

AN INTEGRATED AIR CONDITIONING AND LIQUID HEATING SYSTEM

FIELD OF THE INVENTION

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The invention relates to the field of heat recovery systems, particularly integrated air conditioning and liquid heating systems. More particularly, the invention relates to an integrated air conditioning and liquid heating system for providing switchable operation modes including space cooling, liquid heating or both with similar or different cooling load and heating load.

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BACKGROUND OF THE INVENTION

Energy recovery involves a process of converting waste materials into usable heat, electricity or fuel. It has been widely practised in the manufacturing industry as a cost reduction approach. In recent years, energy recovery is also being adopted in residential buildings in line with rising global environmental awareness. For example, heat pump water heaters are installed at homes to capture waste heat generated by a refrigeration process and convert it into thermal energy for heating shower water.

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Various integrated refrigeration and liquid heating systems have been introduced to the market. For example, a combined refrigerant circuit and hot water preheater was disclosed in US4492092. With advances in technology, integrated refrigeration and liquid heating systems now also offer various operating modes. US4399664 had disclosed a refrigeration circuit for heat pump water heater having six operating modes: one for heating a space, one for heating a space and a liquid, one for cooling a space, two for cooling a space and heating a liquid, and one for heating the liquid without modifying the air in the space. Nevertheless, US4399664 fails to provide a solution that allows space cooling and liquid heating with cooling load being substantially different from the heating load.

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Therefore, there exists a strong need for an integrated refrigeration and liquid heating system that provides space cooling and liquid heating with cooling load being substantially different

from the heating load. In addition, it is preferred that the system provides switchable operating modes which include space cooling only, liquid heating only and both space cooling and liquid heating, with the cooling load and heating load being either similar or different.

5 SUMMARY OF THE INVENTION

The primary object of the invention is to provide an integrated air conditioning and liquid heating system configured to provide switchable operating modes, including space cooling, liquid heating, and both space cooling and liquid heating.

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Another object of the invention is to provide an integrated air conditioning and liquid heating system configured to selectively activate and configure the function of the heat exchangers in the system for providing switchable operation modes.

15 Further another object of the invention is to provide an integrated air conditioning and liquid heating system configured to switchably provide various operating modes with minimal number of flow paths within the refrigeration circuit and liquid heating circuit.

20 Still another object of the invention is to provide an integrated air conditioning and liquid heating system configured to provide simultaneous space cooling and liquid heating, with the cooling load being the same as the heating load.

25 Yet another object of the invention is to provide an integrated air conditioning and liquid heating system configured to provide simultaneous space cooling and liquid heating, with the cooling load being substantially higher than the heating load. Particularly, the system comprises a desuperheater, a condenser and an evaporator in the refrigeration circuit.

30 Further another object of the invention is to provide an integrated air conditioning and liquid heating system configured to provide simultaneous space cooling and liquid heating, with the cooling load being substantially lower than the heating load. Particularly, the system comprises two evaporators and a condenser in the refrigeration circuit.

At least one of the preceding objects is met, in whole or in part, by the present invention, in which the embodiment of the present invention describes an integrated air conditioning and liquid heating system comprising a refrigeration circuit having one or more primary heat exchangers; a liquid heating circuit; and a secondary heat exchanger connected to the refrigeration circuit and liquid heating circuit; wherein the system is configured to selectively activate and configure function of the primary heat exchangers and secondary heat exchanger for providing switchable operation modes including space cooling by the refrigeration circuit, liquid heating by the liquid heating circuit or both with similar or different cooling load and heating load.

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In a preferred embodiment of the invention, the refrigeration circuit comprises a first primary heat exchanger, a compressor and a second primary heat exchanger.

In a preferred embodiment of the invention, the first primary heat exchanger is located downstream of the second primary heat exchanger and upstream of the compressor.

In a preferred embodiment of the invention, the secondary heat exchanger is located downstream of the compressor and upstream of the second primary heat exchanger.

In a preferred embodiment of the invention, the system further comprises a first expansion valve located downstream of the second primary heat exchanger and upstream of the first primary heat exchanger.

In a preferred embodiment of the invention, the system further comprises a first control valve located at a first sub path within the refrigeration circuit, wherein the first sub path is positioned downstream of the second primary heat exchanger and upstream of the compressor.

In a preferred embodiment of the invention, the system further comprises a second control valve located either at a first position or a second position, wherein the first position is at downstream of the secondary heat exchanger and upstream of the second primary heat exchanger, and the second position is positioned at a second sub path within the refrigeration

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circuit that is downstream of the compressor and upstream of the second primary heat exchanger.

5 In a preferred embodiment of the invention, the system further comprises a second expansion valve located either at a third sub path when the second control valve is at the first position, or downstream of the secondary heat exchanger and upstream of the second primary heat exchanger when the second control valve is at the second position.

10 In a preferred embodiment of the invention, the system further comprises at least one liquid receiver for storing excess refrigerant that is positioned downstream of the secondary heat exchanger and upstream of the second expansion valve, and/or downstream of the second primary heat exchanger and upstream of the first expansion valve.

15 In a preferred embodiment of the invention, the primary heat exchanger functions as a condenser or evaporator.

In a preferred embodiment of the invention, the secondary heat exchanger functions as a condenser or desuperheater.

20 In a preferred embodiment of the invention, the operating modes include any one or a combination of a first operating mode that provides space cooling by having the first primary heat exchanger functioning as the evaporator, the second primary heat exchanger functioning as the condenser and the secondary heat exchanger being inoperative; a second operating mode that provides fluid heating by having the first primary heat exchanger being inoperative, the
25 second primary heat exchanger functioning as the evaporator and the secondary heat exchanger functioning as the condenser; a third operating mode that provides both space cooling and fluid heating with the cooling load being similar to the heating load, by having the first primary heat exchanger functioning as the evaporator, the second primary heat exchanger being inoperative and the secondary heat exchanger functioning as the condenser;
30 a fourth operating mode that provides both space cooling and fluid heating with the cooling load being substantially higher than the heating load, by having the first primary heat exchanger functioning as the evaporator, the second primary heat exchanger functioning as

the condenser and the secondary heat exchanger functioning as the desuperheater; and a fifth operating mode that provides both space cooling and fluid heating, with the cooling load being substantially lower than the heating load, by having the first primary heat exchanger functioning as the evaporator, the second primary heat exchanger functioning as the evaporator or condenser and the secondary heat exchanger functioning as the condenser.

The present invention also describes an integrated air conditioning and liquid heating system comprising a refrigeration circuit, having a first primary heat exchanger and a second primary heat exchanger; a liquid heating circuit; and a secondary heat exchanger connected to the refrigeration circuit and liquid heating circuit; wherein the system provides space cooling by the refrigeration circuit and fluid heating by the liquid heating circuit, with the cooling load being different from the heating load.

In a preferred embodiment of the invention, the first primary heat exchanger functions as an evaporator, the second primary heat exchanger functions as a condenser and the secondary heat exchanger functions as a desuperheater for providing space cooling and fluid heating, with the cooling load being substantially higher than the heating load.

In a preferred embodiment of the invention, the first primary heat exchanger functions as an evaporator, the second primary heat exchanger functions as an evaporator or a condenser and the secondary heat exchanger functions as a condenser for providing space cooling and fluid heating, with the cooling load being substantially lower than the heating load.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawings the preferred embodiments from an inspection of which when considered in connection with the following description, the invention, its construction and operation and many of its advantages will be readily understood and appreciated.

Figure 1 is a schematic diagram of an integrated air conditioning and liquid heating system according to the first preferred embodiment of the present invention.

Figure 2 is a schematic diagram of the system according to the first preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for cooling a space without heating a liquid, in which the first operating mode is being performed.

Figure 3 is a schematic diagram of the system according to the first preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for heating a liquid without cooling a space, and showing in broken lines the flow of liquid in the liquid heating circuit, in which the second operating mode is being performed.

Figure 4 is a schematic diagram of the system according to the first preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for cooling a space and heating a liquid with similar cooling load and heating load, and showing in broken lines the flow of liquid in the liquid heating circuit, in which the third operating mode is being performed.

Figure 5 is a schematic diagram of the system according to the first preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for cooling a space and heating a liquid with cooling load being higher than heating load, and showing in broken lines the flow of liquid in the liquid heating circuit, in which the fourth operating mode is being performed.

Figure 6 is a schematic diagram of the system according to the first preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for cooling a space and heating a liquid with heating load being higher than cooling load, and showing in broken lines the flow of liquid in the liquid heating circuit, in which the fifth operating mode is being performed.

- Figure 7 is a schematic diagram of an integrated air conditioning and liquid heating system according to the second preferred embodiment of the present invention.
- 5 Figure 8 is a schematic diagram of the system according to the second preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for cooling a space without heating a liquid, in which the first operating mode is being performed.
- 10 Figure 9 is a schematic diagram of the system according to the second preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for heating a liquid without cooling a space, and showing in broken lines the flow of liquid in the liquid heating circuit, in which the second operating mode is being performed.
- 15 Figure 10 is a schematic diagram of the system according to the second preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for cooling a space and heating a liquid with similar cooling load and heating load, and showing in broken lines the flow of liquid in the liquid heating circuit, in which the third operating mode is being performed.
- 20 Figure 11 is a schematic diagram of the system according to the second preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for cooling a space and heating a liquid with cooling load being higher than heating load, and showing in broken lines the flow of liquid in the liquid heating circuit, in which the fourth operating mode is being performed.
- 25 Figure 12 is a schematic diagram of the system according to the second preferred embodiment of the invention, showing in bold lines the flow of refrigerant in the refrigeration circuit for cooling a space and heating a liquid with heating
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load being higher than cooling load, and showing in broken lines the flow of liquid in the liquid heating circuit, in which the fifth operating mode is being performed.

5 DETAILED DESCRIPTION OF THE INVENTION

One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The embodiment described herein is not intended as limitations on the scope of the invention.

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The present invention describes an integrated air conditioning and liquid heating system (100) for providing space cooling, liquid heating or both at the same time. The term “space” as used herein refers to an area, either enclosed or open, in which the air conditioning system discharges conditioned air. In the preferred embodiment of the invention, the conditioned air is cooled air as heat within the space is absorbed. The liquid heating system is preferred to be water heating that can be used in domestic or industrial applications. Yet, any non-hazardous liquid can also be employed in the liquid heating system.

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In the preferred embodiment of the invention, the system (100) comprises a refrigeration circuit (110) for performing a refrigeration cycle with the use of refrigerant, and a liquid heating circuit (120). The refrigeration circuit (110) comprises one or more primary heat exchangers (101) for performing a full or partial heat transfer between refrigerant and ambient air. Preferably, the primary heat exchanger functions as a condenser or evaporator. In addition, the system (100) comprises a secondary heat exchanger (102) connected to the refrigeration circuit (110) and the liquid heating circuit (120) for performing a full or partial heat transfer between the refrigerant and liquid. Preferably, the secondary heat exchanger functions as a condenser or desuperheater. The system (100) is configured to selectively activate and configure the function of the primary heat exchangers (101) and secondary heat exchanger (102) for providing switchable operation modes including space cooling by the refrigeration circuit (110), liquid heating by the liquid heating circuit (120) or both space cooling and liquid heating simultaneously with similar or different cooling load and heating load.

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With reference to Figure 1, the refrigeration circuit (110) comprises a first primary heat exchanger (101a), a second primary heat exchanger (101b), and a compressor (103). The secondary heat exchanger (102) is shared between the refrigeration circuit and liquid heating circuit. The primary heat exchangers (101a, 101b), compressor (103), and the secondary heat exchanger (102) are located at a main path of the refrigeration circuit (100). In terms of refrigerant flow, the first primary heat exchanger (101a) is located downstream of the second primary heat exchanger (101b) and upstream of the compressor (103). The secondary heat exchanger (102) is located downstream of the compressor (103) and upstream of the second primary heat exchanger (101b). A first expansion valve (104a) is provided for controlling flow of refrigerant from the second primary heat exchanger (101b) into the first primary heat exchanger (101a). Thus, it is located downstream of the second primary heat exchanger (101b) and upstream of the first primary heat exchanger (101a) within the main path of the refrigeration circuit (110). The system (100) further comprises a first control valve (106a) located at a first sub path (110a) within the refrigeration circuit (110) for controlling refrigerant flow into the compressor (103) from the second primary heat exchanger (101b). The first sub path (110a) is positioned downstream of the second primary heat exchanger (101b) and upstream of the compressor (103) that allows refrigerant flow to bypass the first primary heat exchanger (101a). When the first control valve (106a) is shut off and the first expansion valve (104a) is open, refrigerant flows from the second primary heat exchanger (101b) into the first primary heat exchanger (101a). Conversely, when the first control valve (106a) is open and the first expansion valve (104a) is shut off, refrigerant travels from the second primary heat exchanger (101b) into the compressor (103) along the first sub path (110a).

The refrigeration circuit (100) comprises a second control valve (106b) located either at a first position or a second position. The first position is at downstream of the secondary heat exchanger (102) and upstream of the second primary heat exchanger (101b) within the main path of the refrigeration circuit (110), whereas the second position is positioned at a second sub path (110b) within the refrigeration circuit (110). The second sub path (110b) is parallel to the first sub path (110a), and is positioned downstream of the compressor (103) and upstream of the second primary heat exchanger (101b), that allows refrigerant flow to bypass the secondary heat exchanger (102).

Pursuant to a first preferred embodiment of the invention when the second control valve (106b) is situated at the first position as depicted in Figures 1 to 6, the refrigeration circuit (100) further comprises a third sub path (110c) that is located downstream of the secondary heat exchanger (102) and upstream of the second primary heat exchanger (101b). A second expansion valve (104b), which may be arranged parallelly to the second control valve (106b), is provided at the third sub path (110c) which serves as an alternate route for the refrigerant to travel therethrough. Therefore, the refrigerant can flow either through the second control valve (106b) or through the second expansion valve (104b).

According to a second preferred embodiment of the invention when the second control valve (106b) is located at the second position as shown in Figures 7 to 12, the second expansion valve (104b) is located downstream of the secondary heat exchanger (102) and upstream of the second primary heat exchanger (101b). In this embodiment, refrigerant can be regulated to flow through the second sub path (110b) when it exits from the compressor (103) and into the second primary heat exchanger (101b) at the time when the second control valve (106b) is open, instead of traveling through the secondary heat exchanger (102) and the second expansion valve (104b). In this embodiment of the invention shown in Figures 7 to 12, the refrigeration circuit (110) further comprises at least one liquid receiver (107) for storing excess refrigerant that is positioned downstream of the secondary heat exchanger (102) and upstream of the second expansion valve (104b), and/or downstream of the second primary heat exchanger (101b) and upstream of the first expansion valve (104a). It should, however, be noted that, even though the liquid receiver (107) is only shown in the figures of the second preferred embodiment of the invention in this disclosure, the liquid receiver (107) can also be included in the first preferred embodiment of the invention shown in Figures 1 to 6.

As described previously, the secondary heat exchanger (102) is connected to both the refrigeration circuit (110) and the liquid heating circuit (120). It is located downstream of the compressor (103) and upstream of the second primary heat exchanger (101b) in the refrigeration circuit (110). In the liquid heating circuit (120), the secondary heat exchanger (102) is located downstream of a liquid supply apparatus (105) such as a liquid pump that selectively allows liquid to pass therethrough. The heated liquid may be discharged from the liquid heating circuit (120) for immediate use or to be recirculated within the liquid heating

circuit (120) and subjected for further heat transfer in the secondary heat exchanger (102). The liquid heating circuit may further comprise a liquid storage tank for storing heated liquid. The liquid storage tank may be equipped with a temperature control device that detects the temperature of the liquid stored in the liquid storage tank and recirculates the stored liquid
5 through the liquid heating circuit when the detected temperature is below a pre-set temperature.

In the preferred embodiment of the invention, the system (100) provides five switchable operating modes. These operating modes are executable by either of the first and second preferred embodiments of the invention, in which Figures 1 to 6 illustrate the first preferred
10 embodiment whereas Figures 7 to 12 illustrate the second preferred embodiment.

The first operating mode provides only space cooling. The refrigerant flow path when the first operating mode is actuated in the first and second preferred embodiments of the invention are respectively depicted in Figure 2 and Figure 8. In the first preferred embodiment depicted in
15 Figure 2, refrigerant travels along the main path of the refrigeration circuit (100) without flowing through the first and third sub paths (110a, 110c). Refrigerant discharged from the compressor (103) flows through the secondary heat exchanger (102) into the second primary heat exchanger (101b), then into the first primary heat exchanger (101a) and finally returning to the compressor (103) to repeat the refrigeration cycle. In the second preferred embodiment
20 depicted in Figure 8, refrigerant discharged from the compressor (103) flows through the second sub path (110b) to the second primary heat exchanger (101b), then into the first primary heat exchanger (101a) and back into the compressor (103) for repeating the refrigeration cycle. The second control valve (106b) in the second sub path (110b) is set to an open state.

25 In the first operating mode, the secondary heat exchanger (102) is set to be inoperative while the second primary heat exchanger (101b) is configured to function as a condenser. The first expansion valve (104a) is set to allow refrigerant leaving the second primary heat exchanger (101b) to pass therethrough to the first primary heat exchanger (101a) before returning to the compressor (103). The first primary heat exchanger (101a) functions as an evaporator in this
30 operating mode whereby heat from the space is absorbed by the refrigerant flowing through it, thereby cooling the space. Heated refrigerant then returns to the compressor (103). The liquid

heating circuit (120) is inactive when the liquid supply apparatus (105) is set to block liquid flow. The first control valve (106a) is set to a closed state.

Unlike the first operating mode, the second operating mode provides only liquid heating.

5 Figure 3 and Figure 9 respectively shows the refrigerant flow and liquid flow when the second operating mode is actuated in the first and second preferred embodiments of the invention. With reference to Figure 3 and Figure 9, refrigerant circulates within a portion of the refrigeration circuit (100) only. To be specific, the refrigerant travels through the compressor (103) and the secondary heat exchanger (102) at the main path, the second expansion valve (104b) at the third sub path (101c), the second primary heat exchanger (101b) at the main path,
10 and the first control valve (106a) at the first sub path (110a) in the first preferred embodiment. In the second preferred embodiment, the refrigerant travels through the compressor (103), secondary heat exchanger (102), the second expansion valve (104b) and the second primary heat exchanger (101b) at the main path, and the first control valve (106a) at the first sub path
15 (110a). Refrigerant discharged from the compressor (103) flows to the secondary heat exchanger (102), which is configured to function as a condenser. The liquid heating circuit (120) is activated whereby the liquid supply apparatus (105) of the liquid heating circuit (120) is set to allow liquid to pass through the secondary heat exchanger (102) for heat transfer to happen between refrigerant and liquid. Refrigerant in the secondary heat exchanger (102)
20 releases heat which is then absorbed by the liquid. Heated liquid leaves the secondary heat exchanger (102) while cooled refrigerant flows to the second primary heat exchanger (101b) that functions as an evaporator.

In both the embodiments shown in Figure 3 and Figure 9, refrigerant travels along the
25 compressor (103), secondary heat exchanger (101b) and second primary heat exchanger (101b) at the main path without traveling through the first primary heat exchanger (101a) since the first control valve (106a) is opened to allow refrigerant to flow through the first sub path (110a). The second control valve (106b) and first expansion valve (104a) are closed. The first primary heat exchanger (101a) is inoperative for cooling the space since refrigerant does not travel
30 through it, whereas liquid traveling through the liquid heating circuit (102) is heated by heat released by the secondary heat exchanger (102).

Figure 4 depicts the refrigerant flow of the third operating mode in the first preferred embodiment of the invention. The third operating mode provides both space cooling and fluid heating simultaneously, with the cooling load being similar to the heating load. Refrigerant circulates within the main path of the refrigeration circuit (110) through the compressor (103), primary heat exchangers (101a, 101b) and secondary heat exchanger (102) without flowing through the first and third sub paths (110a, 110c) while liquid circulates within the liquid heating circuit (120). Refrigerant discharged from the compressor (103) flows through the secondary heat exchanger (102), in which heat transfer between refrigerant and liquid takes places. The secondary heat exchanger (102) functions as a condenser whereby heat from the refrigerant is transferred to the liquid. Heated liquid and cooled refrigerant then leave the secondary heat exchanger (102). Although refrigerant flows through the second primary heat exchanger (101b), the second primary heat exchanger (101b) is configured to be inoperative whereby refrigerant merely flows therethrough without performing heat transfer. In this operating mode, the first expansion valve (104a) is set to allow refrigerant from the second primary heat exchanger (101b) to flow into the first primary heat exchanger (101a) where a second heat transfer takes places. The first primary heat exchanger (101a) functions as an evaporator whereby heat from the space is absorbed by the refrigerant. Heated refrigerant then returns to the compressor (103). In this embodiment, the first control valve (106a) is shut off to prevent refrigerant from flowing into the compressor (103) without undergoing heat transfer performed by the first primary heat exchanger (101a).

In the second preferred embodiment of the invention as shown in Figure 10 for executing the third operating mode, the refrigerant flows along the main path of the refrigeration circuit (110) without passing through the first and second sub paths (110a, 110b), while liquid flows through the liquid heating circuit (120). Refrigerant discharged from the compressor (103) flows through the secondary heat exchanger (102), in which heat transfer between refrigerant and liquid takes places. Subsequently, refrigerant flows through the second primary heat exchanger (101b) and the first primary heat exchanger (101a) prior to returning to the compressor (103). The secondary heat exchanger (102) functions as a condenser whereas the second primary heat exchanger (101b) is set to be inoperative whereby refrigerant merely flows therethrough without performing heat transfer. The first primary heat exchanger (101a) functions as an evaporator. The first expansion valve (104a) is configured to permit partial

refrigerant flow while the second expansion valve (104b) is set to allow complete refrigerant flow.

5 The refrigerant flow and liquid flow of the fourth operating mode in the first preferred embodiment of the invention are shown in Figure 5. In this operating mode, both space cooling and fluid heating are provided at the same time, with the cooling load being substantially higher than the heating load. The fourth operating mode is executable when the heated liquid is stored in a liquid storage tank and the stored liquid is subjected for further heating after its temperature has dropped below the pre-set temperature. The refrigerant flow and liquid flow
10 paths in the fourth operating mode are similar to the ones in the third operating mode except for the functions of the first primary heat exchanger (101a), second primary heat exchanger (101b) and secondary heat exchanger (102), in which refrigerant flows through the main path of the refrigeration circuit (100) without traveling through the first and third sub paths (110a, 110c) while liquid travels through the liquid heating circuit (120).

15 Unlike the third operating mode, in the fourth operating mode, the secondary heat exchanger (102) serves as a desuperheater as relatively lower heating load is required. The refrigerant is not fully condensed in the secondary heat exchanger (102). The second primary heat exchanger (101b) is activated and functions as a condenser in which refrigerant discharged
20 from the secondary heat exchanger will be further condensed. In this operating mode, the first primary heat exchanger (101a) functions as an evaporator. Since the space cooling load is substantially higher than the liquid heating load, refrigerant is condensed or releases heat at least twice before it is used in the first primary heat exchanger (101a) to absorb heat from the space.

25 On the other hand, Figure 11 illustrates the refrigerant flow and liquid flow of the fourth operating mode of the second preferred embodiment of the invention. The refrigerant and liquid flow paths are similar to the third operating mode of the second preferred embodiment as depicted in Figure 10. Refrigerant circulates through the main path of the refrigeration circuit (100) passing through the compressor (103), secondary heat exchanger (102), second
30 primary heat exchanger (101b) and first primary heat exchanger (101a) without flowing through the first and second sub paths (110a, 110b). At the same time, liquid receives heat

discharged from refrigerant at the secondary heat exchanger (102) and heats liquid flowing through the liquid heating circuit (120). In the fourth operating mode, the secondary heat exchanger (102) functions as a desuperheater, the second primary heat exchanger (101b) functions as a condenser, and the first primary heat exchanger (101a) functions as an evaporator. The first expansion valve (104a) is set to allow partial refrigerant flow while the second expansion valve (104b) is set to allow complete refrigerant flow.

Figure 6 illustrates the refrigerant flow and liquid flow of the fifth operating mode in the first preferred embodiment of the invention whereby both space cooling and fluid heating are provided simultaneously, with the cooling load being substantially lower than the heating load. The refrigerant flows through the compressor (103), secondary heat exchanger (102) and into the third sub path (110c) through the second expansion valve (104b) before entering the second primary heat exchanger (101b) and the first primary heat exchanger (101a), whereas liquid flows along the liquid heating path (120). In this embodiment the second control valve (106b) is shut off to block refrigerant from flowing therethrough prior to entering the second primary heat exchanger (101b).

In the second preferred embodiment of the invention as shown in Figure 12 for executing the fifth operating mode, the refrigerant flows through the main path of the refrigeration circuit (100) while liquid flows through the liquid heating circuit (120). The refrigerant does not flow through the first and second sub paths (110a, 110b). Refrigerant discharged from the compressor (103) flows through the secondary heat exchanger (102), in which heat transfer between refrigerant and liquid takes place. Next, refrigerant flows through the second primary heat exchanger (101b) and the first primary heat exchanger (101a) prior to returning to the compressor (103).

In the fifth operating mode, the secondary heat exchanger (102) is activated and serves as a condenser while the first primary heat exchanger (101a) is activated and serves as an evaporator. The second primary heat exchanger (101b) is operative and can be set to function as either an evaporator or a condenser. In the embodiment whereby the second primary heat exchanger (101b) is set to function as evaporator, the refrigerant absorbs heat from the space at least twice before it transfers heat to the liquid. The first expansion valve (104a) is set to

allow complete refrigerant flow while the second expansion valve (104b) is set to allow partial refrigerant flow in this embodiment.

5 In another embodiment of the fifth operating mode whereby the second primary heat exchanger (101b) is set to function as condenser, refrigerant passing through the second primary heat exchanger (101b) does not undergo heat transfer with the ambient air. Instead, fan speed of the second primary heat exchanger (101b) is lowered in order to reduce air flow through the second primary heat exchanger (101b). Consequently, condensing pressure in the second primary heat exchanger (101b) is increased and temperature of the refrigerant is
10 thereby increased. If the condensing pressure is insufficient to achieve the liquid heating capacity, speed of compressor is increased. The first primary heat exchanger (101a) will be set to an inoperative status if the space cooling load is substantially low or negligible.

The present invention also describes an integrated air conditioning and liquid heating system
15 (100) comprising a refrigeration circuit (110) for performing a full or partial heat transfer between refrigerant and ambient air, having a first primary heat exchanger (101a) and a second primary heat exchanger (101b); a liquid heating circuit (120); and a secondary heat exchanger (102) for performing either a full or partial heat transfer between the refrigerant and liquid, and being connected to the refrigeration circuit (110) and liquid heating circuit (120); wherein
20 the system (100) provides space cooling by the refrigeration circuit (110) and fluid heating by the liquid heating circuit (120), with the cooling load being different from the heating load.

In a preferred embodiment of the invention, the first primary heat exchanger (101a) is an evaporator, the second primary heat exchanger (101b) is a condenser and the secondary heat
25 exchanger (102) is a desuperheater for providing space cooling and fluid heating, with the cooling load being substantially higher than the heating load. Particularly, the refrigeration and liquid flow paths are the fourth operating mode as described in the preceding description. More particularly, the refrigerant circulates within the main path(110b) of the refrigeration circuit (100), without passing through any of the sub paths (110a, 110b, 110c) in both the first
30 and second preferred embodiments shown respectively in Figure 5 and Figure 11.

In a preferred embodiment of the invention, the first primary heat exchanger (101a) is an evaporator, the second primary heat exchanger (101b) is an evaporator or a condenser and the secondary heat exchanger (102) is a condenser for providing space cooling and fluid heating, with the cooling load being substantially lower than the heating load. Particularly, the refrigeration and liquid flow paths are the fifth operating mode as described in the preceding description. More particularly, the refrigerant flows through the compressor (103), secondary heat exchanger (102) and into the third sub path (110c) through the second expansion valve (104b) before entering the second primary heat exchanger (101b) and the first primary heat exchanger (101a) in the first preferred embodiment shown in Figure 6.