which in this case is formed by part of a main tank 39. The main tank 39 is of cylindrical construction having a cylindrical side wall 40 extending upwardly from a base 41 to a domed shape top wall 42. An intermediate dome shaped wall 43 substantially halfway between the base 41 and the top wall 42 divides the main tank 39 in two forming the lower storage tank 38 and an upper domestic hot water supply tank 44. The intermediate dome shaped wall 43 forms an upper wall of the storage tank 38 and a base of the domestic hot water supply tank 44 for facilitating heat transfer from the heat transfer water in the storage tank 38 to water in the domestic hot water supply tank 44. A water inlet 46 to the domestic hot water supply tank 44 delivers a cold water supply into the tank 44 while an expansion pipe 47 and a hot water supply pipe 48 exit from the top wall 42 of the tank 44 for delivering the domestic hot water supply. An inlet 50 and an outlet 51 to and from the storage tank 38 connect the storage tank 38 into the heat transfer medium circuit 8. In this case, the storage tank 38 is of 30 gallons capacity, and the domestic hot water supply tank 44 is also of 30 gallons capacity.

A circulating means, namely, a circulating pump 52 in the return line 10 circulates heat transfer water in the heat transfer medium circuit 8 through the main heat exchanger 6, the secondary heat exchange coils 19 of the remote unit 3 and the storage tank 38. An expansion tank 53 connected to the flow line 9 accommodates expansion of the heat transfer water in the heat transfer medium circuit 8.

A make-up heat source comprising an immersion heater 55 is located in the storage tank 38 for raising the temperature of the heat transfer water to a predetermined final temperature, in this case approximately 85°C while the apparatus 1 is operating in a heat storage mode during the heat storage period which is described below, for use when the apparatus 1 is operating in a minimum demand mode during the minimum demand period. A main temperature sensing means, namely, a main temperature sensor 56 is located on the storage tank 38 for monitoring the temperature of the heat transfer water in the storage tank 38.

The circulating pump 52 is driven by an electrically powered motor (not shown) which is controlled by the main control circuit 5 through a motor driver 57. The main control circuit 5 controls the immersion heater 55 through a driver 58, and the heat pump circuit 4 through a driver 59. An analog to digital converter 60 converts the analog signal of the temperature monitored by the main temperature sensor 56 into digital signals for delivery to the main control circuit 5. A keypad 61 connected to the main control circuit 5 enables inputting to the main control circuit 5 of upper and lower set point temperatures and times at which the air temperature in the rooms in the respective zones is to be controlled at various times during a twenty-four hour or seven day cycle of the apparatus 1 and also the times at which the selected set point temperatures inputted through the respective keypads 35 into the secondary control circuits 26 of the remote units 3 are to be overridden by the main control circuit 5 as will be described below. The keypad 61 also enables inputting to the main control circuit 5 of the start and stop times of the heat storage period and the minimum demand period during which the apparatus is to be operated in the heat storage mode and the minimum demand mode, respectively. Times and temperatures are displayed on a liquid crystal display 62 which is connected to the main control circuit 5.

In this embodiment of the invention, the main control circuit 5 and the secondary control circuit 26 are provided with respective microprocessors.

The heat pump circuit 4, the heat exchanger 6, the expansion tank 53, the circulating pump 52, the main control circuit 5 and its associated circuitry are all housed in a housing (not shown) which essentially forms the central unit 2.

The main control circuit 5 communicates with the secondary control circuits 26 through a six wire communicating link 65. The secondary control circuits 26 also communicate to a limited extent with each other through the six wire link 65. Before describing the six wire link 65 and the detailed operation of the main and secondary control circuits 5 and 26, the operation of the apparatus 1 will first be described in outline.

During a twenty-four hour cycle, the apparatus 1 cycles through three modes, namely, a normal mode, the heat storage mode and the minimum demand mode. Each remote unit 3 operates under the control of its secondary control circuit 26 which is subject to the control of the main control circuit 5 depending on the mode in which the apparatus 1 is operating. Additionally, the main control circuit 5 controls the remote units 3 to operate in set back mode. In set back mode, the main control circuit 5 overrides the set point temperatures at which the remote units 3 in the respective zones 1 to 3 operate based on the set point temperatures entered through the keypads 35, and forces the remote units 3 to operate at upper and lower set back set point temperatures which are entered into the main control circuit 5 through the keypad 61.

When the apparatus 1 is operating in normal mode each remote unit 3 operates under the control of its secondary control circuit 26. The secondary control circuit 26 reads the air temperature from the secondary temperature sensor 28 which is compared with the upper and lower set points inputted into the secondary control circuit 26 through the keypad 35, and on the air temperature sensed by the secondary temperature sensor 28 lying within the two set points, the remote unit continues to operate as it has been. However, on the air temperature falling below the lower set point value, if the fan 20 is not operating, the fan 20 is activated to pass air over the heat exchange coil 19, assuming that the heat pump circuit 4 is operating in a heating cycle, and that the temperature of the heat transfer water exceeds 30°C. Otherwise, the heater 25 of the remote unit 3 is activated and the fan 20 delivers air over the heater 25. Should the fan 20 be operating when the air temperature drops below the lower set point, or should the temperature of the air returning to the remote unit 3 continue to fall after the fan has been activated, the heater 25 is activated and the fan 20 continues to operate. In the event that the heat pump circuit 4 is operating in a cooling cycle when the air temperature drops below the lower set point, then the heater 25 is activated, and if the fan is not already operating, the fan 20 is also activated. A requirement for heat by the remote unit 3 is continuously communicated through the six wire link 65 as will be described below in more detail to the main control circuit 5 until the requirement for heat no longer applies. Accordingly, on the heat pump circuit 4 finishing operating in a cooling cycle, the heat pump circuit 4 can immediately be activated to operate in a heating cycle for supplying heat to the heat exchange coil 19 of the remote unit 3 should the demand for heat still exist.

In the event that the air temperature exceeds the upper set point temperature of a remote unit 3, if the fan 20 is operating, it is switched off. If the temperature continues to rise above the upper set point temperature, the heater 25 of the remote unit is switched off. Should the air temperature continue to rise above the upper set point temperature, cooling is required by the remote unit 3. A cooling demand by any remote unit 3 takes priority over a demand for heating, and on a remote unit 3 making a demand for cooling, provided the apparatus is not operating in the heat storage mode or the minimum demand mode, the heat pump circuit 4 is operated under the control of the main control circuit 5 in a cooling cycle. The heat pump circuit 4 continues to operate in a cooling cycle until all demands for cooling by remote units 3 have been satisfied. At that stage, the heat pump circuit 4 is deactivated, unless a remote unit is demanding heating, in which case the heat pump circuit 4 is operated in a heating cycle.

Operation of the remote units 3 when in the set back mode is similar to the operation just described with the exception that the remote units 3 are operated around the relevant set back set point temperatures.

The apparatus 1 operates in the minimum demand mode for one minimum demand period in each twenty-four hours. In this case, the minimum demand period is a two hour period from 16.30 to 18.30 hours. In the minimum demand mode, the electrical power requirement of the apparatus 1 is minimized. The two hour minimum demand period from 16.30 to 18.30 hours is selected to co-incide with the onpeak demand period of an electricity supply utility. To enable the apparatus 1 to operate with minimum power requirement during the minimum demand period, the apparatus is operated for a thirty minute heat storage period immediately before the minimum demand period in a heat storage mode for storing heat for subsequent use during the minimum demand period. In other words, the apparatus 1 is operated in a heat storage mode from 16.00 to 16.30 hours.

During the heat storage period, the temperature of the heat transfer water in the heat transfer medium circuit 8 is raised to a final predetermined temperature, in this case, 85°C. This is achieved as follows. Under the control of the main control circuit 5, the isolating valves 23 of each remote unit 3 are closed, thereby preventing loss of heat from the heat exchange coils 19 in the remote units 3. Immediately on commencement of the heat storage period the heat pump circuit 4 is activated to operate in a heating cycle for heating the heat transfer water. The temperature of the heat transfer water is monitored by the main temperature sensor 56, and on the temperature of the heat transfer water reaching a predetermined intermediate temperature, namely, 60°C, the heat pump circuit 4 is immediately deactivated and the immersion heater 55 is activated for raising the temperature of the heat transfer water from 60°C to the final temperature of 85°C. The temperature is maintained at 85°C by the immersion heater 55 until the heat storage period terminates, at which stage the immersion heater 55 is deactivated. During the heat storage mode the heaters 25 and fans 20 of the remote units 3 are enabled by the main control circuit 5 and operate under the control of the secondary circuits 26 of the remote units 3 for heating the rooms.

Immediately on termination of the heat storage period, the minimum demand period commences, and under the control of the main control circuit 5 the heat pump circuit 4 is disabled for the entire duration of minimum demand period. The fans 20 of the remote unit 20 are enabled so that the fans can transfer heat from the heat exchange coils 19 to the air in the respective rooms. However, in order to minimize the power requirement of the apparatus 1 during the minimum demand period the heaters 25 in the remote units 3 are disabled by the main control circuit 5. Accordingly, during the minimum demand period heat is supplied to the rooms of the dwelling by the remote units from the fan coil heat exchangers 18 only. The remote units 3 are unable to provide cooling during the minimum demand period. During both the heat storage period and the minimum demand period, the remote units 3 operate essentially under their respective secondary control circuits 26 but subject to the components which are disabled by the main control circuit 5.

In the event that at any stage while the apparatus 1 is operating in normal, heat storage or minimum demand mode, the main control circuit 5 determines that the remote units 3 in any of the zones 1 to 3 should be operated in set back mode, the main control circuit 5 transmits a signal as will be described below through the six wire link 65 to the remote units 3 of the relevant zone or zones which then operate in set back mode. In other words, the remote units 3 operate between the upper and lower set back set point temperatures of the set back mode.

The water capacity of the heat transfer medium circuit 8 including the capacities of the storage tank 38, the main heat exchanger 6 and the secondary heat exchange coils 19 and the heat output of the immersion heater 55 and the heat output from the heat pump circuit 4 are chosen and matched so that the temperature of the heat transfer water can be raised to 85°C within the heat storage period.

The main control circuit 5 controls the heat pump circuit 4 during operation of the apparatus 1 in normal mode so that on the temperature of the water in the heat transfer medium circuit 8 reaching 45°C, the heat pump circuit 4 is deactivated for maximising the efficiency of operation of the apparatus 1 in normal mode. Additionally, at start-up of the apparatus 1 or on changeover of the heat pump circuit 4 from a cooling cycle to a heating cycle, the isolating valves 23 of those remote units 3 which are calling for heating are closed until the temperature of the water in the heat transfer medium circuit 8 reaches 30°C for efficient running of the apparatus 1.

Returning now to the six wire control link 65, the six wire control link comprises six wires, namely, first to six wires 71 to 76. The first and second wires 71 and 72 permit the remote units 3 to communicate to the central unit 2 a demand for heating and cooling, respectively. The first and second wires 71 and 72 are operable in two states, namely, continuously high or continuously low state. When no demand for heating or cooling exists at any of the remote units 3, each wire 71 and 72 is held high by the main control circuit 5. On any of the remote units requiring heating, the secondary control circuit 26 of that remote unit 3 pulls the first wire 71 low. The main control circuit 5, on seeing a low in the first wire 71, if the heat pump circuit 4 is not operating in a cooling cycle, then the main control circuit 5 activates the heat pump circuit 4. The wires 71 and 72 are also monitored by the secondary control circuits 26 of the remote units 3, and on a remote unit 3 which does not require heat determining that the line 71 has been pulled low, the secondary control circuit 26 of that remote unit 3 closes the isolating valve 23 of the remote unit 3. On a remote unit 3 requiring cooling, the wire 72 is pulled low by the secondary control circuit 26 of that unit 3. On the main control circuit 5 determining that a demand for cooling exists, irrespective of the operating state of the heat pump circuit 4, the main control circuit 5 operates the heat pump circuit 4 in a cooling cycle. The remote units 3 which do not require cooling, on their respective secondary control circuits 26 determining that the wire 72 has been pulled low close their respective isolating valves 23. In either case, when a remote unit 3 is calling for heating or cooling, the secondary control circuit 26 of the relevant remote units 3 continues to pull the relevant wire 71 or 72 low until the demand for heating or cooling as the case may be has been fully satisfied. On a demand for cooling having been satisfied, should a demand for heating still be indicated by the first wire 71 being pulled low, the main control circuit 5 operates the heat pump circuit 4 in a heating cycle after the second wire 72 goes high, and until the first wire 71 also goes high again.

It will be noted from the above that a demand for cooling on the second wire 72 always takes priority over a demand for heating on the first wire 71. Thus, should the first wire 71 and the heat pump circuit 4 be operating in a heating cycle when a demand for cooling by a remote unit 3 causes the wire 72 to be pulled low, the heat pump circuit 4 is immediately reversed to operate in a cooling cycle. During the time while the heat pump circuit is operating in a cooling cycle, a heat demand by any of the remote units 3 is satisfied by the heaters 25. Since the main control circuit 5 controls the operation of the apparatus virtually entirely during the heat storage period and minimum demand period, the state of the first and second wires 71 and 72 is ignored by the main control circuit 5 during these periods.

The third wire 73 indicates to the remote units under the control of the main control circuit 5 the mode in which the apparatus 1 is operating, and also disables the relevant components of the remote units 3 during the heat storage period and minimum demand period. Additionally, the third wire 73 also indicates to the remote units 3 as to whether they should be operating in set back mode or otherwise. The third wire 73 is operable in four states, namely, a continuously high state, a continuously low state, a fast pulsed state and a slow pulsed state. In the fast pulsed state a pulsed signal at the rate of twenty pulses per second is applied to the third wire 73. In the slow pulsed state, a pulsed signal of ten pulses per second is applied to the third wire 73. A continuously high signal on the third wire 73 indicates that the apparatus 1 and the remote units 3 are operating in normal mode. A continuous low signal on the third wire 73 indicates to the remote units 3 that the apparatus 1 is operating in minimum demand mode, and accordingly the heaters 25 of the remote units 3 are disabled. A fast pulsed signal on the third wire 73 indicates that the apparatus 1 is operating in the heat storage mode and accordingly the isolating valves 23 of all the remote units 3 are closed. A slow pulsed signal on the third wire 73 indicates that the remote units 3 being addressed as will be discussed below are to operate in the set back mode.

Two wires 74 and 75 are provided for addressing the remote units 3 in the respective zones 1, 2 and 3. The fourth and fifth wires 74 and 75 are each operated in two states, namely, a continuously high state or a continuously low state. By varying the combinations of high and low signals on the fourth and fifth wires 74 and 75, the remote units 3 in the respective zones 1 to 3 are addressed. A high on the two wires 74 and 75 addresses the remote units 3 of zone 1. A high and a low on the wires 74 and 75, respectively, addresses the remote units 3 of zone 2 and reversing the high and low on the wires 74 and 75 addresses the remote units 3 in zone 3. While the remote units 3 of the respective zones 1 to 3 are being addressed, the secondary control circuit 26 of the relevant remote units 3 read the third wire 73 for determining the mode in which they are to operate.

The sixth wire 76 is a common earth wire.

Turning now to Figs. 3 to 6 there is illustrated flow charts of computer programmes which control the operation of the main control circuits 5 and the secondary control circuits 26. Referring to Fig. 3 a flow chart illustrating the main features of the computer programme which controls the main control circuit 5 will now be described.

Block 100 reads a cycle timing means, namely, a real time clock in the microprocessor of the main control circuit 5, and the computer programme moves to block 101. Block 101 checks if the time read by block 100 indicates that the remote units in any of the zones should be put into set back mode. If block 101 determines that a zone or zones is to operate in set back mode the computer programme moves to block 102 which checks if the relevant zones are in set back mode. If not, the computer programme moves to block 103 which calls up the set back mode subroutine which puts the remote units 3 of the relevant zone or zones in set back mode. This subroutine is described below with reference to Fig. 4. The computer programme moves on to block 104. Should block 102 determine that the relevant zone or zones are in set back mode, the computer programme moves to block 104. Should block 101 determine that the time read by block 100 is not a start time for a set back mode, the computer programme moves to block 105 which checks if the time read by block 100 indicates that a set back mode in any of the zones should be terminated. If so, the computer programme moves to block 106 which calls up the set back mode subroutine which ends the set back mode in the remote units 3 of the relevant zone or zones. The computer programme then moves to block 104. Should block 105 determine that the time read by the block 100 is not an end time for the set back mode in any of the zones the computer programme moves to block 104.

Block 104 checks if the time read by block 100 is the start time for the heat storage period. If so, the computer programme moves to block 107. Block 107 calls up the heat storage subroutine which puts the apparatus 1 in the heat storage mode. This subroutine is described below with reference to Fig. 5. The computer programme then moves to block 108. Should block 104 determine that it is not time to commence a heat storage period, the computer programme moves to block 109 which checks if it is time to commence a minimum demand period. If so, the computer programmes moves to block 110 which calls up the minimum demand subroutine, which puts the apparatus in the minimum demand mode. This subroutine is described below with reference to Fig. 6. The computer programme then moves to block 108.

Block 108 reads the signal on the first wire 71 and the computer programme moves to block 111 which reads the signal on the second wire 72, and the computer programme moves to block 112. Block 112 checks if the signal on the second line 72 is low, in other words, if there is a call for cooling. If so, the computer programme moves to block 114 which reads the state of the heat pump circuit 4 to ascertain if the heat pump circuit 4 is operating in a heating or a cooling cycle, and the computer programme moves to block 115. Block 115 checks if the heat pump circuit 4 is operating in a cooling cycle. If so, the computer programme returns to block 100. Should block 115 determine that the heat pump circuit 4 is not operating in a cooling cycle, the computer programme moves to block 116 which checks if the apparatus 1 is operating in normal mode. If the apparatus 1 is not operating in normal mode, the computer programme is returned to block 100. On the other hand should block 116 determine that the apparatus 1 is operating in normal mode, the computer programme moves to block 117 which operates the heat pump circuit 4 in a cooling cycle and returns the computer programme to block 100. Should block 112 determine that the second wire 72 is high, the computer programme moves to block 118 which checks if the first wire 71 is low, in other words, if any of the remote units 3 are calling for heating. If the first wire 71 is high, the computer programme returns to block 100. In the event that the first wire 71 is low, the computer programme moves to block 119 which reads the operating state of the heat pump circuit 4 and the computer programme moves to block 120. Block 120 checks if the heat pump circuit 4 is operating in a heating cycle, and if so, the computer programme is returned to block 100. On the other hand, should block 120 determine that the heat pump circuit 4 is not operating in a heating cycle, the computer programme moves to block 121 which checks if the heat pump circuit 4 is operating in a cooling cycle. If so, the computer programme returns to block 100. On the other hand, should block 121 determine that the heat pump circuit 4 is not operating in a cooling cycle, the computer programme moves to block 122 which checks if the apparatus 1 is operating in a minimum demand mode. If so, the computer programme returns to block 100. If not, the computer programme moves to block 123 which activates the heat pump circuit 4 to operate in a heating cycle and the computer programme is returned to block 100.

The computer programme operating the main control circuit 5 carries out other tasks and functions to enable the apparatus 1 to operate as described, these will be readily apparent to those skilled in the art, and it is not intended to describe them in this specification. For example, the computer programme will switch on and off the heat pump circuit 4 and the relevant units of the remote units 3 when no heating and cooling is required, for example, during nighttime periods, for example, from 23.00 hours to 7.00 hours the next day. The main control circuit 26 of each remote unit is also provided with a computer programme for facilitating communicating with the main control circuit 5 and receiving instructions therefrom. The computer programme of the secondary control circuit 26 will also operate the components of the remote units, and will apply relevant signals to the first and second wires 71 and 72, and will also read the signals on the first and second wires 71 and 72. This will be readily apparent to those skilled in the art.

Referring now to Fig. 4, there is illustrated a flow chart of a subroutine for placing the remote units 3 of one or more zones into set back mode or taking the remote unit 3 of the relevant zones out of set back mode. Should the remote units of the relevant zones not be in set back mode, the subroutine of Fig. 4

places the relevant remote units 3 in set back mode, and vice versa.

Block 130 starts the subroutine. Block 131 applies the slow pulsed signal at the rate of ten pulses per second on the third wire 73 and the subroutine moves to block 132. Block 132 checks if the remote units of zone 1 are to be placed in or removed from set back mode. If so, the subroutine moves to block 133 which places a high on the fourth and fifth wires 74 and 75 for a period of one second for addressing the remote units 3 of zone 1 for one second during which they read the signal on the third line 73 and the subroutine moves to block 134. Should block 132 determine that the remote units 3 of zone 1 are not to be placed in or removed from set back mode, the subroutine moves to block 134 which determines if the remote units 3 of zone 2 are to be placed in or removed from set back mode. If so, the subroutine moves to block 135 which places a high on the fourth wire 74 and a low on the fifth wire 75 for a period of one second for addressing the remote units 3 in zone 2. The subroutine then moves to block 136. Should block 134 have determined that the remote units 3 of zone 2 are not to be placed in set back mode or removed therefrom the subroutine moves to block 136. Block 136 determined if the remote units 3 of zone 3 are to be placed in or removed from set back mode. If so, the subroutine moves to block 137 which places a high on the wire 75 and a low on the wire 74 for a period of one second, thereby addressing the remote units 3 of zone 3. The subroutine then moves to block 138 which returns control of the main control circuit 4 to the main computer programme of Fig. 3. Likewise, should block 136 determine that the remote units 3 of zone 3 are not to be placed in or removed from set back mode, the computer programme moves to block 138.

Referring now to Fig. 5 the subroutine for placing the apparatus 1 in the heat storage mode will now be described. Block 140 starts the subroutine and the subroutine moves to block 141 which applies a fast pulsed signal at the rate of twenty pulses per second on the third wire 73 thus indicating that the isolating valves 23 of the remote units 3 are to be closed. The subroutine then moves to block 142 which sequentially addresses the remote units 3 of the respective zones 1 to 3 as already described with reference to the subroutine of Fig. 4. The subroutine then moves to block 143 which immediately activates the heat pump circuit 4 to operate in a heating cycle. The subroutine then moves to block 144 which reads the main temperature sensor 56 to determine the temperature of the water in the storage tank 38 and moves to block 145. Block 145 checks if the temperature read by block 144 is greater than or equal to the intermediate temperature of 60°C. If not, the subroutine returns to block 144. Should block 145 determine that the temperature of the water is greater than or equal to 60°C, the computer programme moves to block 146 which activates the immersion heater 55. The subroutine then moves to block 147 which reads the main temperature sensor 56 to determine the temperature of the water in the storage tank 38, and moves to block 148. Block 148 checks if the temperature read by block 147 is greater than or equal to the final temperature of 85°C. If not, the subroutine returns to block 147. If the temperature read by block 147 is greater than or equal to 85°C, the subroutine moves to block 149 which deactivates the immersion heater 55. Block 150 checks if the heat storage period has terminated, and if so, the subroutine moves to block 151 which returns control of the main control circuit 5 to the computer programme of Fig. 3. On block 150 determining that the heat storage period is not yet terminated, the subroutine moves to block 152 which again reads the main temperature sensor 56 and moves to block 153. Block 153 checks if the temperature read by block 152 is greater than or equal to 85°C. If so, the subroutine returns to block 152. If not, the subroutine returns to block 146 which again activates the immersion heater 55 and the subroutine then continues to block 147 and so on.

Referring now to Fig. 6 the subroutine for operating the apparatus 1 during the minimum demand period will now be described. Block

160 starts the subroutine. Block 161 places a low on the third wire 73 to indicate to the remote units 3 of all the zones that the heaters 25 of the remote units 3 are to be disabled and the subroutine moves to block 162. Block 162 sequentially addresses the remote units of the three zones 1 to 3 while the low is still on the wire 73 thereby disabling the heaters 25 of the remote units 3. The subroutine then moves to block 163 which checks if the minimum demand period has terminated. If not, the computer programme moves to block 164 which causes the subroutine to wait and in due course return to block 163. Should block 163 determine that the minimum demand period has terminated the subroutine moves to block 165 which returns control of the main control circuit 5 to the computer programme of Fig. 3.

Returning now to Fig. 1, air circulating means for circulating air through the dwelling house for providing for air changes comprises an air inlet duct 80 which terminates in an outlet grille 81 through which air is delivered into the domestic dwelling. Typically, the outlet grille 81 is mounted in the ceiling of an upstairs landing, and the inlet duct 80 extends through the attic. An outlet duct 82 terminating in an inlet grille 83 which would typically be mounted in a ground floor room of the domestic dwelling draws air from the dwelling for exhaust to atmosphere. An air heat exchanger 85 in this case, a honeycomb structure heat exchanger of aluminium with alternate passages is mounted in a suitable location, for example, the attic for exchanging heat between the exhaust air being expelled from the building and fresh air being drawn into the building. Two fans are provided in the heat exchanger 85 for drawing in fresh air from outside the dwelling and for expelling exhaust air from the dwelling. Air through the inlet duct 80 is drawn by one of the fans through the heat exchanger 85 through one lot of passages in the heat exchanger 85, while air through the outlet duct 82 is delivered by the other fan through the heat exchanger 85 through the other passages of the heat exchanger 85 for exchanging heat with the inlet air. Air is drawn into the heat exchanger 85 through an air inlet 86. Expelled air is delivered from the heat exchanger 85 through an air outlet 87. It has been found that once the temperature difference between the inlet and the outlet air exceeds 4°C, heat transfer of approximately 70% of the available heat is achievable between the outlet air and the inlet air.

In use, the upper and lower set point temperatures within which each remote unit 3 is to operate are entered through the keypads 35. The time during which the apparatus 1 is to operate in heat storage mode and the time during which the apparatus 1 is to operate in the minimum demand mode are entered through the keypad 61 into the main control circuit 5. The times during which the remote units 3 are to operate are entered through the keypad 61 to the main control circuit 5. The time during which the remote units 3 of the various zones 1 to 3 are to be operated in set back mode are entered through the keypad 61, and the upper and lower set point temperatures for the set back periods are also entered through the keypad 61. Periods during which the apparatus is not to operate, typically during the nighttime period from 23.00 to 7.00 hours are also entered through the keypad 61. During such periods, the main control circuit 5 controls the apparatus 1 and the remote units 3 in a deactivated mode.

When the apparatus 1 is activated initially in the morning, a demand for heating by any of the remote units 3 is satisfied by their respective secondary heaters 25 until the water temperature in the heat transfer medium circuit 8 reaches 30°C. Initially, the temperature of the water in the heat transfer medium circuit 8 is monitored by the main control circuit 5 reading the main temperature sensor 56, and a fast pulsed signal is applied to the third wire 73 for closing the isolating valves 23 of the remote units 3 of all the zones 1 to 3 which are addressed sequentially using the fourth and fifth address wires 74 and 75, thereby preventing heat transfer water from circulating through the heat exchange coils 19. This condition is maintained, in other words, the valves 23 of the remote units 3 are held closed until the temperature of the water in the heat transfer medium circuit 8 exceeds 30°C. Thereafter, the apparatus 1 operates as already described depending on the time of the day.

While the apparatus has been described as including an air change system, in certain cases, this may be omitted.

Needless to say, the heat storage period and minimum demand period may be of length other than those described. It will also be appreciated that the predetermined final temperature and predetermined intermediate temperature may vary around those values described.

It is also envisaged that during the heat storage period instead of closing the isolating valves of the remote units to reduce heat loss from the secondary heat exchange coils, the fans associated with the respective secondary heat exchange coils could be disabled. Additionally, it will be appreciated that where a remote unit is demanding heating or cooling while the heat pump circuit is operating in the other cycle, namely, cooling or heating, in order to prevent the remote unit delivering cool or heated air when the opposite type of air is required, the fan may be switched off instead of closing of the isolating means.

It is envisaged that the third wire of the six wire control link may be operated in more than four states, for example, it may be operated in five, six or any number of states, thereby providing further control of the remote units by the main control circuit 5. For example, it is envisaged that the third wire may be operated in a fifth state, which would indicate to the remote units, or some of the remote units, that they were to be switched off completely. It is envisaged that the fifth and further states could be provided by providing pulsed signals of different frequencies than the fast and slow pulsed signals, or alternatively, by mark space ratio of the pulsed signal. Indeed, it will be readily apparent to those skilled in the art that the third wire may be operated in less than four states, for example, in three states only, and indeed, in certain cases, only two states.

Additionally, it is envisaged that in the third state, all the components of the remote units may be disabled, in other words, the isolating valves would be closed, and the fan and secondary heater would be disabled.

CLAIMS

1. Space heating apparatus (1) comprising at least one secondary heat exchange means (19) for space heating, a main heat exchange means (6) for transferring heat to and from a heat transfer medium, a heat transfer medium circuit (8) for communicating the main heat exchange means (6) with each secondary heat exchange means (19) for transferring heat between the main heat exchange means (6) and the respective secondary heat exchange means (19) by the heat transfer medium, a heat pump means (4) for transferring heat to the main heat exchange means (6), a storage means (38) in the heat transfer medium circuit (8) for storing the heat transfer medium for storing heat for subsequent transfer to the secondary heat exchange means (19), a make-up heat source (55) in the storage means (38) for heating the heat transfer medium, a circulating means (52) in the heat transfer medium circuit (8) for circulating the heat transfer medium through the main heat exchange means (6), each secondary heat exchange means (19) and the storage means (38), a cycle timing means (5) for timing a cycle of the apparatus (1) and for timing a heat storage period during which the apparatus (1) is operated for storing heat in the heat transfer medium, and a minimum demand period during which the apparatus (1) is operated for minimising power consumption of the apparatus (1), the minimum demand period being after the heat storage period, and a main control means (5) for controlling the operation of the apparatus (1), characterised in that the main control means (5) is responsive to the cycle timing means (5) for enabling the heat pump means (4) to heat the heat transfer medium in the storage means (38) during the heat storage period to a predetermined intermediate temperature, and for enabling the make-up heat source (55) on the temperature of the heat transfer medium reaching the predetermined intermediate temperature for rising the temperature of the heat transfer medium in the storage means (38) to a predetermined final temperature during the heat storage period.

2. Space heating apparatus as claimed in Claim 1 characterised in

that the main control means (5) is responsive to the cycle timing means (5) for disabling the heat pump means (4) during the minimum demand period.

3. Space heating apparatus as claimed in Claim 1 or 2 characterised in that the minimum demand period follows immediately sequentially after the heat storage period.

4. Space heating apparatus as claimed in any preceding claim characterised in that the predetermined intermediate temperature of the heat transfer medium is at least 45°C.

5. Space heating apparatus as claimed in any preceding claim characterised in that the predetermined intermediate temperature of the heat transfer medium is at least 50°C.

6. Space heating apparatus as claimed in any preceding claim characterised in that the predetermined intermediate temperature of the heat transfer medium is approximately 60°C.

7. Space heating apparatus as claimed in any preceding claim characterised in that the predetermined final temperature of the heat transfer medium is in the range of 75°C to 95°C.

8. Space heating apparatus as claimed in any preceding claim characterised in that the predetermined final temperature of the heat transfer medium is in the range of 80°C to 90°C.

9. Space heating apparatus as claimed in any preceding claim characterised in that the predetermined final temperature of the heat transfer medium is approximately 85°C.

10. Space heating apparatus as claimed in any preceding claim characterised in that each secondary heat exchange means (19) is provided with an associated fan (20) for transferring heat between the secondary heat exchange means (19) and its associated

environment.

11. Space heating apparatus as claimed in Claim 10 characterised in that the main control means (5) is responsive to the cycle timing means for disabling the associated fan (20) of each secondary heat exchange (19) means during the heat storage period.

12. Space heating apparatus as claimed in any preceding claim characterised in that each secondary heat exchange means (19) is provided with an associated isolating means (23) for isolating the secondary heat exchange means (19) from the heat transfer medium circuit (8).

13. Space heating apparatus as claimed in Claim 12 characterised in the control means (5) is responsive to the cycle timing means (5) for disabling each isolating means (23) during the heat storage period.

14. Space heating apparatus as claimed in any preceding claim characterised in that each secondary heat exchange means (19) is provided with an associated secondary heat source (25), operable independently of the secondary heat exchange means (19).

15. Space heating apparatus as claimed in Claim 14 characterised in that each secondary heat source (25) comprises an electrically powered heat source (25).

16. Space heating apparatus as claimed in Claims 14 or 15 characterised in that the control means (5) is responsive to the cycle timing means (5) for disabling each secondary heat source (25) during the minimum demand period.

17. Space heating apparatus as claimed in any preceding claim characterised in that the heat pump means (4) is reversible and is operable in a heating cycle and a cooling cycle.

18. Space heating apparatus as claimed in any preceding claim characterised in that the cycle timing means (5) times a twenty-four hour cycle.

19. Space heating apparatus as claimed in any preceding claim characterised in that the cycle timing means times (5) a seven day cycle.

20. Space heating apparatus as claimed in Claim 18 or 19 characterised in that one heat storage period and one minimum demand period occur in each twenty-four hour cycle.

21. Space heating apparatus as claimed in any preceding claim characterised in that the minimum demand period co-incides with an onpeak demand period of a mains electricity supply utility supplying electrical power to the apparatus (1).

22. Space heating apparatus as claimed in any preceding claim characterised in that a main temperature sensing means (56) is provided in the storage means (38) for monitoring the temperature of the heat transfer medium.

23. Space heating apparatus as claimed in any preceding claim characterised in that a secondary temperature sensing means (28) is provided associated with each secondary heat exchange means (19) for monitoring the air temperature of the environment in which the respective secondary heat exchange means (19) are located.

24. Space heating apparatus as claimed in Claim 23 characterised in that each secondary temperature sensing means (28) is located in the path of the return air being returned to the associated secondary heat exchange means (19).

25. Space heating apparatus as claimed in Claim 23 or 24 characterised in that the secondary heat source (25) and the fan

(20) associated with each secondary heat exchange means (19) is responsive to the associated secondary temperature sensing means (28).

26. Space heating apparatus as claimed in any preceding claim characterised in that a plurality of remotely located secondary heat exchange means (19) are provided.

27. Space heating apparatus as claimed in any preceding claim characterised in that each secondary heat exchange means (19) is provided with a secondary control means (26) for controlling the secondary heat exchange means (19), the associated fan (20), secondary heat source (25) and the isolating means (23).

28. Space heating apparatus as claimed in Claim 27 characterised in that a communicating means (65) communicates each secondary control means (26) with the main control means (5).

29. Space heating apparatus as claimed in Claim 28 characterised in that the communicating means (65) communicates each secondary control means (26) with the other secondary control means (26).

30. Space heating apparatus as claimed in Claim 28 or 29 characterised in that the communicating means (65) comprises at least two wires (71,72), namely, a first wire (71) and a second wire (72) extending between the main control means (5) and the secondary control means (26) for enabling each secondary control means (26) to communicate with the main control means (5) and the other secondary control means (26), each of the two wires (71,72) being operable in two states so that on a secondary heat exchange means (19) requiring heating or cooling, the secondary control means (26) of that secondary heat exchange means (19) changes the state of the appropriate wire (71,72) indicating the relevant demand to the main control means (5).

31. Space heating apparatus as claimed in Claim 30 characterised

in that a change in state of either of the first and second wires (71,72) caused by a secondary control means (26) causes the secondary control means (26) of the other secondary heat exchange means (19) to operate the isolating means (23) for isolating the secondary heat exchange means (19) from the heat transfer medium circuit (8) of those secondary heat exchange means (19) which are not making the same demand as that being made by the secondary control circuit (26) which changed the state of the wire (71,72).

32. Space heating apparatus as claimed in Claims 30 or 31 characterised in that the first wire (71) communicates a demand for heating and the second wire (72) communicates demand for cooling.

33. Space heating apparatus as claimed in any of Claims 30 to 32 characterised in that the main control means (5) controls the heat pump means (4) for operating in a heating cycle until a demand for heating no longer exists or until a secondary control means (26) changes the state of the second wire (72) to indicate a demand for cooling.

34. Space heating apparatus as claimed in any of Claims 28 to 33 characterised in that the communicating means (65) comprises a third wire (73) which is operable in three states, namely, a first state, a second state and a third state, the state of the third wire (73) being determined by the main control means (5) such that in the first state the secondary heat exchange means (19) are allowed to operate under the control of their associated secondary control means (26), in the second state the secondary heat source (25) associated with each secondary control means is disabled, and in the third state the isolating valve (23) associated with each secondary heat exchange means (19) is closed.

35. Space heating apparatus as claimed in Claim 34 characterised in that the third wire (73) is operable in a fourth state, and in the fourth state some of the secondary heat exchange means are

subject to the control of the main control means.

36. Space heating apparatus as claimed in Claim 34 or 35 characterised in that in the third state the fan (20) associated with each secondary heat exchange means (19) is disabled.

37. Space heating apparatus as claimed in any of Claims 34 to 36 characterised in that in the first state a continuous high signal is applied to the third wire (73), in the second state a continuous low signal is applied to the third wire (73), in the third state a pulsed signal of relatively low frequency is applied to the third wire (73), and in the fourth state a pulsed signal of relatively high frequency is applied to the third wire (73).

38. Space heating apparatus as claimed in any of Claims 28 to 37 characterised in that the communicating means (65) comprises a fourth wire (74) and a fifth wire (75) for addressing the respective secondary control means (26) in three respective zone, each of the fourth and fifth wires (74,75) being operable in two states so that the secondary control means (26) in the three different zones are addressed by different combinations of signals on the fourth and fifth wires (74,75).

39. Space heating apparatus as claimed in Claim 38 characterised in that the respective secondary control means (26) are responsive to the signal on the third wire (73) while being addressed by the fourth and fifth wires (74,75).

40. Space heating apparatus as claimed in any of Claims 28 to 39 characterised in that the communicating means (65) comprises a sixth wire (76) which acts as a ground wire.

41. Space heating apparatus as claimed in preceding claim characterised in that the storage means (38) comprises an enclosed storage tank (38).

42. Space heating apparatus as claimed in Claim 41 characterised in that the storage tank (38) is an elongated storage tank (38) comprising a base (41) and a side wall (40) extending upwardly from the base (41) and terminating in an upper wall (43) closing the storage tank (38).

43. Space heating apparatus as claimed in Claim 42 characterised in that the upper wall (43) is dome shaped.

44. Space heating apparatus as claimed in Claim 42 or 43 characterised in that the upper wall (43) is convex when viewed from above.

45. Space heating apparatus as claimed in any of Claims 42 to 44 characterised in that the side wall (40) is of cylindrical construction.

46. Space heating apparatus as claimed in any of Claims 41 to 45 characterised in that a domestic hot water supply tank (44) is located on top of the storage tank (38) for facilitating heat transfer from the storage tank (38) to the domestic hot water supply tank (44).

47. Space heating apparatus as claimed in Claim 46 characterised in that the upper wall (43) of the storage tank (38) forms a base of the domestic hot water supply tank (44) for facilitating heat transfer from the storage tank (38) to the domestic hot water supply tank (44).

48. Space heating apparatus (1) comprising at least one secondary heat exchange means (19) for space heating, a main heat exchange means (6) for transferring heat to and from a heat transfer medium, a heat transfer medium circuit (8) for communicating the main heat exchange means (6) with each secondary heat exchange means (19) for transferring heat between the main heat exchange means (6) and the respective secondary heat exchange means (19) by

the heat transfer medium, a heat pump means (4) for transferring heat to the main heat exchange means (6), a storage means (38) in the heat transfer medium circuit (8) for storing the heat transfer medium for storing heat for subsequent transfer to the secondary heat exchange means (19), a make-up heat source (55) in the storage means (38) for heating the heat transfer medium, a circulating means (52) in the heat transfer medium circuit (8) for circulating the heat transfer medium through the main heat exchange means (6), each secondary heat exchange means (19) and the storage means (38), a cycle timing means (5) for timing a cycle of the apparatus (1) and for timing a heat storage period during which the apparatus (1) is operated for storing heat in the heat transfer medium, and a minimum demand period during which the apparatus (1) is operated for minimising power consumption of the apparatus (1), the minimum demand period being after the heat storage period, and a main control means (5) for controlling the operation of the apparatus (1), characterised in that each secondary heat exchange means (19) is provided with a secondary control means (26) and a communicating means (65) communicates each secondary control means (26) with the main control means (5).

49. Space heating apparatus as claimed in Claim 48 characterised in that the communicating means (65) communicates each secondary control means (26) with the other secondary control means (26).

50. Space heating apparatus as claimed in Claims 48 or 49 characterised in that the communicating means (65) comprises at least two wires (71,72), namely, a first wire (71) and a second wire (72) extending between the main control means (5) and the secondary control means (26) for enabling each secondary control means (26) to communicate with the main control means (5) and the other secondary control means (26), each of the two wires (71,72) being operable in two states so that on a secondary heat exchange means (19) requiring heating or cooling, the secondary control means (26) of that secondary heat exchange means (19) changes the state of the appropriate wire (71,72) indicating the relevant

demand to the main control means (5).

51. Space heating apparatus as claimed in Claim 50 characterised in that a change in state of either of the first and second wires (71,72) caused by a secondary control means (26) causes the secondary control means (26) of the other secondary heat exchange means (19) to operate the isolating means (23) for isolating the secondary heat exchange means (19) from the heat transfer medium circuit (8) of those secondary heat exchange means (19) which are not making the same demand as that being made by the secondary control circuit (26) which changed the state of the wire (71,72).

52. Space heating apparatus as claimed in Claim 50 or 51 characterised in that the first wire (71) communicates a demand for heating and the second wire (72) communicates demand for cooling.

53. Space heating apparatus as claimed in any of Claims 50 to 52 characterised in that the main control means (5) controls the heat pump means (4) for operating in a heating cycle until a demand for heating no longer exists or until a secondary control means (26) changes the state of the second wire (72) to indicate a demand for cooling.

54. Space heating apparatus as claimed in any of Claims 48 to 53 characterised in that the communicating means (65) comprises a third wire (73) which is operable in three states, namely, a first state, a second state and a third state, the state of the third wire (73) being determined by the main control means (5) such that in the first state the secondary heat exchange means (19) are allowed to operate under the control of their associated secondary control means (26), in the second state the secondary heat source (25) associated with each secondary control means is disabled, and in the third state the isolating valve (23) associated with each secondary heat exchange means (19) is closed.

55. Space heating apparatus as claimed in Claim 54 characterised in that the third wire (73) is operable in a fourth state, and in the fourth state some of the secondary heat exchange means are subject to the control of the main control means.

56. Space heating apparatus as claimed in Claims 54 or 55 characterised in that in the third state the fan (20) associated with each secondary heat exchange means (19) is disabled.

57. Space heating apparatus as claimed in any of Claims 54 to 56 characterised in that in the first state a continuous high signal is applied to the third wire (73), in the second state a continuous low signal is applied to the third wire (73), in the third state a pulsed signal of relatively low frequency is applied to the third wire (73), and in the fourth state a pulsed signal of relatively high frequency is applied to the third wire (73).

58. Space heating apparatus as claimed in any of Claims 48 to 57 characterised in that the communicating means (65) comprises a fourth wire (74) and a fifth wire (75) for addressing the respective secondary control means (26) in three respective zone, each of the fourth and fifth wires (74,75) being operable in two states so that the secondary control means (26) in the three different zones are addressed by different combinations of signals on the fourth and fifth wires (74,75).

59. Space heating apparatus as claimed in Claim 58 characterised in that the respective secondary control means (26) are responsive to the signal on the third wire (73) while being addressed by the fourth and fifth wires (74,75).

60. Space heating apparatus as claimed in any of Claims 48 to 59 characterised in that the communicating means (65) comprises a sixth wire (76) which acts as a ground wire.

61. Space heating apparatus (1) comprising at least one secondary

heat exchange means (19) for space heating, a main heat exchange means (6) for transferring heat to and from a heat transfer medium, a heat transfer medium circuit (8) for communicating the main heat exchange means (6) with each secondary heat exchange means (19) for transferring heat between the main heat exchange means (6) and the respective secondary heat exchange means (19) by the heat transfer medium, a heat pump means (4) for transferring heat to the main heat exchange means (6), a storage means (38) in the heat transfer medium circuit (8) for storing the heat transfer medium for storing heat for subsequent transfer to the secondary heat exchange means (19), a make-up heat source (55) in the storage means (38) for heating the heat transfer medium, a circulating means (52) in the heat transfer medium circuit (8) for circulating the heat transfer medium through the main heat exchange means (6), each secondary heat exchange means (19) and the storage means (38), a cycle timing means (5) for timing a cycle of the apparatus (1) and for timing a heat storage period during which the apparatus (1) is operated for storing heat in the heat transfer medium, and a minimum demand period during which the apparatus (1) is operated for minimising power consumption of the apparatus (1), the minimum demand period being after the heat storage period, and a main control means (5) for controlling the operation of the apparatus (1), characterised in that the storage means (38) co-operates with a domestic hot water supply tank (44) for heat transfer from the storage means (38) to the domestic hot water supply tank (44).

62. Space heating apparatus as claimed in Claim 61 characterised in that the storage means (38) is an elongated storage tank (38) comprising a base (41) and a side wall (40) extending upwardly from the base (41) and terminating in an upper wall (43) closing the storage tank (38).

63. Space heating apparatus as claimed in Claim 62 characterised in that the upper wall (43) is dome shaped.

64. Space heating apparatus as claimed in Claim 62 or 63 characterised in that the upper wall (43) is convex when viewed from above.

65. Space heating apparatus as claimed in any of Claims 62 to 64 characterised in that the side wall (40) is of cylindrical construction.

66. Space heating apparatus as claimed in any of Claims 62 to 65 characterised in that a domestic hot water supply tank (44) is located on top of the storage tank (38) for facilitating heat transfer from the storage tank (38) to the domestic hot water supply tank (44).

67. Space heating apparatus as claimed in Claim 66 characterised in that the upper wall (43) of the storage tank (38) forms a base of the domestic hot water supply tank (44) for facilitating heat transfer from the storage tank (38) to the domestic hot water supply tank (44).

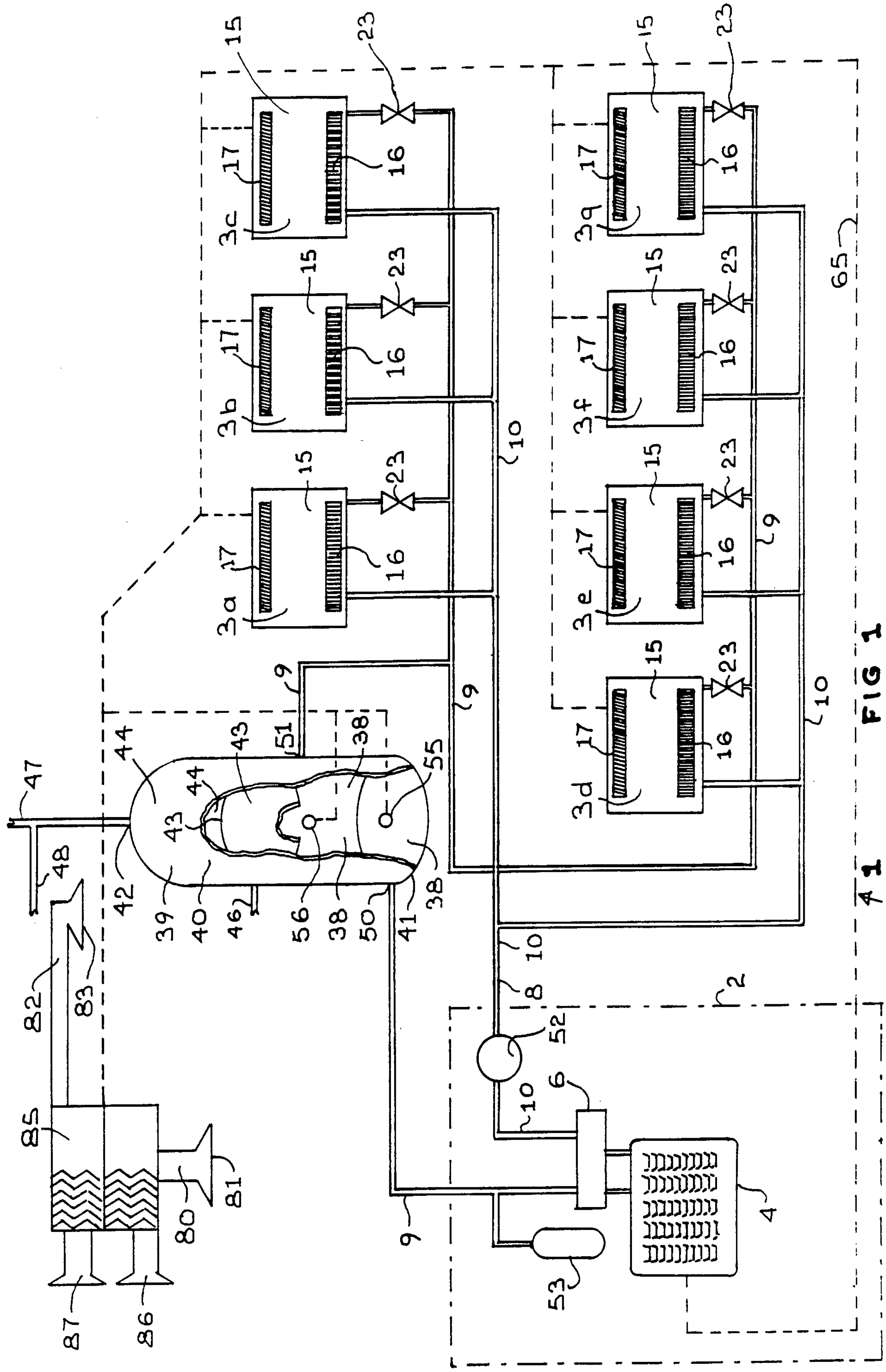
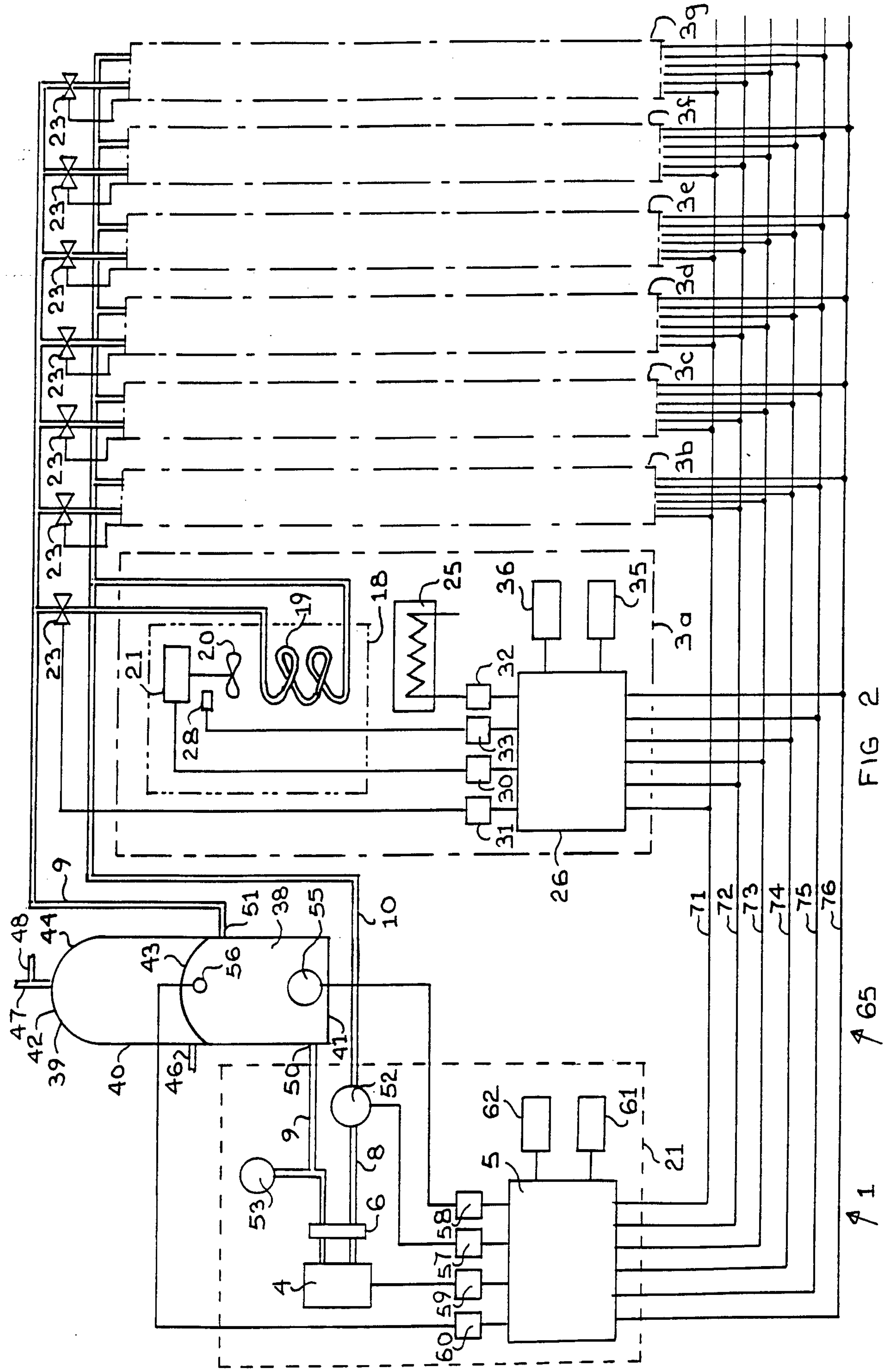

15
23
17
16
3a
3b
3c
3d
3e
3f
3g
10
9
65
44
43
38
51
55
56
47
48
42
39
40
46
50
41
8
52
2
1
6
4
53
82
83
85
80
81
87
86

FIG 1


3g
3f
3e
3d
3c
3b
3a
23
25
36
35
18
19
20
21
32
28
33
30
31
26
9
10
48
44
51
38
55
43
56
47
42
39
40
46
50
41
52
71
72
73
74
75
76
65
62
61
5
8
53
6
58
57
4
59
60
1
FIG 2

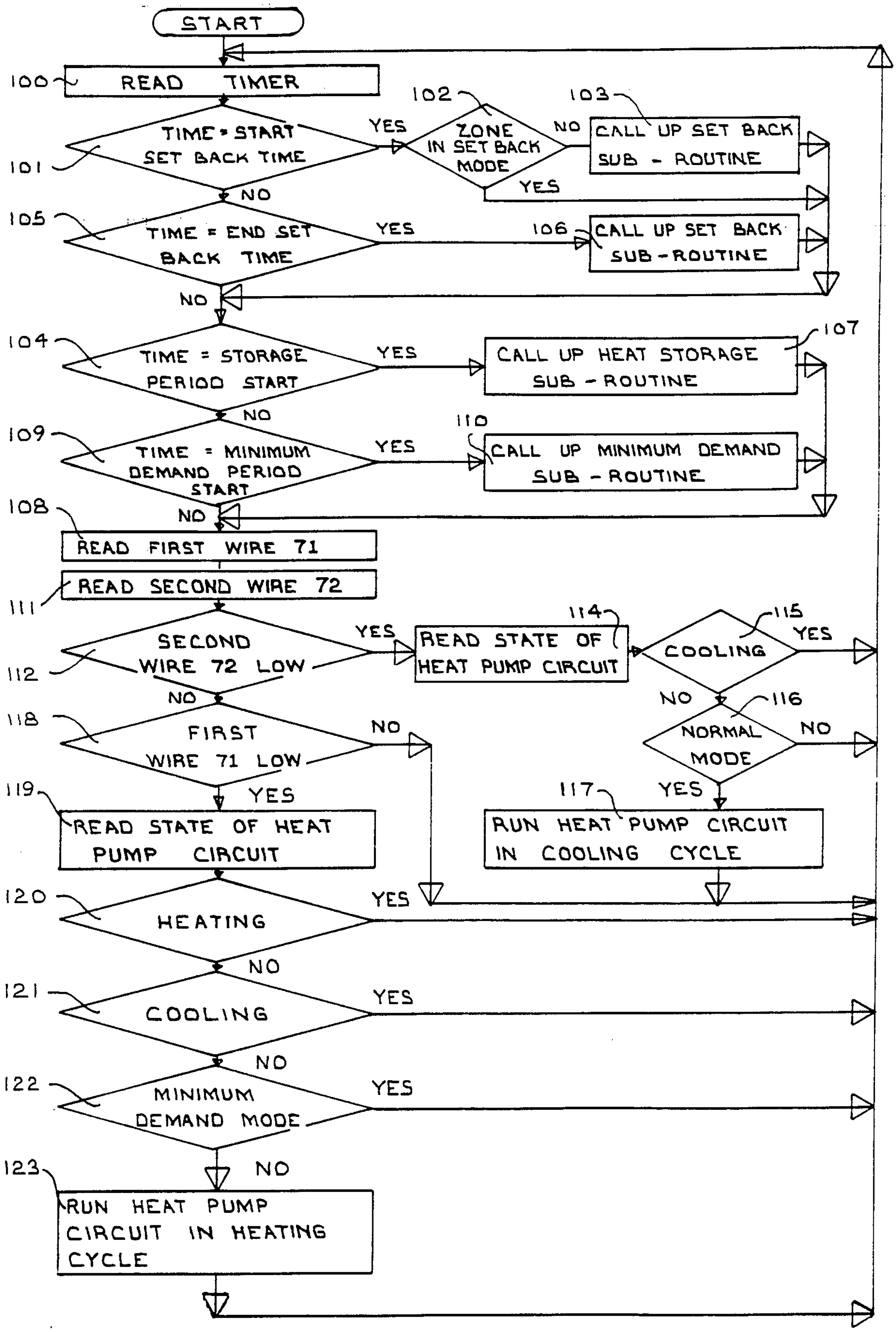

START
100
READ TIMER
101
TIME = START SET BACK TIME
YES
102
ZONE IN SET BACK MODE
NO
103
CALL UP SET BACK SUB - ROUTINE
YES
NO
105
TIME = END SET BACK TIME
YES
106
CALL UP SET BACK SUB-ROUTINE
NO
104
TIME = STORAGE PERIOD START
YES
CALL UP HEAT STORAGE SUB - ROUTINE
107
NO
109
TIME = MINIMUM DEMAND PERIOD START
YES
110
CALL UP MINIMUM DEMAND SUB - ROUTINE
108
NO
READ FIRST WIRE 71
READ SECOND WIRE 72
111
112
SECOND WIRE 72 LOW
YES
114
READ STATE OF HEAT PUMP CIRCUIT
115
COOLING
YES
NO
116
NORMAL MODE
NO
YES
117
RUN HEAT PUMP CIRCUIT IN COOLING CYCLE
NO
118
FIRST WIRE 71 LOW
NO
YES
119
READ STATE OF HEAT PUMP CIRCUIT
120
HEATING
YES
NO
121
COOLING
YES
NO
122
MINIMUM DEMAND MODE
YES
NO
123
RUN HEAT PUMP CIRCUIT IN HEATING CYCLE

FIG 3

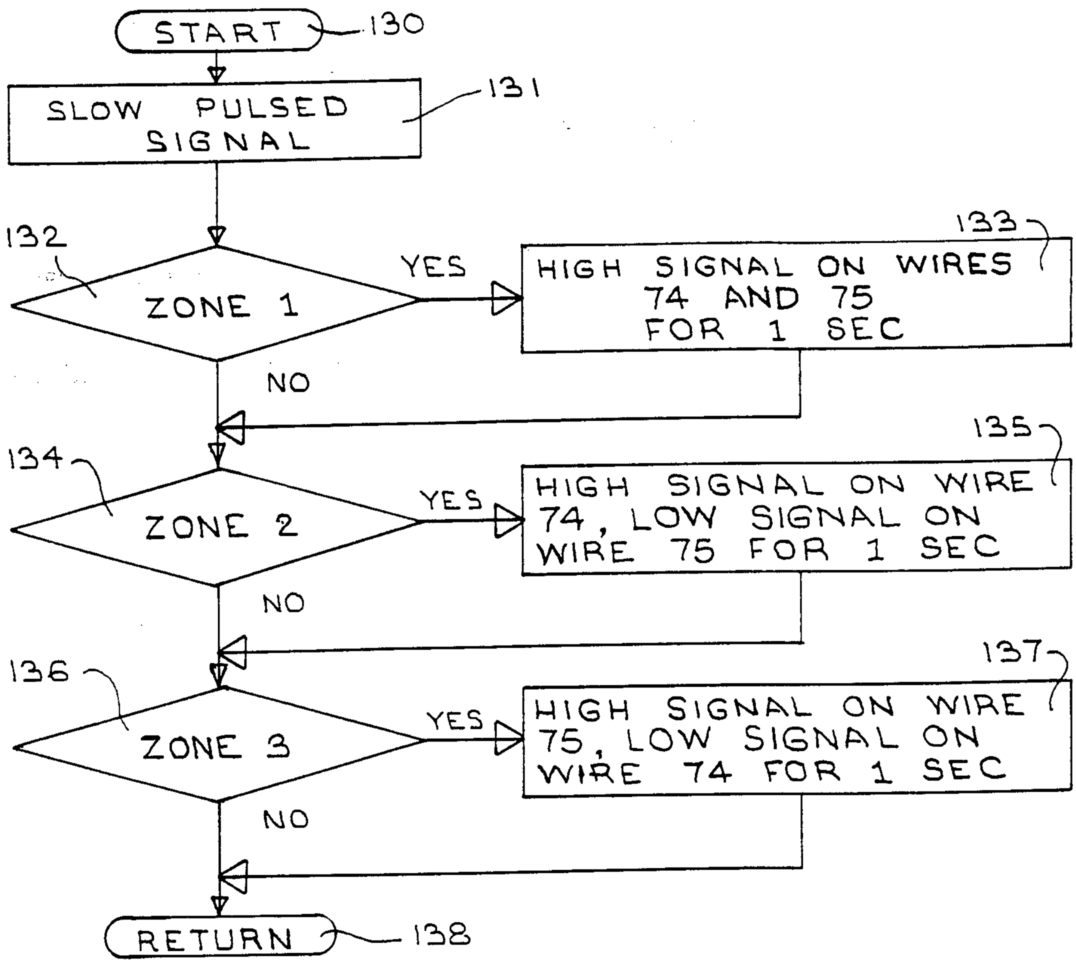

START
130
SLOW PULSED SIGNAL
131
132
ZONE 1
YES
HIGH SIGNAL ON WIRES 74 AND 75 FOR 1 SEC
133
NO
134
ZONE 2
YES
HIGH SIGNAL ON WIRE 74, LOW SIGNAL ON WIRE 75 FOR 1 SEC
135
NO
136
ZONE 3
YES
HIGH SIGNAL ON WIRE 75, LOW SIGNAL ON WIRE 74 FOR 1 SEC
137
NO
RETURN
138

FIG 4

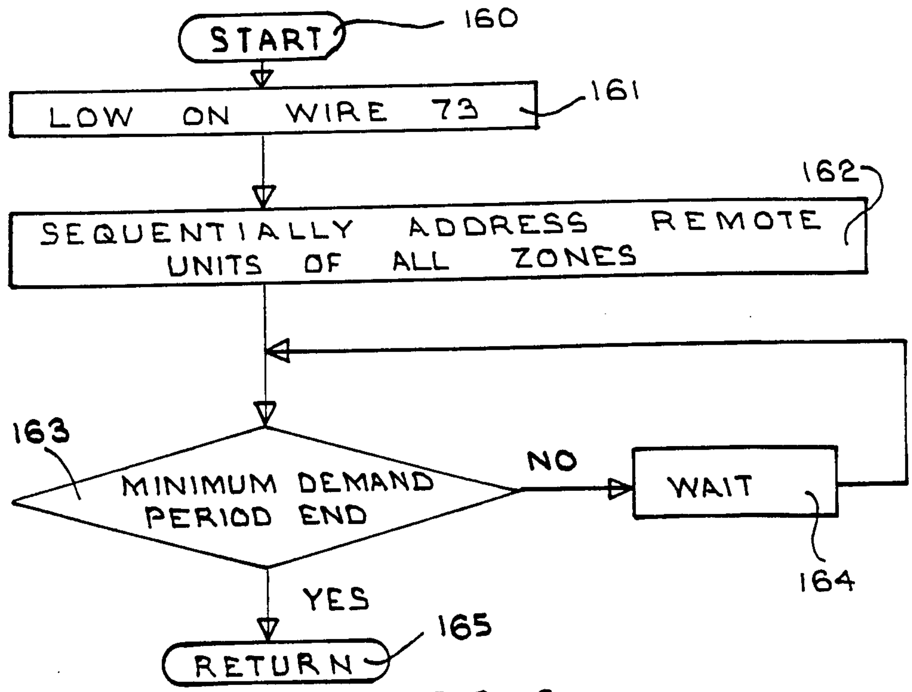

START
160
LOW ON WIRE 73
161
SEQUENTIALLY ADDRESS REMOTE UNITS OF ALL ZONES
162
163
MINIMUM DEMAND PERIOD END
NO
WAIT
164
YES
RETURN
165

FIG 6

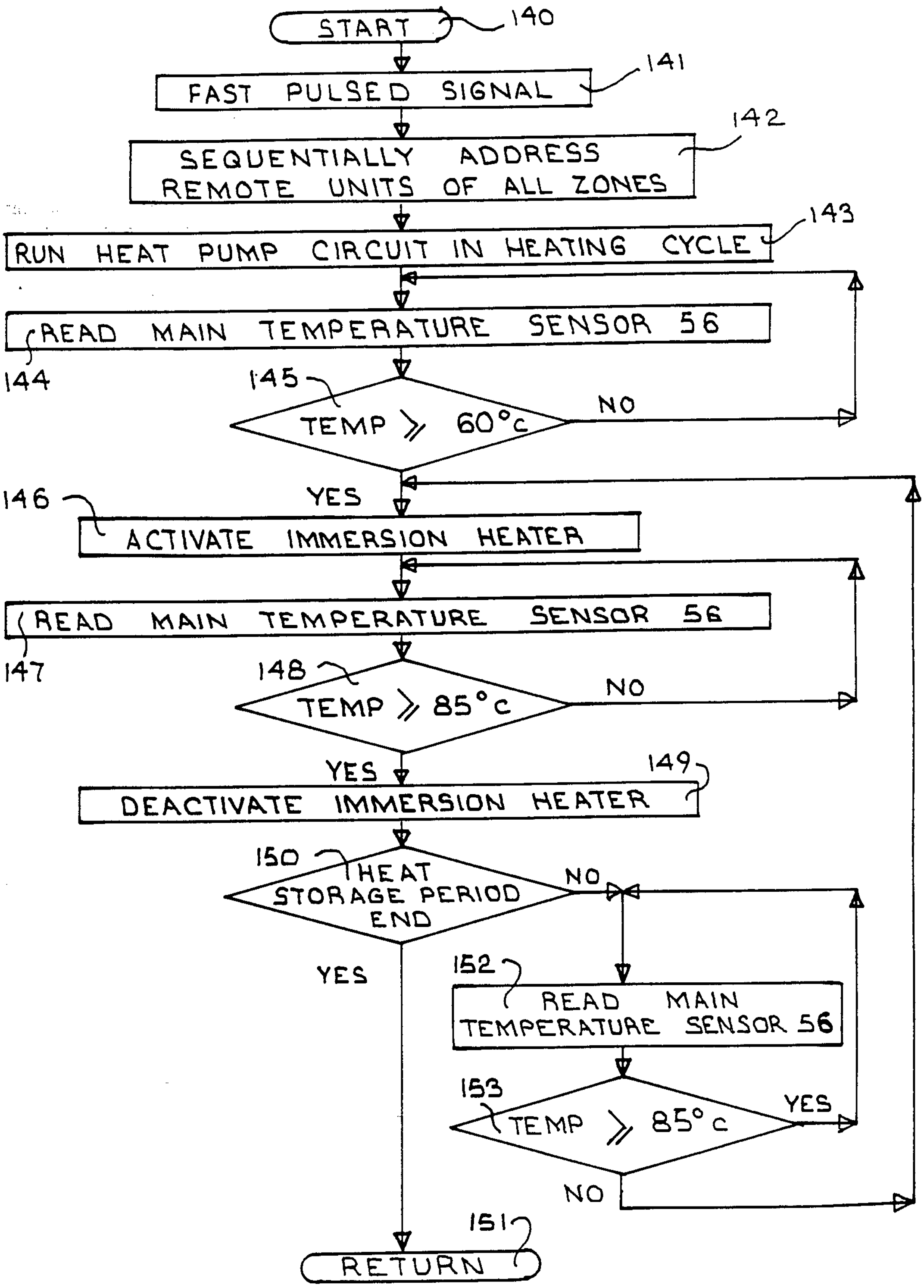

START
140
FAST PULSED SIGNAL
141
SEQUENTIALLY ADDRESS REMOTE UNITS OF ALL ZONES
142
RUN HEAT PUMP CIRCUIT IN HEATING CYCLE
143
READ MAIN TEMPERATURE SENSOR 56
144
145
TEMP ≥ 60°c
NO
YES
146
ACTIVATE IMMERSION HEATER
READ MAIN TEMPERATURE SENSOR 56
147
148
TEMP ≥ 85°c
NO
YES
149
DEACTIVATE IMMERSION HEATER
150
HEAT STORAGE PERIOD END
NO
YES
152
READ MAIN TEMPERATURE SENSOR 56
153
TEMP ≥ 85°c
YES
NO
151
RETURN

FIG 5

INTERNATIONAL SEARCH REPORT

Intern. ial Application No
PCT/IE 94/00009

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 F24D11/02 F24D19/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 F24D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE,A,25 17 610 (STIEBEL ELTRON GMBH & CO KG) 4 November 1976 see claims; figures ---	1
A	DE,A,34 07 453 (DIETRICH) 12 September 1985 see claims; figures -----	1,46

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
9 May 1994	26.05.94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van Gestel, H

INTERNATIONAL SEARCH REPORT

Inten   .ial Application No
PCT/IE 94/00009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-2517610	04-11-76	NONE	
DE-A-3407453	12-09-85	NONE	

Form PCT/ISA/210 (patent family annex) (July 1992)