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(54) **INTEGRATED HEAT PUMP AND WATER HEATING CIRCUIT**

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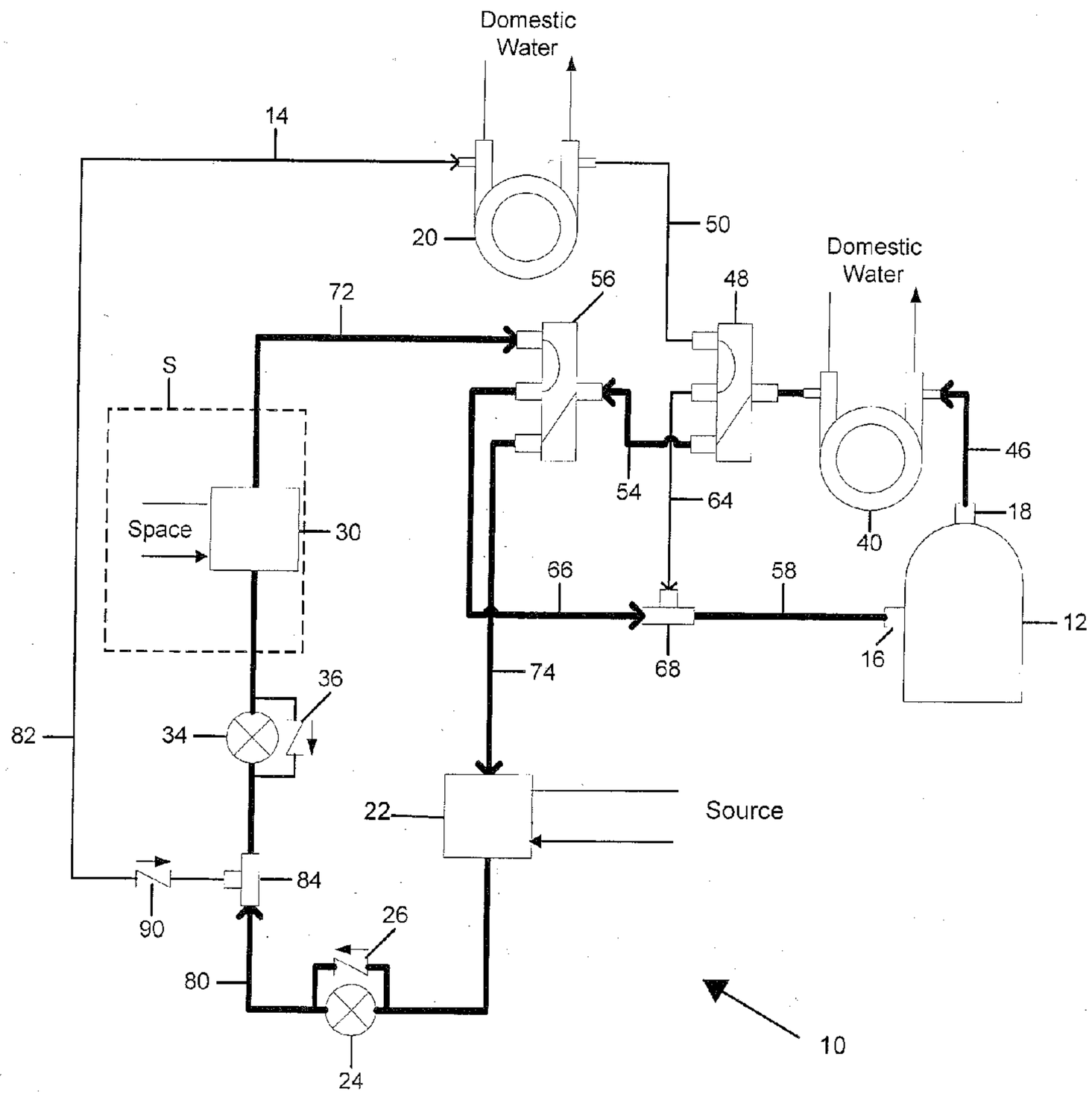
(57) **ABSTRACT**

An integrated heat pump and water heating circuit for space heating and cooling and heating domestic water. The circuit includes a first heat exchanger for the domestic water, a second heat exchanger for the source (heat source/sink) with a first dedicated expansion valve, and a third exchanger for the space with a second dedicated expansion valve. The circuit has four modes of operation. In the first mode, the space is cooled and heat is rejected to the source. In the second mode, the space is heated while heat is absorbed from the source. In the third mode, the circuit absorbs heat from the source and heats the water supply. In a fourth mode, the water supply is heated and the space is cooled simultaneously. In each mode, one heat exchanger is inactive, and the charge from the inactive heat exchanger is reclaimed to the suction side of the compressor.



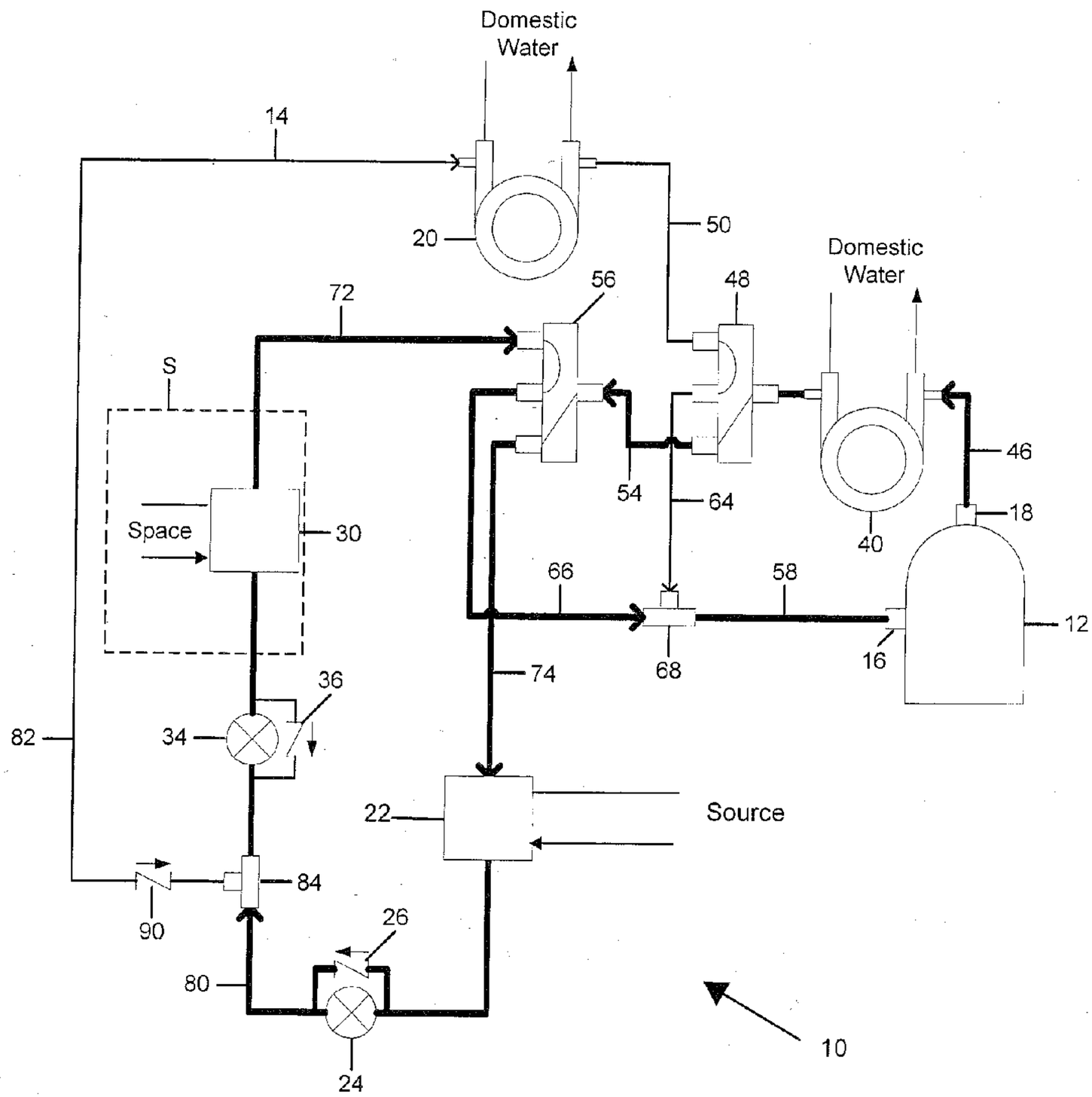

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FIG. 1

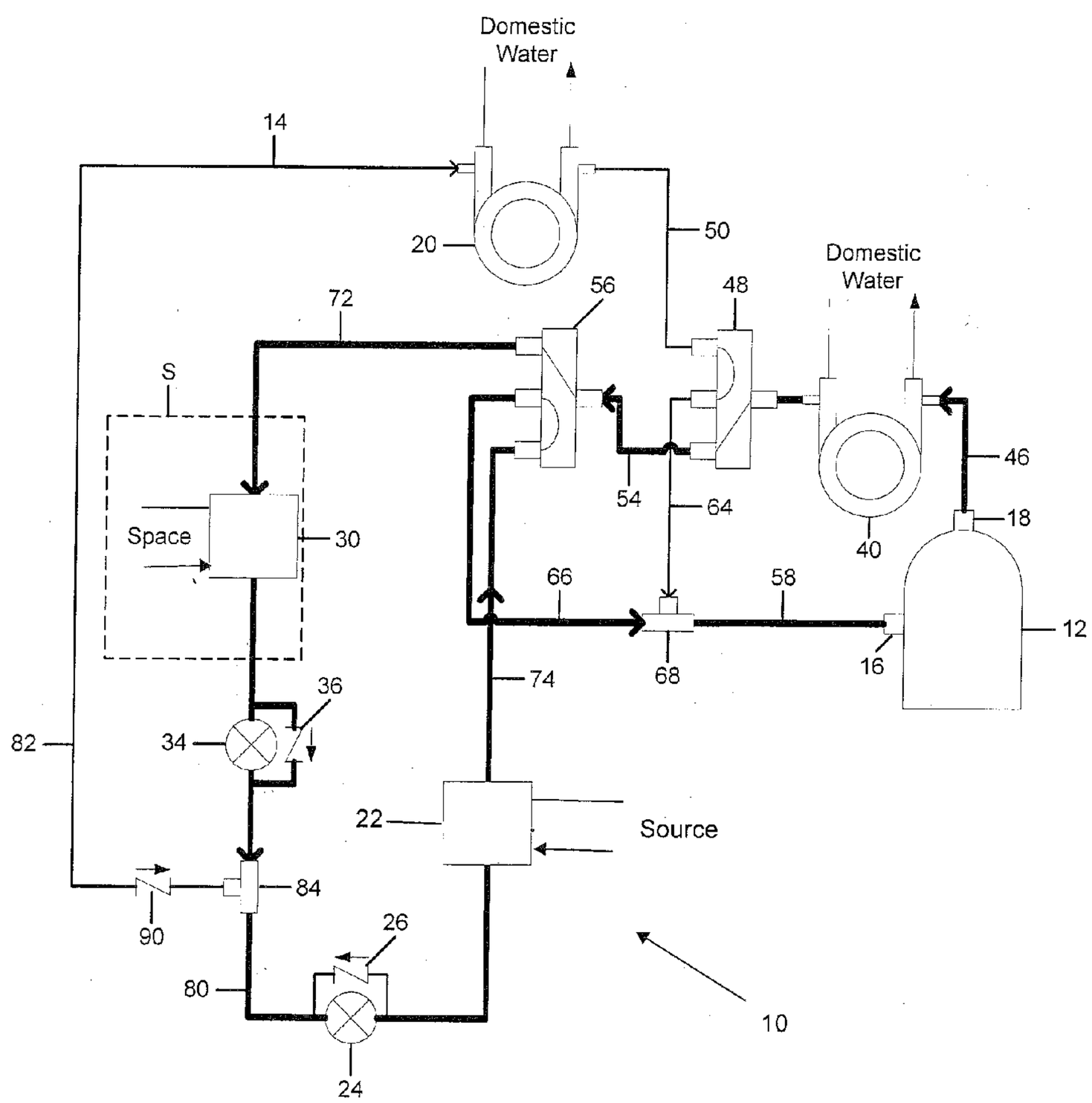
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FIG. 2

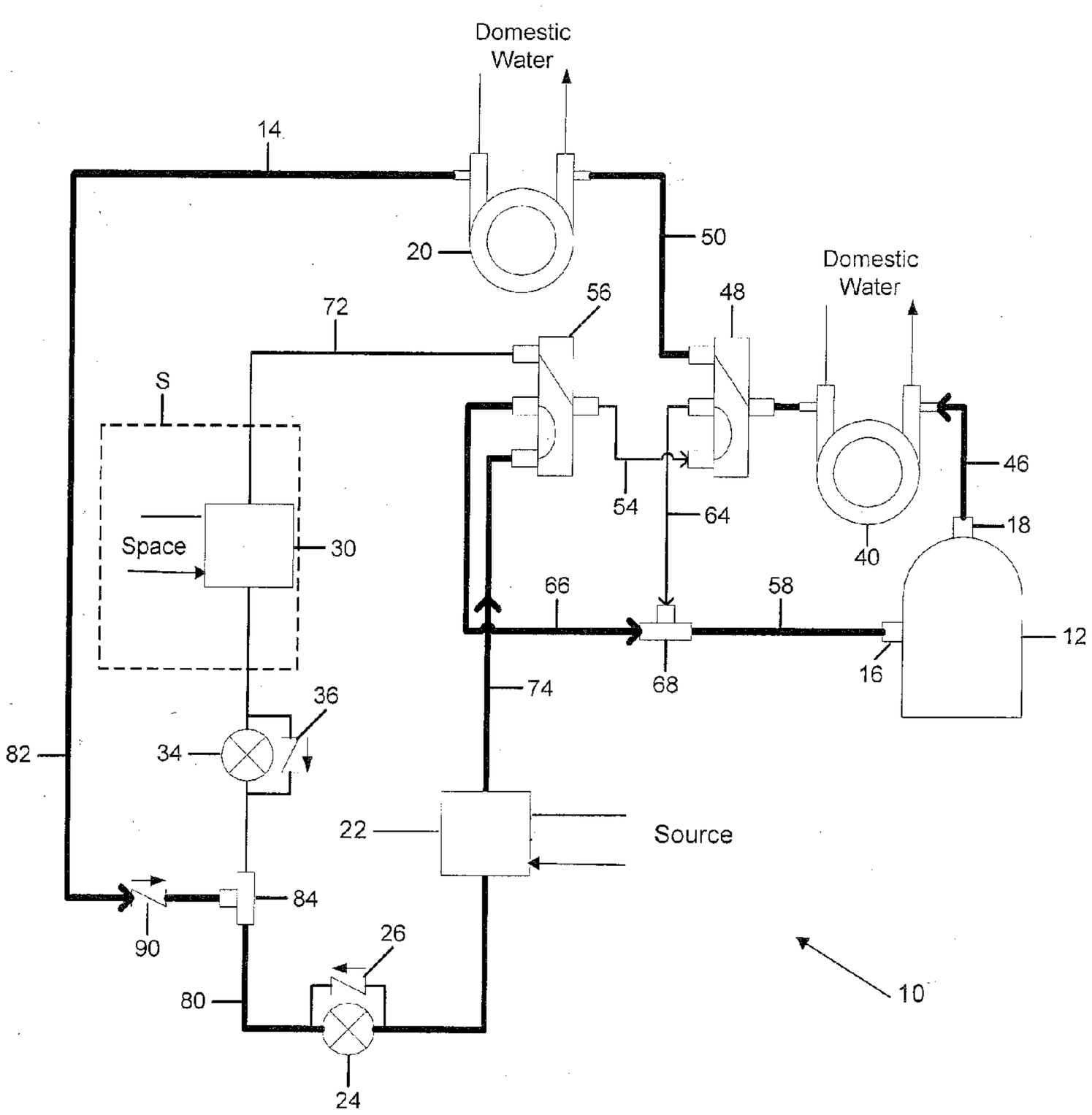
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FIG. 3

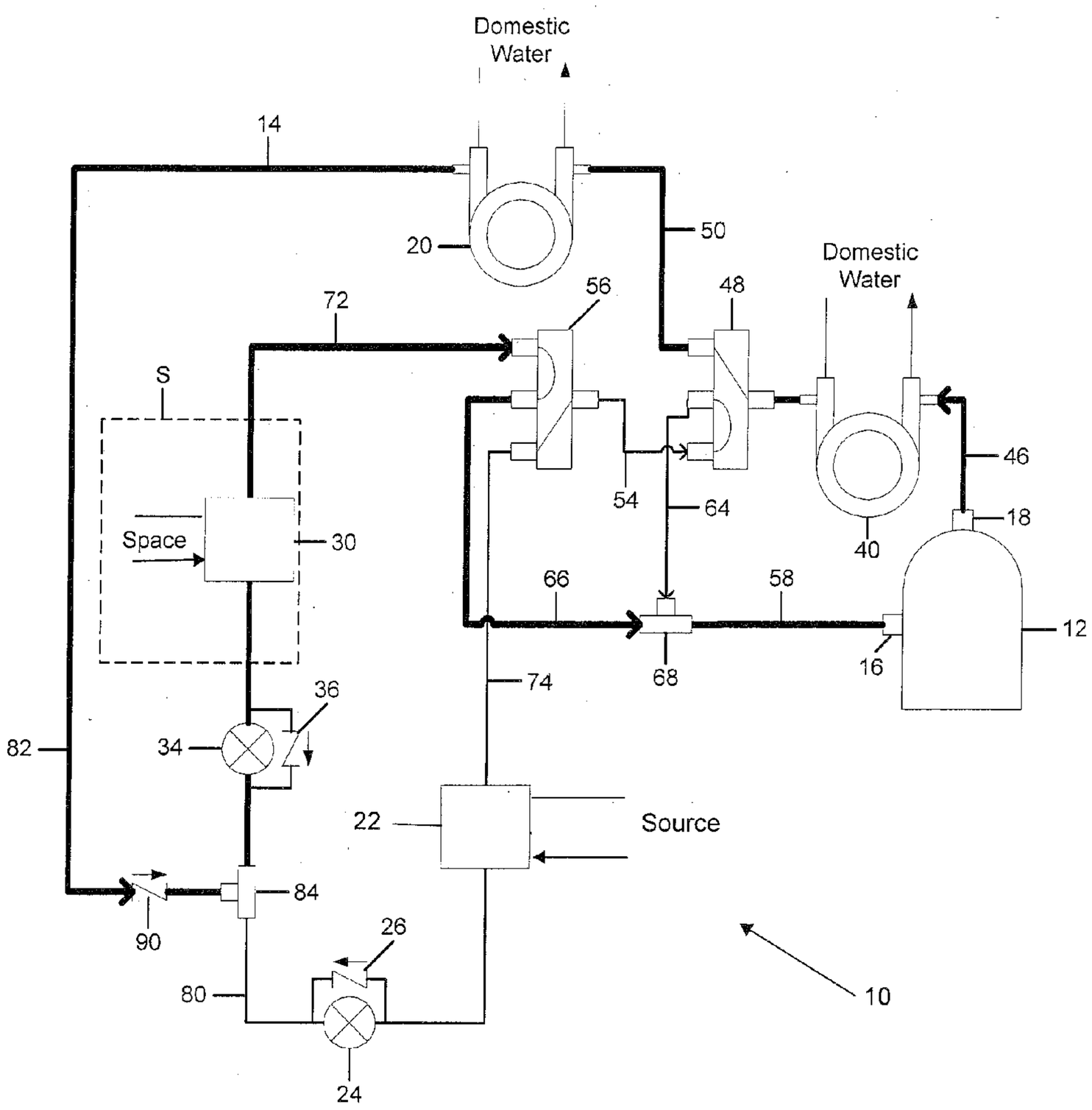
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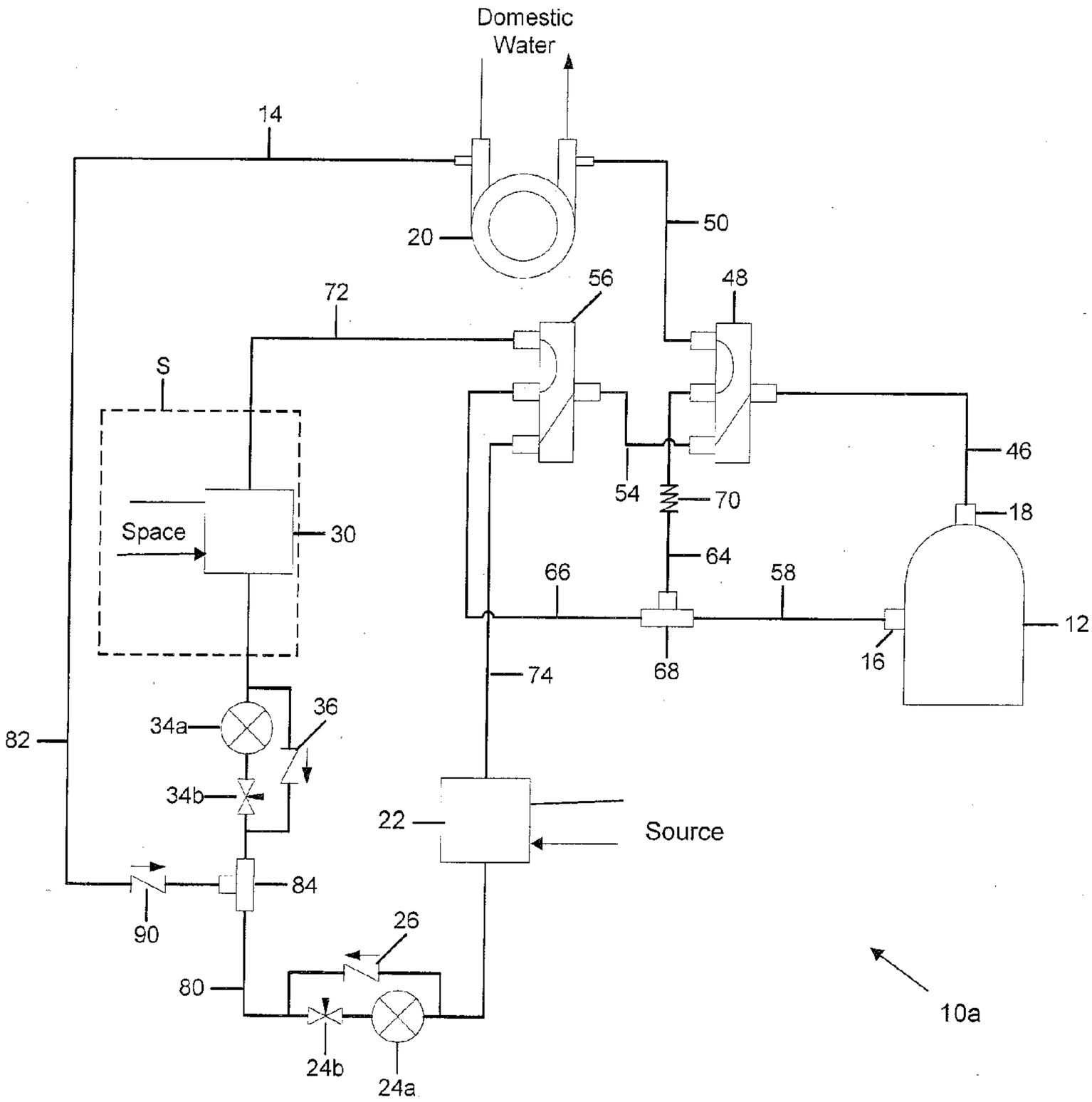
FIG. 4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24b
24a

FIG. 5

INTEGRATED HEAT PUMP AND WATER HEATING CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional application No. 61/614,070 entitled "Integrated Heat Pump and Water Heating Circuit," filed Mar. 22, 2012, the contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to heating, ventilation, and air conditioning methods and systems and, more particularly but without limitation, to heat pump systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The accompanying drawings, which are incorporated into and form a part of the specification, illustrate one or more embodiments of the present invention and, together with this description, serve to explain the principles of the invention. The drawings merely illustrate preferred embodiments of the invention and are not to be construed as limiting the scope of the invention.

[0004] FIG. **1** is a schematic diagram of an integrated heat pump and water heating circuit constructed in accordance with a first preferred embodiment of the present invention. The bolded line illustrates the refrigerant flow path when the system is operating in a first space cooling only mode.

[0005] FIG. **2** is a schematic diagram of the circuit of FIG. **1** illustrating the refrigerant flow path when the system is operating in a second space heating only mode.

[0006] FIG. **3** is a schematic diagram of the circuit of FIG. **1** illustrating the refrigerant flow path when the system is operating in a third water heating only mode.

[0007] FIG. **4** is a schematic diagram of the circuit of FIG. **1** illustrating the refrigerant flow path when the system is operating in a fourth mode in which the space is cooled and the domestic water supply is heated simultaneously.

[0008] FIG. **5** is a schematic diagram of an integrated heat pump and water heating circuit constructed in accordance with a second preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0009] Modern space heating and cooling systems are increasingly improving in efficiency decreasing the energy used to condition buildings. As this energy use is reduced, other energy using items, specifically heating domestic water, become an increasingly large part of the building's energy usage. One promising approach to reduce building energy consumption is through a single integrated heat pump system to condition the space and heat the domestic water. The energy benefits of this system stem from the ability to utilize otherwise wasted energy; for example, heat rejected by the space cooling operation can be used for water heating.

[0010] The present invention comprises a refrigeration circuit that has four modes of operation: cooling a space, heating a space, heating water, and simultaneously cooling a space while heating water. Furthermore, the improved refrigeration circuit is designed such that passive charge control is provided by reclaiming charge from the inactive heater exchanger to the suction side of the compressor along with minimizing valves required for proper operation in any of the four modes.

[0011] Turning now to the drawings in general and to FIG. **1** in particular a first preferred embodiment of the circuit of the present invention will be described. The circuit, designated generally by the reference number **10**, includes a compressor **12** and a plurality of heat exchangers interconnected in a conduit assembly **14**. The compressor **12** includes an inlet **16** on the suction side and an outlet **18** on the discharge side. The compressor **12** circulates refrigerant through the circuit **10**.

[0012] The plurality of heat exchangers includes a first heat exchanger **20** fluidly connectable to the structure's domestic water supply. The water supply heat exchanger **20** is operable as a condenser to heat the water supply. In most instances, the water supply heat exchanger will be a refrigerant-to-water heat exchanger.

[0013] Also included is a second heat exchanger **22** fluidly connectable to the heat pump's source. As used herein, "source" refers to a source such as water or air that serves as a heat sink or heat source. The source heat exchanger **22** is operable alternately as an evaporator and a condenser to selectively reject heat to or absorb heat from the source. In most instances, the source heat exchanger will be a refrigerant-to-water heat exchanger and the source will be water. However, other types of heat exchangers may be substituted. For example, for an outside air source, the heat exchanger may be a refrigerant-to-air type.

[0014] A first one-way expansion valve preferably is included in the conduit assembly **14** and is dedicated to the source heat exchanger **22**, that is, it serves only the source heat exchanger.

[0015] The first expansion valve is positioned to meter refrigerant only entering the source heat exchanger **22** and only when it is operating as an evaporator. In the embodiment of FIG. **1**, the expansion valve comprises an electronic expansion valve **24** and a check valve **26**. The electronic expansion valve **24** meters refrigerant only when the heat exchanger **22** is operating as an evaporator and otherwise remains completely closed. The check valve **26** allows unrestricted flow of refrigerant in the direction opposite to that of the one-way expansion valve.

[0016] Referring still to FIG. **1**, the refrigerant circuit **10** includes a third heat exchanger **30** fluidly connected to the space in the structure "S" to heat and cool the space. Thus, the space heat exchanger **30** is operable alternately as an evaporator and a condenser. In most instances, the space heat exchanger will be a refrigerant-to-air heat exchanger. However, other types of heat exchangers may be substituted. For example, for a radiant type heating system, the heat exchanger may be a refrigerant-to-water type.

[0017] A second one-way expansion valve preferably is included in the conduit assembly **14** and is dedicated to the space heat exchanger, that is, it is positioned to meter refrigerant only entering the source heat exchanger **30** and only when it is operating as an evaporator. In this embodiment, the expansion valve comprises an electronic expansion valve **34** and a check valve **36**. The electronic expansion valve **34** meters refrigerant only when the heat exchanger **30** is operating as an evaporator and otherwise remains completely closed. The check valve **36** allows unrestricted flow of refrigerant in the direction opposite to that of the one-way expansion valve.

[0018] A desuperheater **40** may be included in the circuit **10**. The desuperheater **40** is fluidly connectable to the domestic water supply and may be a refrigerant-to-water heat exchanger.

[0019] The conduit assembly includes conduits connecting the various components of the circuit **10**. A discharge line **46** connects the compressor **12** to the desuperheater **40**. The outlet of the desuperheater **40** is connected to the inlet port of a diverter valve **48**. One port of the diverter valve **48** connects to one side of the water supply heat exchanger **20** through the conduit **50**. Another port of the diverter valve **48** connects via the conduit **54** to the inlet port of a reversing valve **56**. The fourth port of the diverting valve **48** is connected to the suction line **58** by means of the conduit **64**.

[0020] One port of the reversing valve **56** connects to the suction line **58** to the inlet **16** of the compressor **12** through the conduit **66** and the three way coupling **68**. Another port of the reversing valve **56** connects to the space heat exchanger **30** by the conduit **72**. The fourth port of the reversing valve **56** connects to the source heat exchanger **22** by the conduit **74**.

[0021] The conduit **80** connects the source heat exchanger **22** to the space heat exchanger **30**. A conduit **82** connects the water supply heat exchanger **20** to the conduit **80** through the three way coupling **84**.

[0022] Now it will be apparent that the preferred refrigerant circuit **10** includes an assembly of valves in the conduit assembly **14** configured to direct refrigerant between the compressor **12** and the heat exchangers **20**, **22**, **30**, and **40**. The valve assembly is configured to selectively direct the refrigerant in four different paths to provide four operating modes. The four modes of operation include a first space-cooling-only mode, a second space-heating-only mode, a third water-heating-only mode, and a fourth mode in which the water supply is heated and the space is cooled simultaneously. To that end, the preferred valve assembly includes the previously described diverter valve **48**, the reversing valve **56**, and the check valves **26**, **36** and **90**. The one-way expansion valves **24** and **34** also participate in directing the refrigerant according to the four modes. The operation of these valves to achieve the four different operating modes now will be explained.

[0023] The first flow path for the refrigerant through the circuit **10** is illustrated in FIG. **1** by the thicker lines. This flow path provides the first mode, that is, the mode in which only cooling of the space is provided. Refrigerant fluid leaving the compressor outlet **18** through the discharge line **46** passes through the desuperheater **40**, where heat can be rejected to the domestic water. From the desuperheater **40**, fluid enters the diverter valve **48**. The diverter valve **48** directs the refrigerant through the conduit **54** to the reversing valve **56**, which then routes it to the source heat exchanger **22** through the conduit **74**, where heat is rejected to the source.

[0024] Fluid leaving the heat exchanger **22** passes through the conduit **80** to the space heat exchanger **30**. In this path, the high pressure fluid passes through the check valve **26**, bypassing the expansion valve **24**, which is closed, and entering the expansion valve **34**, as the check valve **36** is closed to flow in this direction. The refrigerant is metered in the expansion valve **34** prior to entering the heat exchanger **30**, which in this mode is operating as an evaporator, absorbing heat from the space to cool the space.

[0025] Refrigerant vapor exits the heat exchanger/evaporator **30** and flows to the reversing valve **56** through the conduit **72**. The reversing valve **56** in turn directs the fluid through the conduit **66** into the suction line **58** of the compressor **12**. Now it will be apparent that the expansion valves **24** and **34** act also as directional valves to route the refrigerant through the circuit as well as to meter the refrigerant as it enters an evaporator. It should also be noted that in this mode condensed refrigerant is prevented from entering the hot water heat exchanger **20** by the check valve **90**. At the same time, the water supply heat exchanger **20**, which is inactive in this mode, is reclaimed as the diverter valve **48** opens the exchanger **20** to the suction line **58** through the conduits **50** and **64**. Therefore, any refrigerant present in the water supply heat exchanger **20** will be evaporated and pulled back into the active refrigerant circuit for proper operation.

[0026] Turning now to FIG. **2**, the second mode of operation will be described. In this mode, the space is heated. In this flow path, the compressor **12** discharges high-pressure refrigerant vapor through conduit **46** to the desuperheater **40**, where heat can be rejected to the domestic water. The fluid passes from the desuperheater **40** to the diverter valve **48** and then to the reversing valve **56** from which is routed to the space heat exchanger **30** through the conduit **72**. In this mode, the heat exchanger **30** is operating as a condenser to heat the space "S."

[0027] High-pressure liquid then leaves the space heat exchanger **30** in the conduit **80** bypassing the expansion device **34**, which is closed, and passing through the check valve **36** instead. From here, the fluid passes through the expansion valve **24**, the check valve **26** being closed to flow in this direction. Expanded low-pressure refrigerant is metered into the source heat exchanger **22**, which in this mode is operating as an evaporator, absorbing heat. Refrigerant vapor exits the heat exchanger **22** and passes to the reversing valve **56** through the conduit **74** and then to the suction line **58** through the conduit **66**. As in space cooling mode, liquid refrigerant is prevented from entering the water supply heat exchanger **20** by the check valve **90**. In this mode, the heat exchanger **20** is inactive, but this heat exchanger is reclaimed to the suction line **58** of the compressor **12** through the conduits **50** and **60** and the diverter valve **48**, thereby providing proper refrigerant charge control.

[0028] With reference now to FIG. **3**, the third mode of operation will be described. In this mode, the circuit **10** is used to heat the domestic water supply. The compressor **12** discharges high-pressure refrigerant vapor through the desuperheater **40**, and is directed by the diverter valve **48** to the water supply heat exchanger **20** through the conduit **50**. High-pressure liquid, having rejected heat to the water supply, leaves the heat exchanger **20** through the conduit **82** and passes through the check valve **90**, open in this direction, into the conduit **80**.

[0029] The electronic expansion device **34** is closed in this mode, so the fluid is routed through the expansion valve **24** and metered into the source heat exchanger **22**, which in this mode is operating as an evaporator, absorbing heat from the water source.

[0030] Refrigerant vapor exits the heat exchanger **22** through the conduit **74** and is returned to the compressor **12** through the reversing valve **56**, which directs the fluid into the conduit **66** and suction line **58**. In this mode, liquid refrigerant is prevented from entering the space heat exchanger by check valve **36** and closed electronic expansion valve **34**. In this mode, the space heat exchanger **30** is inactive, but it is reclaimed to the suction line **58** of the compressor **12** through

the conduits **72**, **54**, and **64** and valves **48** and **56** so as to maintain proper refrigerant charge control.

[0031] To simultaneously cool the space and heat water, the refrigerant circuit **10** is operated in the mode depicted in FIG. **4**. The compressor **12** discharges high-pressure refrigerant vapor through the desuperheater **40** and then to the diverter valve **48**. The diverter valve **48** directs the fluid to the water supply heat exchanger **20** through the conduit **50**, where heat is rejected to the structure's water supply. High-pressure liquid then leaves the water supply heat exchanger **20** and travels through check valve **90** in the conduit **82** to the expansion device **34**, where it is metered into a low-pressure liquid traveling to the space heat exchanger **30**, where it evaporates, absorbing heat from the space.

[0032] Refrigerant vapor exits the space heat exchanger **30** and flows through the conduit **72** to the reversing valve **56** from which it is returned to the compressor suction line **58** through the conduit **66**. During this mode of operation, the source heat exchanger **22** is inactive, and liquid refrigerant is prevented from entering this heat exchanger by the check valve **26** and the electronic expansion valve **24**, which is closed. Thus, the source heat exchanger **22** is reclaimed to the suction line **58** of the compressor **12** through the conduit **74** and **66** and the reversing valve **56** to insure proper refrigerant charge control.

[0033] FIG. **5** illustrates another embodiment of the refrigerant circuit present invention, which is designated generally by the reference number **10**A. In this figure, no flow path is highlighted, as it will function similarly in the same modes as previously described. In this embodiment, the circuit **10**A comprises the same compressor **12**, domestic water heat exchanger **20**, source heat exchanger **22**, and space heat exchanger **30**. Similarly, the valve assembly of this embodiment includes the same diverter valve **48** and reversing valve **56**, as well as the check valves **26**, **36**, and **90**. However, the desuperheater is omitted. Additionally, the electronic expansion valves **24** and **34** in the previous embodiment each have been replaced with a mechanical expansion valve **24***a* and **34***a*. Since mechanical expansion valves may not close tightly and typically will allow some reverse migration of refrigerant, each of the mechanical expansion valves is coupled with a solenoid shut-off valve **24***b* and **34***b*. Still further, a capillary tube or restrictor **40** is included in the conduit **64** between the diverter valve **48** and the suction line **58** of the compressor. This device restricts the amount of refrigerant entering the suction line **58** of the compressor **12**.

[0034] In accordance with the method of the present invention, air conditioning and water heating is provided to a structure, wherein the structure has a heat pump source, a water supply, and a space to be cooled and heated. The method comprises selectively circulating refrigerant in a single refrigerant circuit, wherein the refrigerant circuit comprises a plurality of heat exchangers and a compressor interconnected by a conduit assembly. The step of circulating the refrigerant includes directing refrigerant selectively through four different fluid paths to provide four operating modes including a first space-cooling-only mode, a second space-heating-only mode, a third water-heating-only mode, and a fourth mode in which the water supply is heated and the space is cooled simultaneously.

[0035] The embodiments shown and described above are exemplary. Many details are often found in the art and, therefore, many such details are neither shown nor described herein. It is not claimed that all of the details, parts, elements, or steps described and shown were invented herein. Even though numerous characteristics and advantages of the present inventions have been described in the drawings and accompanying text, the description is illustrative only. Changes may be made in the details, especially in matters of shape, size, and arrangement of the parts within the principles of the inventions to the full extent indicated by the broad meaning of the terms of the attached claims. The description and drawings of the specific embodiments herein do not point out what an infringement of this patent would be, but rather provide an example of how to use and make the invention. Likewise, the abstract is neither intended to define the invention, which is measured by the claims, nor is it intended to be limiting as to the scope of the invention in any way. Rather, the limits of the invention and the bounds of the patent protection are measured by and defined in the following claims.

What is claimed is:

1. A heat pump and water heating circuit for a structure, wherein the structure has a heat pump source, a domestic water supply, and an space to be cooled and heated, the circuit comprising;

a compressor having an inlet and an outlet;

a plurality of heat exchangers comprising:

a first heat exchanger fluidly connectable to the structure's domestic water supply, the first heat exchanger operable as a condenser to heat the water supply;

a second heat exchanger fluidly connectable to the heat pump's source, the second heat exchanger being operable alternately as an evaporator and a condenser to selective reject heat to or absorb heat from the source;

a third heat exchanger fluidly connected to the space, the third heat exchanger being operable alternately as an evaporator and a condenser to selectively cool or heat the space;

a conduit assembly fluidly connecting the compressor and the plurality of heat exchangers to form a refrigerant circuit;

a first one-way expansion valve in the conduit assembly positioned to meter only refrigerant entering the second heat exchanger and only when the second heat exchanger is operating as an evaporator; and

a second one-way expansion valve in the conduit assembly positioned to meter only refrigerant entering the third heat exchanger and only when the third heat exchanger is operating as an evaporator; and

a valve assembly in the conduit assembly configured to direct refrigerant between the compressor and the heat exchangers selectively in four different paths to provide four operating modes including a first space-cooling-only mode, a second space-heating-only mode, a third water-heating-only mode, and a fourth mode in which the water supply is heated and the space is cooled simultaneously.

2. The heat pump and water heating circuit of claim **1** further comprising a desuperheater between the outlet of the compressor and the plurality of heat exchangers, wherein the desuperheater is fluidly connectable to the structure's domestic water supply.

3. The heat pump and water heating circuit of claim **1** wherein the each of the first and second expansion valves comprises an electronic expansion valve operable between a metering position in which refrigerant is metered into the heat exchanger and a closed position in which flow through the expansion valve is blocked, and wherein the valve assembly

includes a check valve for each expansion valve configured to allow fluid to bypass the expansion valve.

4. The heat pump and water heating circuit of claim **1** wherein each of the first and second expansion valves comprises a mechanical expansion valve and a solenoid shut-off valve, and wherein the valve assembly includes a check valve for each expansion valve configured to allow fluid to bypass the expansion valve.

5. The heat pump and water heating circuit of claim **1** wherein the valve assembly comprises a diverting valve and a reversing valve.

6. The heat pump and water heating circuit of claim **1** wherein in any of the four modes of operation one of the plurality of heat exchangers is inactive and wherein the conduit assembly and the valve assembly are configured to direct refrigerant from the inactive heater exchanger to the suction side of the compressor whereby the charge from the inactive heater exchanger is reclaimed.

7. The heat pump and water heating circuit of claim **1** wherein the heat pump source is a water source.

8. A method for providing air conditioning and water heating to a structure, wherein the structure has a heat pump source, a domestic water supply, and a space to be cooled and heated, the method comprising:

selectively circulating refrigerant in a single refrigerant circuit, wherein the refrigerant circuit comprises a plurality of heat exchangers and a compressor interconnected by a conduit assembly, and wherein the circulating step includes directing refrigerant through four different fluid paths to provide four operating modes including a first space-cooling-only mode, a second space-heating-only mode, a third water-heating-only mode, and a fourth mode in which the domestic water supply is heated and the space is cooled simultaneously.

9. The method of claim **8** wherein the refrigerant circuit further comprises a desuperheater between the outlet of the compressor and the plurality of heat exchangers and wherein the desuperheater is fluidly connectable to the structure's water supply.

10. The method of claim **8** wherein the plurality of heat exchangers in the refrigerant circuit includes:

a first heat exchanger fluidly connectable to the structure's domestic water supply, the first heat exchanger operable as a condenser to heat the water supply;

a second heat exchanger fluidly connectable to the heat pump's source, the second heat exchanger being operable alternately as an evaporator and a condenser to selective reject heat to or absorb heat from the source; and

a third heat exchanger fluidly connected to the space, the third exchanger being operable alternately as an evaporator and a condenser to selectively cool or heat the space.

11. The method of claim **10** wherein the refrigerant circuit further comprises:

a first one-way expansion valve in the conduit assembly positioned to meter only refrigerant entering the second heat exchanger and only when the second heat exchanger is operating as an evaporator; and

a second one-way expansion valve in the conduit assembly positioned to meter only refrigerant entering the third heat exchanger and only when the third heat exchanger is operating as an evaporator.

12. The method of claim **11** wherein each of the first and second expansion valves comprises an electronic expansion valve operable between a metering position in which refrigerant is metered into the heat exchanger and a closed position in which flow through the expansion valve is blocked, and wherein the valve assembly includes a check valve for each electronic expansion valve configured to allow fluid to bypass the expansion valve.

13. The method of claim **11** wherein each of the first and second expansion valves comprises a mechanical expansion valve and a solenoid shut-off valve, and wherein the valve assembly includes a check valve for each expansion valve configured to allow fluid to bypass the expansion valve.

14. The method of claim **8** wherein the refrigerant circuit further comprises a valve assembly in the conduit assembly, and wherein valve assembly comprises a diverting valve and a reversing valve.

15. The method of claim **8** further wherein in any of the four modes of operation one of the plurality of heat exchangers is inactive and wherein the method further comprises reclaiming charge from the inactive heater exchanger to the suction side of the compressor.

* * * * *