# United States Patent [19]

**Akiyama et al.**

[11] **3,779,031**

[45] **Dec. 18, 1973**



[54] **AIR-CONDITIONING SYSTEM FOR COOLING DEHUMIDIFYING OR HEATING OPERATIONS**


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[73] Assignee: **Hitachi, Ltd.,** Tokyo, Japan



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[21] Appl. No.: **173,037**

[30] **Foreign Application Priority Data**

| | | |
|---|---|---|
| Aug. 21, 1970 | Japan | 45/82845 |
| Sept. 24, 1970 | Japan | 45/93953 |
| Dec. 23, 1970 | Japan | 45/128957 |

[52] **U.S. Cl.** .......... **62/160,** 62/173, 62/199, 62/324

[51] **Int. Cl.** .......... **F25b 13/00**

[58] **Field of Search** .......... 62/173, 160, 324, 62/428, 198, 199, 200



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*Primary Examiner*—Meyer Perlin
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[57] **ABSTRACT**

An air conditioner comprising a compressor, an outdoor heat exchanger, a first indoor heat exchanger, a second indoor heat exchanger, a first capillary tube, a second capillary tube, a third capillary tube, a first valve, a second valve and a piping communicating said elements with each other, said compressor communicating with one side of said outdoor heat exchanger and said first indoor heat exchanger, the other side of said outdoor heat exchanger communicating with one side of said first capillary tube and said second capillary tube, the other side of said first capillary tube communicating with the other side of said first indoor heat exchanger, the other side of said second capillary tube communicating with one side of said second indoor heat exchanger, the other side of said second indoor heat exchanger and said compressor communicating with each other by said second valve, a series circuit of said second capillary tube and said second indoor heat exchanger and said first valve being connected in parallel with each other, said third capillary tube being connected between the side of said first indoor heat exchanger closer to said first capillary tube and the side of said second indoor heat exchanger closer to said second capillary tube, said first valve being closed and said second valve being opened during a cooling operation, and said first valve being opened and said second valve being closed during a dehumidifying operation.


**4 Claims, 14 Drawing Figures**

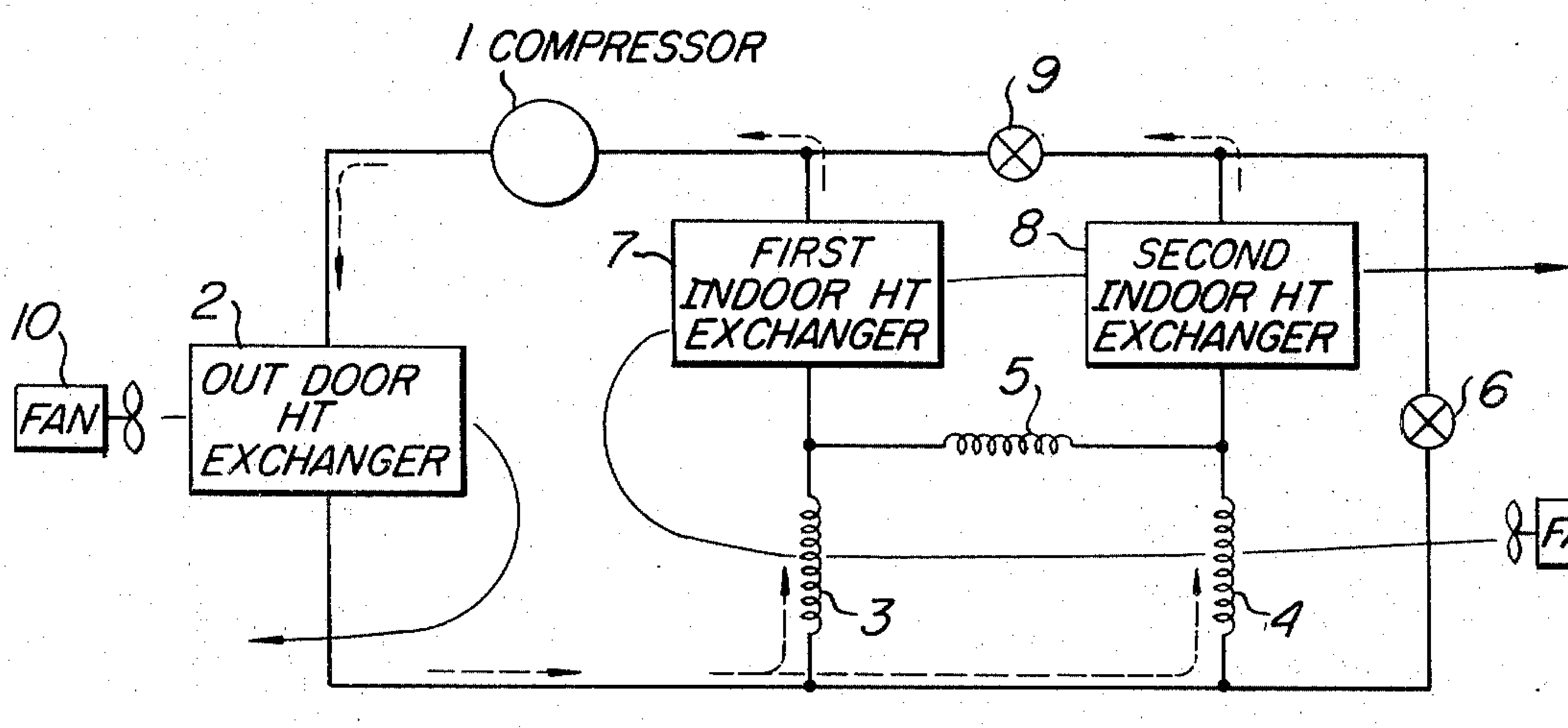

FIG. 1 PRIOR ART

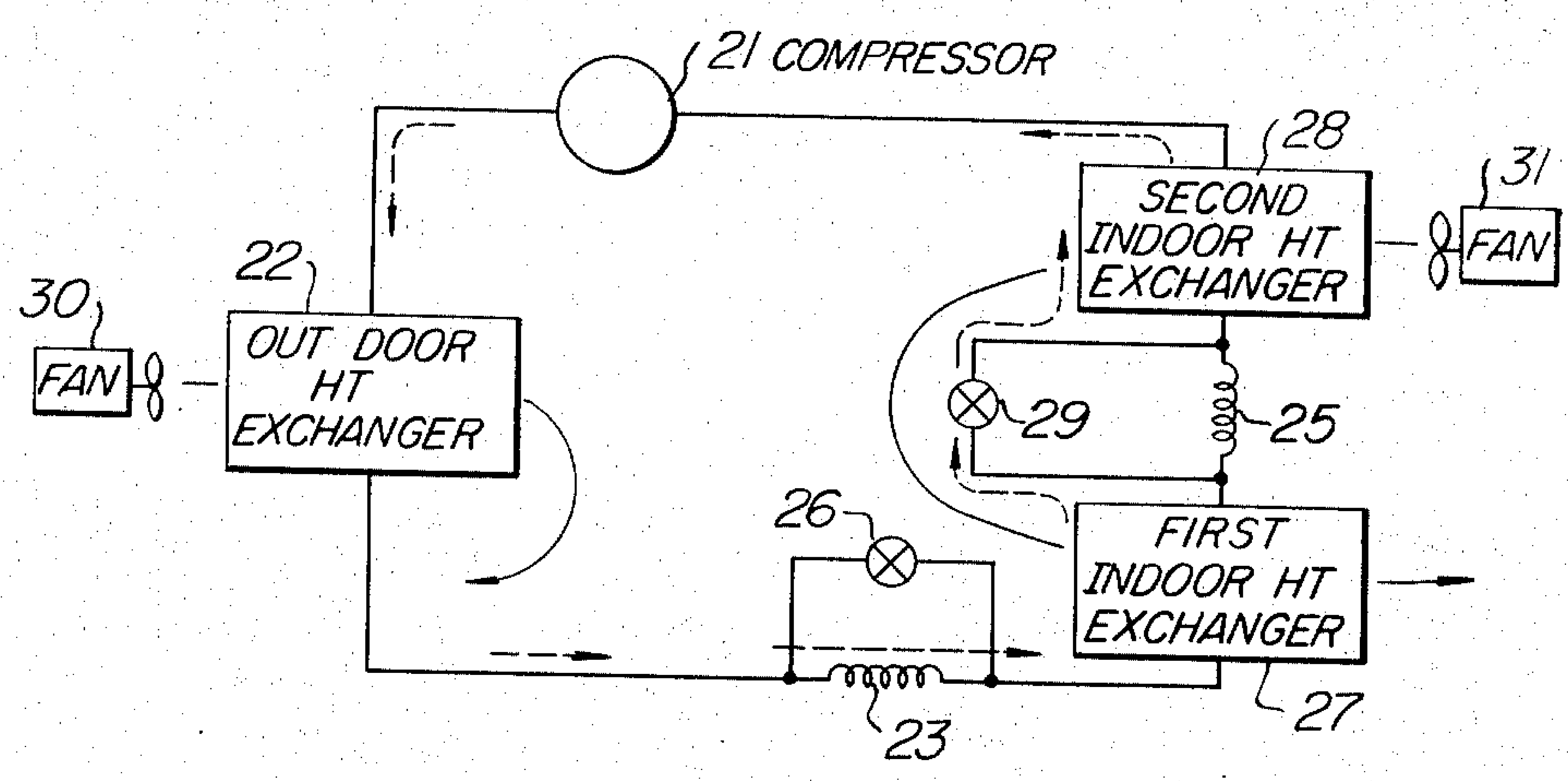


FIG. 2 PRIOR ART

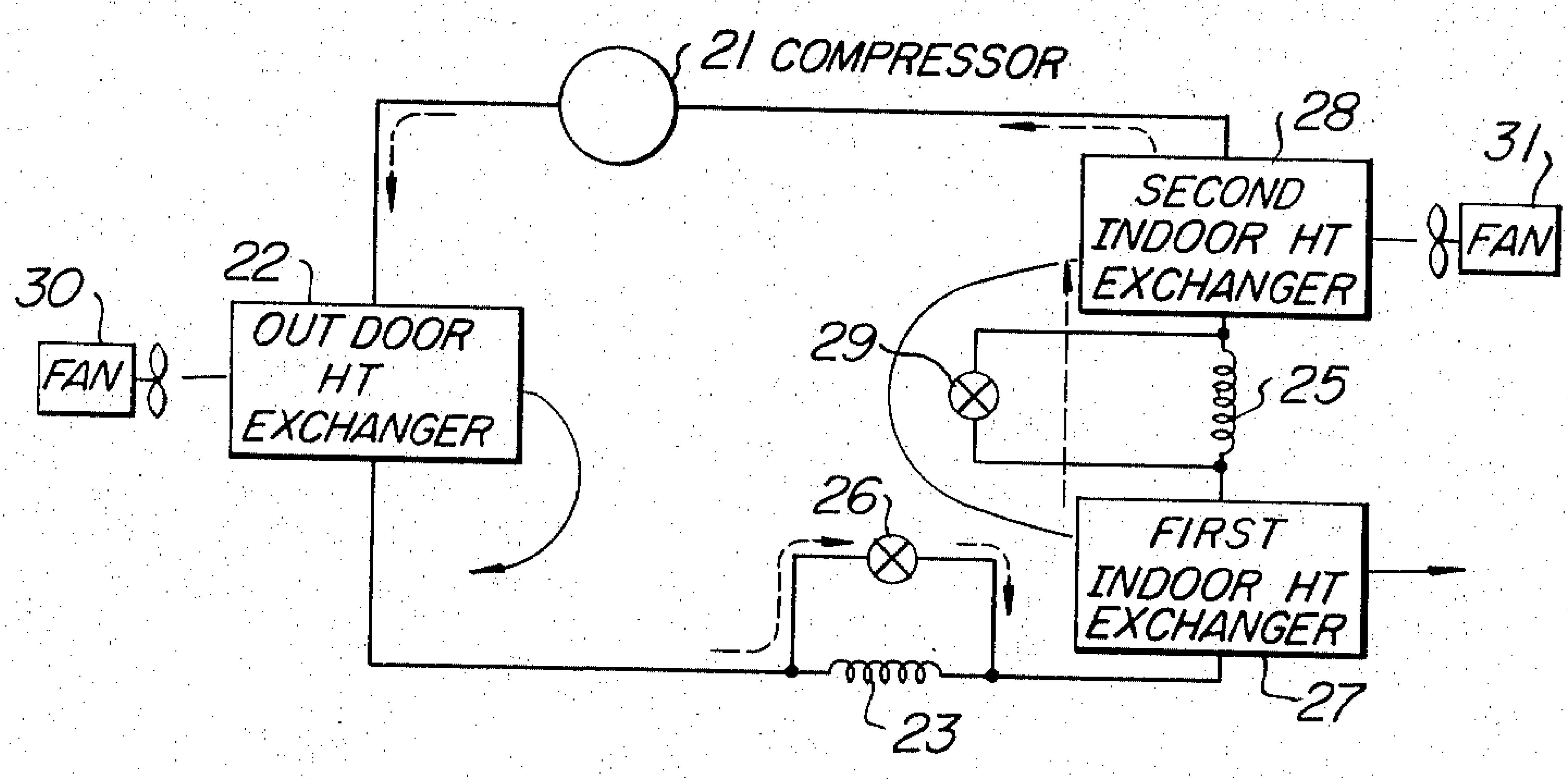


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FIG. 3

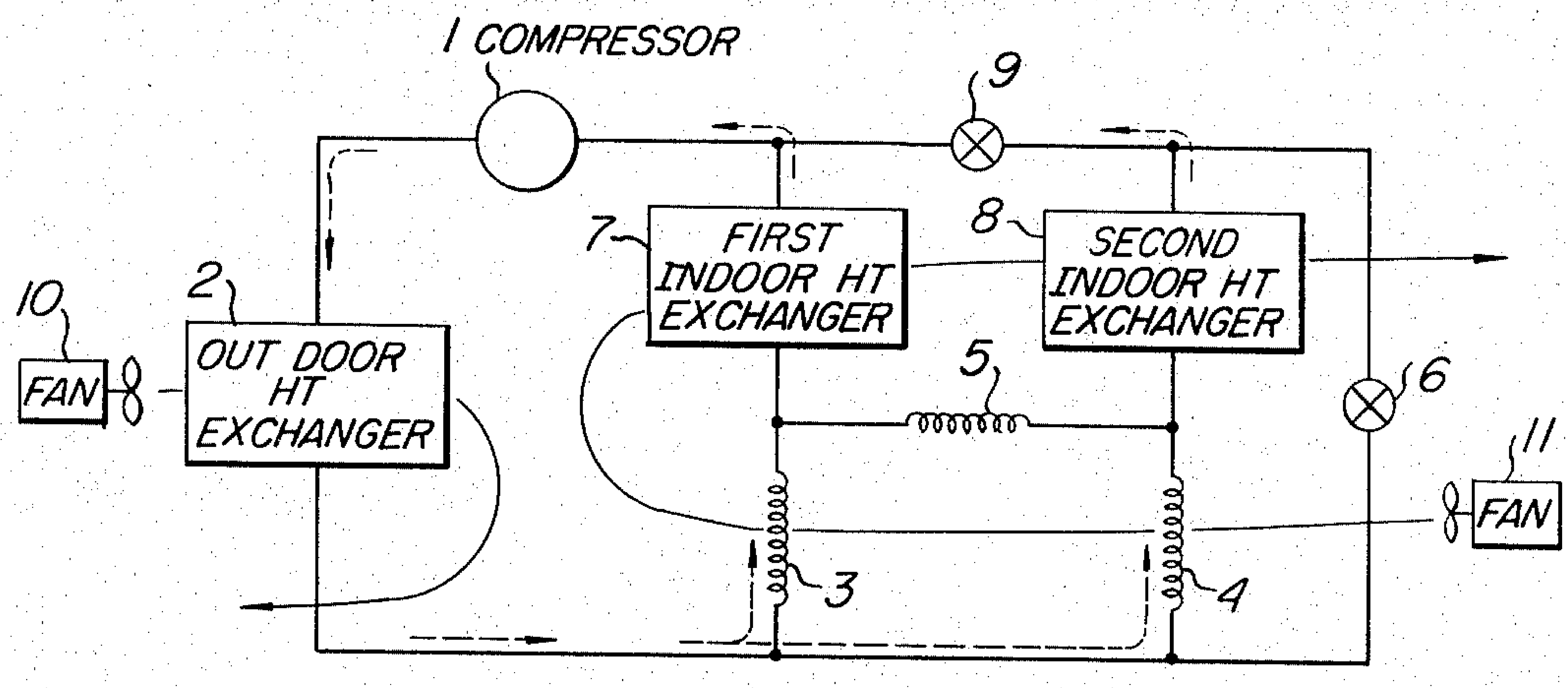


FIG. 4

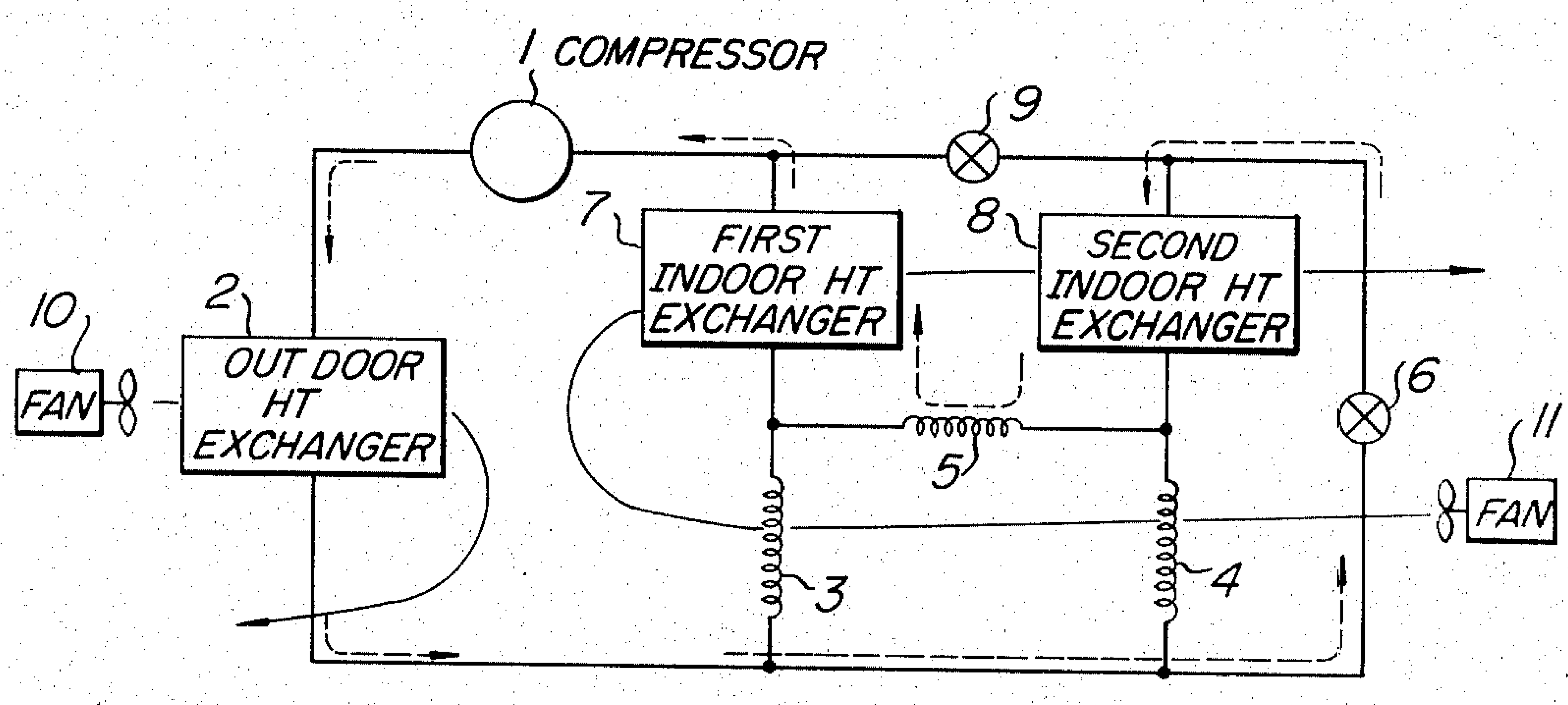


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FIG. 5

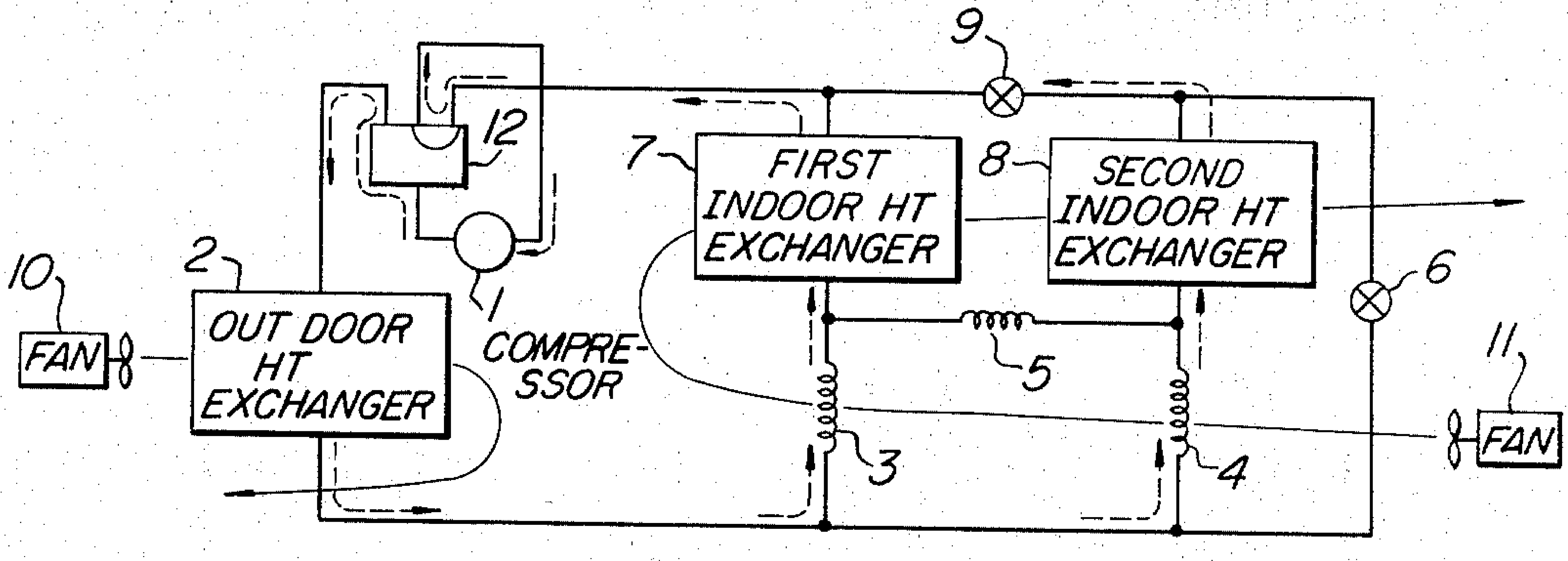


FIG. 6

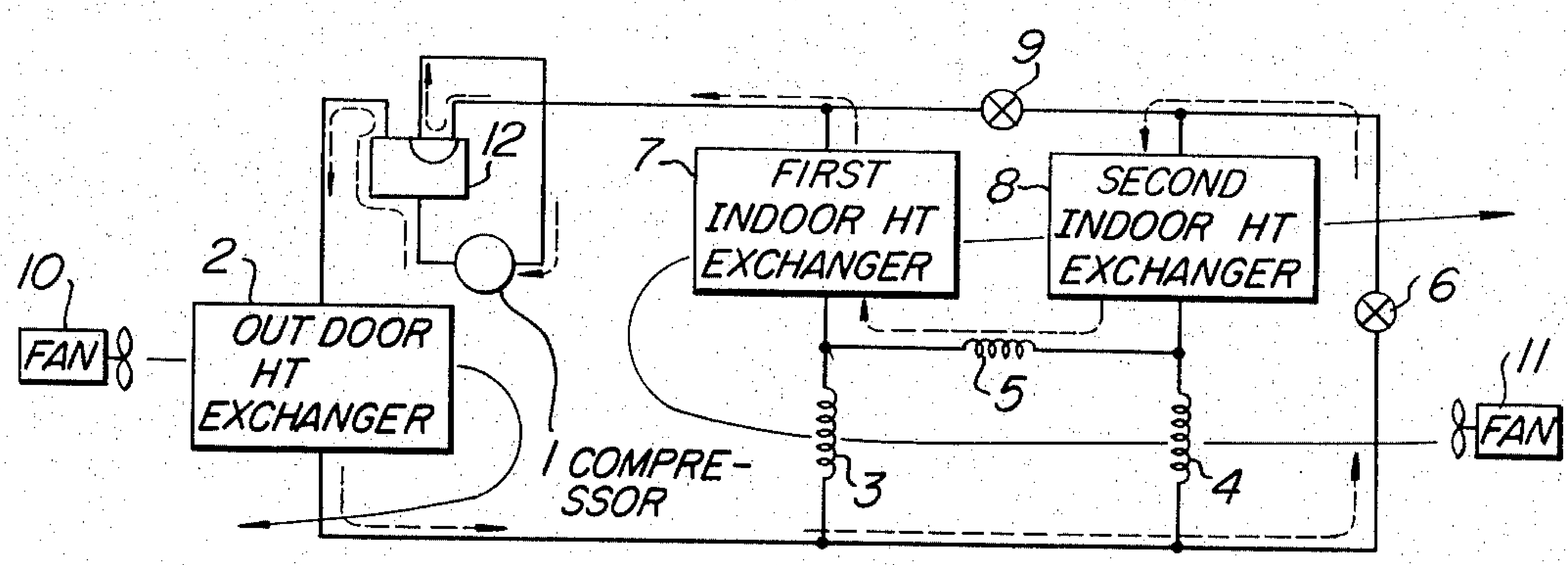


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FIG. 7

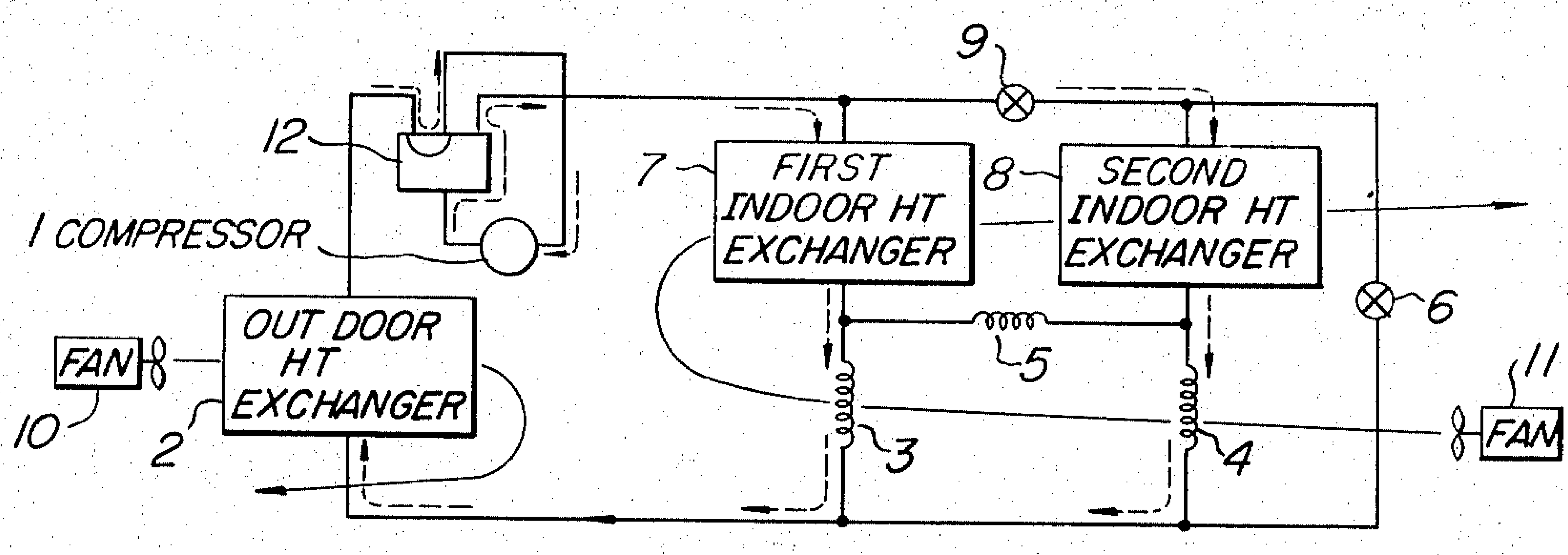


FIG. 8

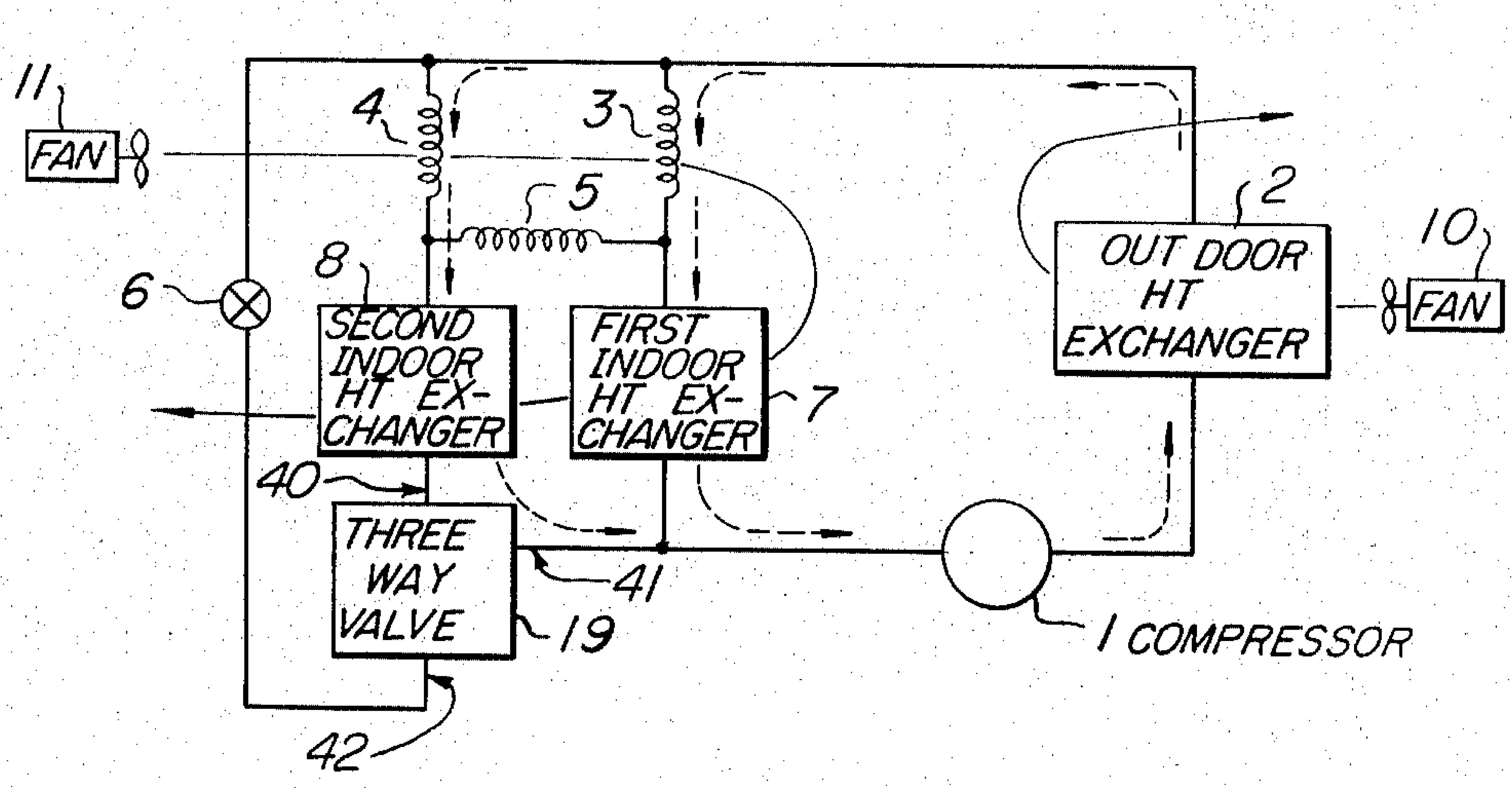


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FIG. 9

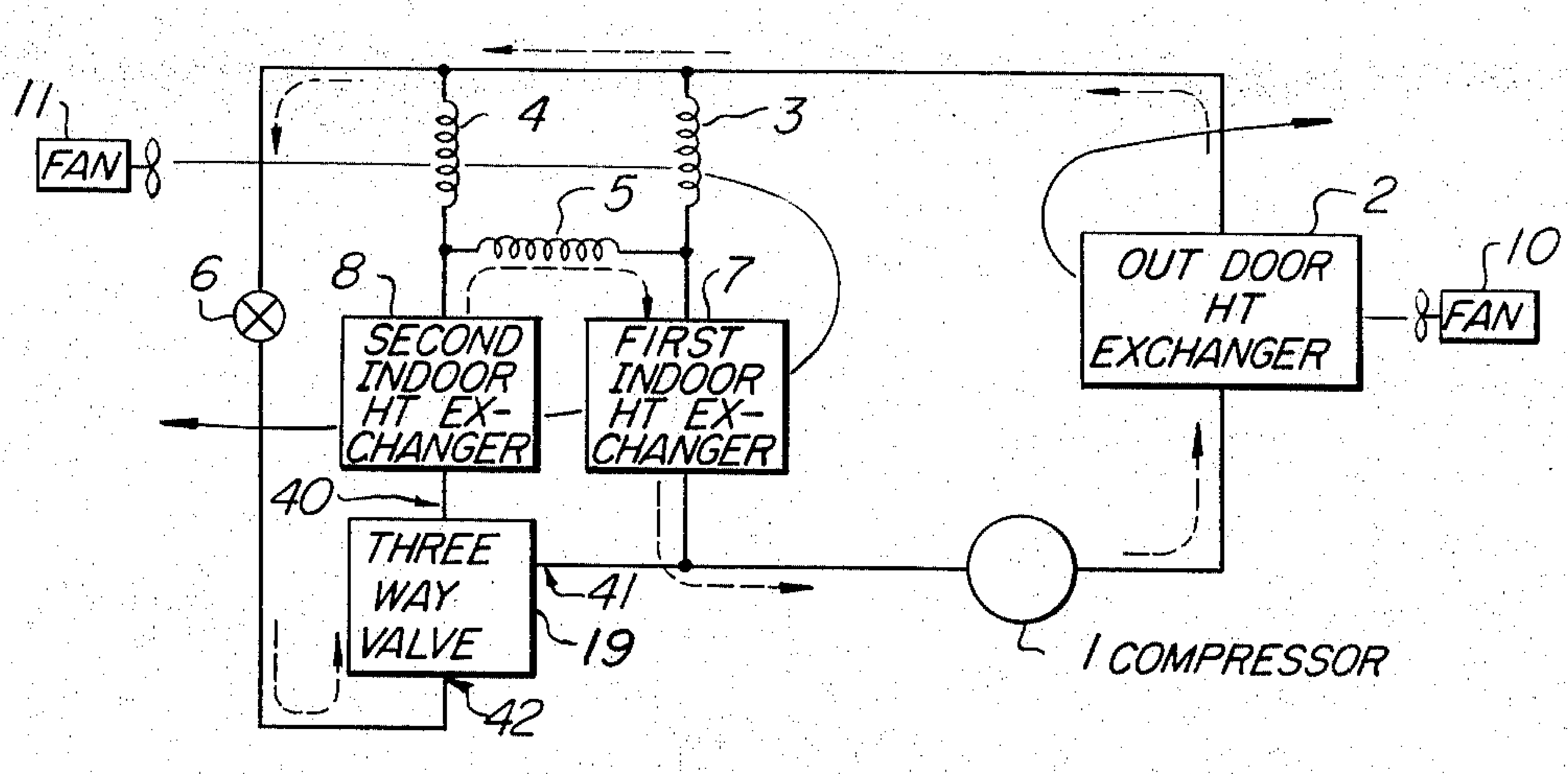


FIG. 10

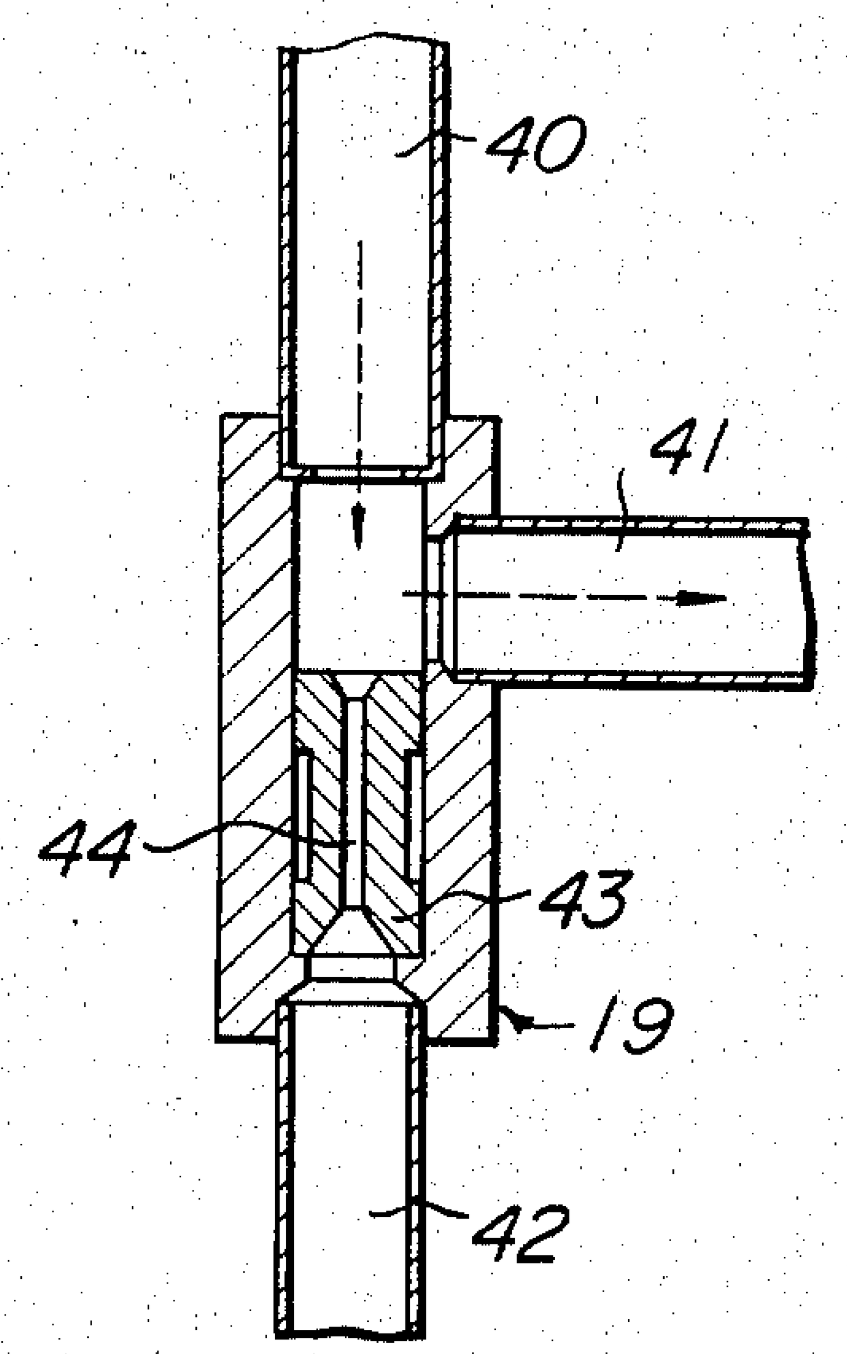


FIG. 11

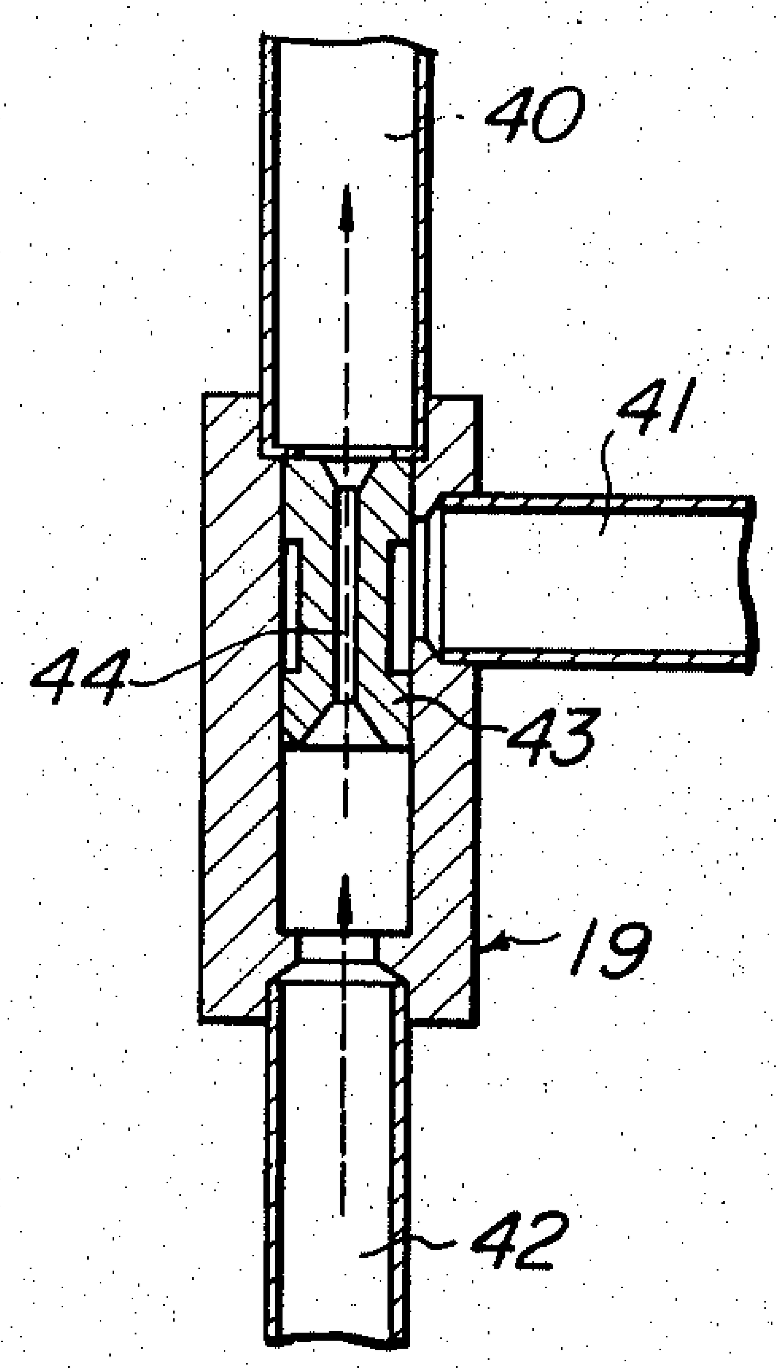


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FIG. 12

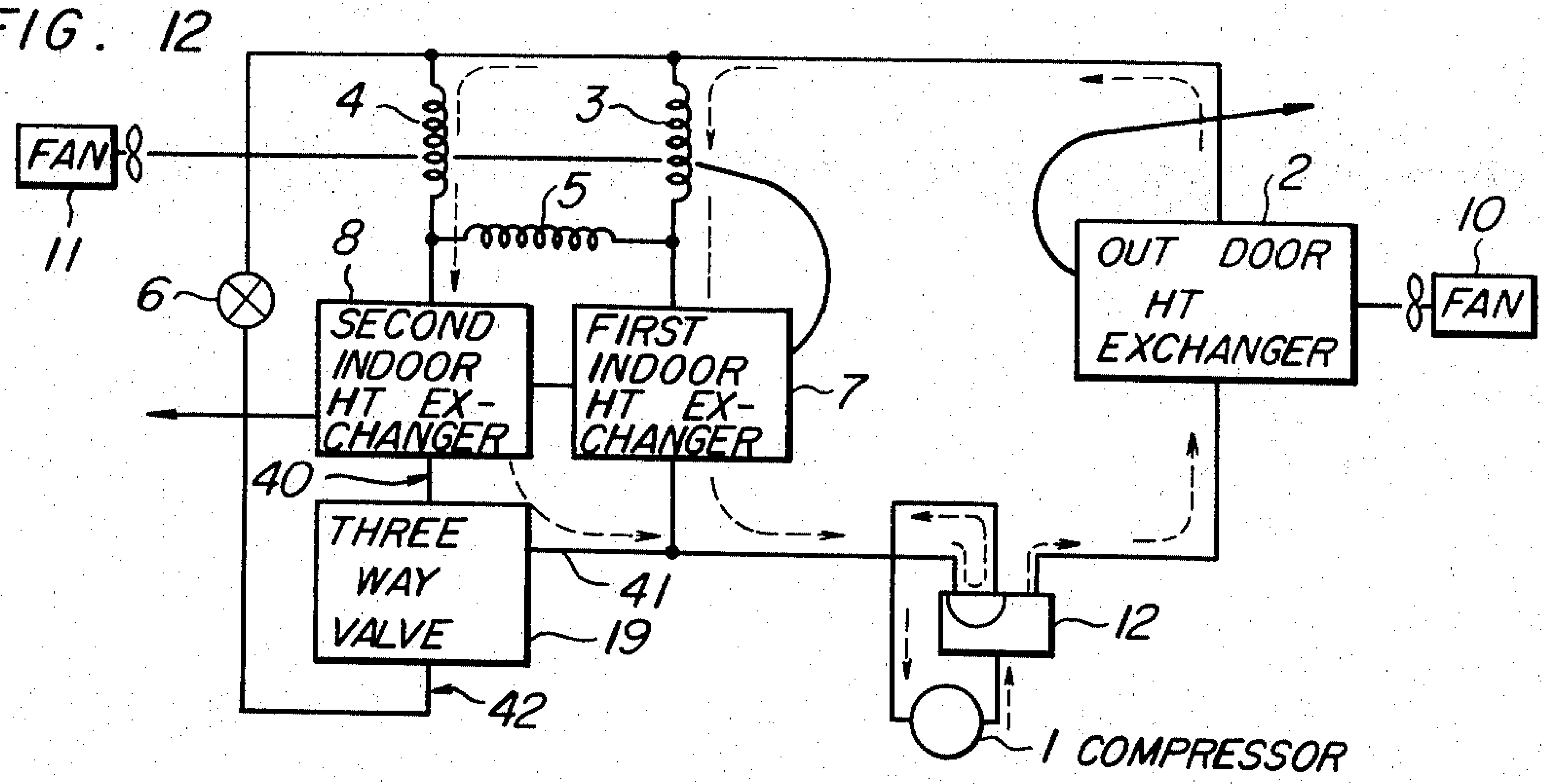



FIG. 13

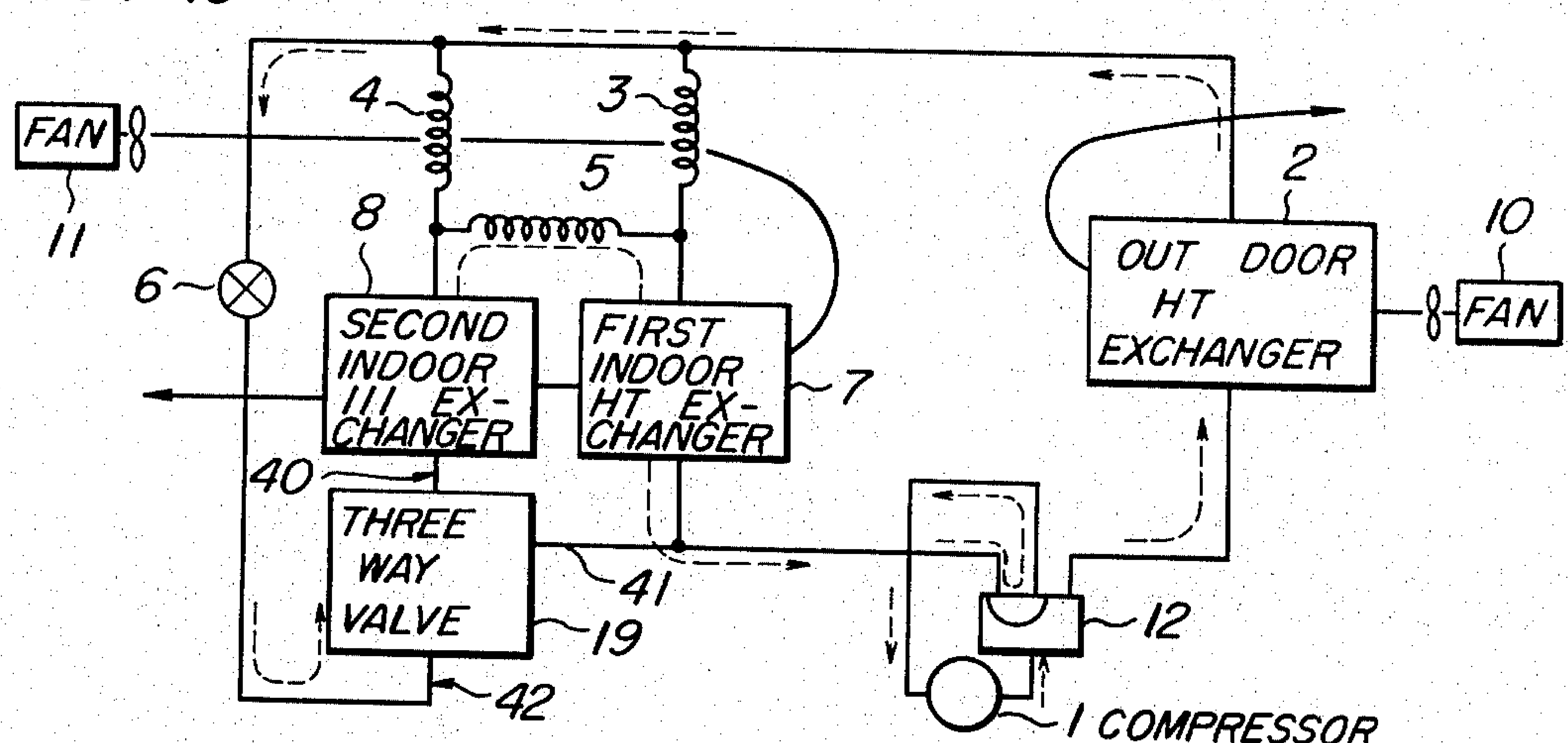
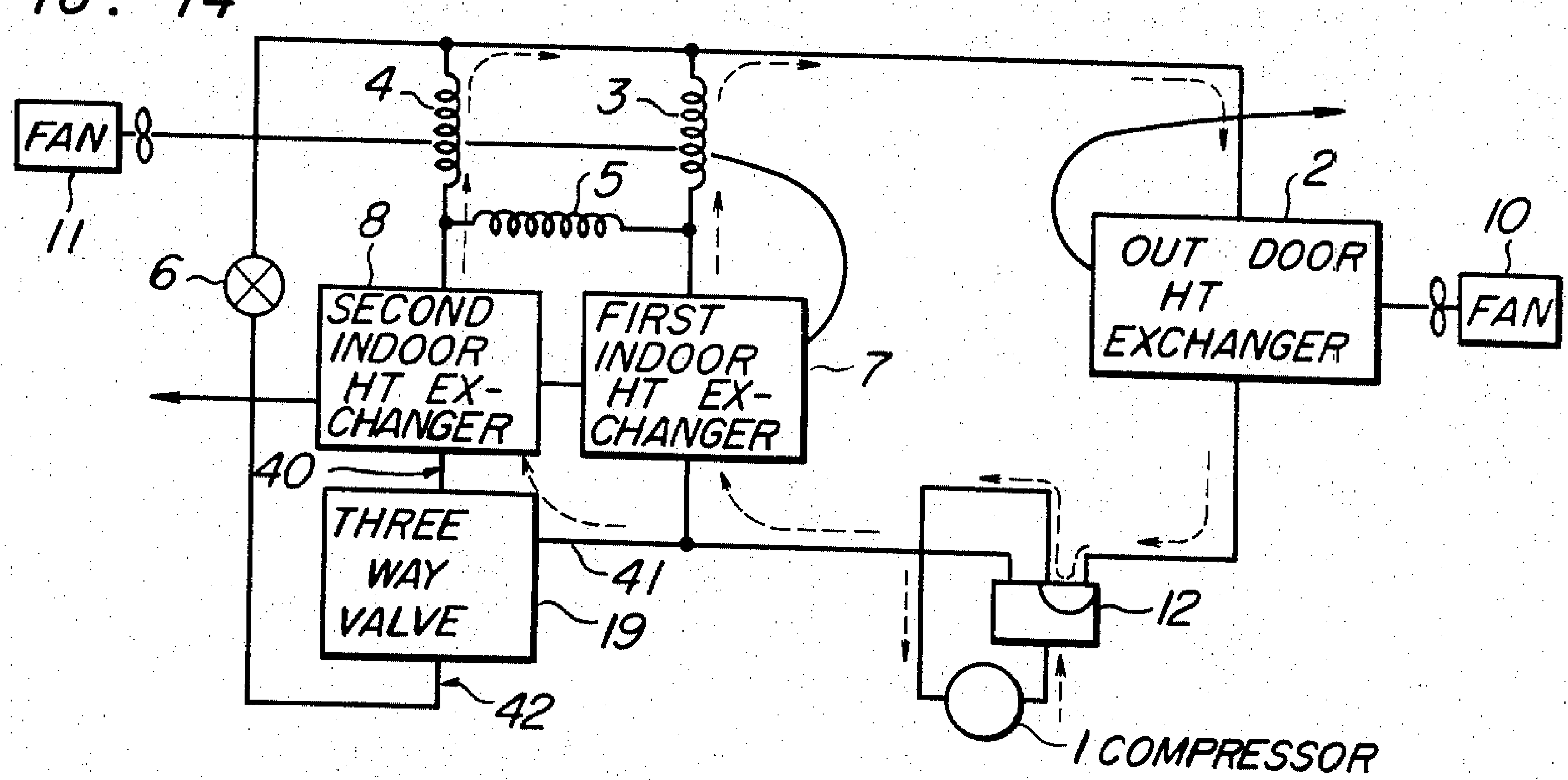



FIG. 14



# AIR-CONDITIONING SYSTEM FOR COOLING DEHUMIDIFYING OR HEATING OPERATIONS

## BACKGROUND OF THE INVENTION

This invention relates to an air conditioner capable of cooling operation and dehumidifying operation.

In a conventional air conditioner of the type described, two spaced indoor heat exchangers have been connected in series with each other as shown in FIGS. 1 and 2 of the accompanying drawing, and therefore, there has been the disadvantage that a loss of the cooling capacity of a refrigerant due to the flow resistance during passage of the coolant through these heat exchangers is great during the cooling operation and hence the cooling efficiency of the air conditioner is substantially degraded.

## SUMMARY OF THE INVENTION

The primary object of the present invention, therefore, is to provide an air conditioner in which the loss of cooling capacity due to the flow resistance is reduced, whereby the cooling efficiency is drastically improved.

Namely, according to the present invention there is provided an air conditioner which comprises a compressor, an outdoor heat exchanger, a first indoor heat exchanger, a second indoor heat exchanger, a first capillary tube, a second capillary tube, a third capillary tube, a first valve, a second valve and a piping communicating said elements with each other, said compressor communicating with one side of said outdoor heat exchanger and said first indoor heat exchanger, the other side of said outdoor heat exchanger communicating with one side of said first capillary tube and said second capillary tube, the other side of said first capillary tube communicating with the other side of said first indoor heat exchanger, the other side of said second capillary tube communicating with one side of said second indoor heat exchanger, the other side of said second indoor heat exchanger and said compressor communicating with each other by said second valve, a series circuit of said second capillary tube and said second indoor heat exchanger and said first valve being connected in parallel with each other, said third capillary tube being connected between the side of said first indoor heat exchanger closer to said first capillary tube and the side of said second indoor heat exchanger closer to said second capillary tube, said first valve being closed and said second valve being opened during a cooling operation, and said first valve being opened and said second valve being closed during a dehumidifying operation.

Further, according to the present invention there can be obtained an air conditioner capable of heating operation in addition to the cooling and dehumidifying operations, simply by adding a four-way cock to the air conditioner of the character described above.

Still further, according to the present invention there can be provided an air conditioner of the character described above, in which (when the valves are electromagnetic valves) an electric wiring for actuating said valves is simplified and the opening and closing operations of the valves are also simplified, simply by arranging such that the operation of one of the valves can be concurrently controlled by the operation of the other valve.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is the cycle diagram of a conventional air conditioner during a cooling operation;

FIG. 2 is the cycle diagram of the air conditioner of FIG. 1 during a dehumidifying operation;

FIG. 3 is the cycle diagram of a first embodiment of the air conditioner according to the present invention during a cooling operation;

FIG. 4 is the cycle diagram of the air conditioner of FIG. 3 during a dehumidifying operation;

FIG. 5 is the cycle diagram of a second embodiment of the air conditioner of the present invention during a cooling operation;

FIG. 6 is the cycle diagram of the air conditioner of FIG. 5 during a dehumidifying operation;

FIG. 7 is the cycle diagram of the air conditioner of FIGS. 5 and 6 during a heating operation;

FIG. 8 is the cycle diagram of a third embodiment of the air conditioner of the present invention during a cooling operation;

FIG. 9 is the cycle diagram of the air conditioner of FIG. 8 during a dehumidifying operation; and

FIGS. 10 and 11 are vertical sectional views of opening and closing valves used in the air conditioner of FIGS. 8 and 9 respectively.

FIGS. 12–14 are cycle diagrams of a further embodiment of the air conditioner of the present invention during cooling operation, dehumidifying operation, and heating operation, respectively.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

A conventional air conditioner of this type has a refrigeration cycle as shown in FIGS. 1 and 2. During a cooling operation, this cycle is operated with a first valve **26** closed and a second valve **29** opened, and a refrigerant discharged from a compressor **21** releases its heat during passage through an outdoor heat exchanger **22**, is reduced in pressure in a capillary tube **23**, absorbs heat during passage through a first indoor heat exchanger **27**, a second valve **29** (substantially no refrigerant passes through a second capillary tube **25** as the flow resistance in said second capillary tube is greater than that in said valve **29**) and a second indoor heat exchanger **28**, and returns to the compressor **21** as indicated by the broken line arrows shown in FIG. **1.** During a dehumidifying operation, the cycle is operated with the first valve **26** opened and the second valve **29** closed, and the refrigerant discharged from the compressor **21** releases its heat during passage of the outdoor heat exchanger **22** (in this case, it is preferable to make small the amount of heat released by the refrigerant by lowering the rate of rotation of an outdoor fan **30**) and further releases its heat to the air interior of a room during passage through the first indoor heat exchanger **27**, absorbs heat from the air interior of the room during passage through the capillary tube **25** and returns to the compressor **21** as shown in FIG. **2.** In such a cycle, since the indoor heat exchangers **27, 28** are connected in series with each other, during the cooling operation the refrigerant passing through the first indoor heat exchanger **27** is reduced in pressure by the capillary tube **25** and then passes through the second indoor heat exchanger **28.** Therefore, a loss of cooling capacity of the refrigerant due to the flow resistance is great, resulting in a substantial degradation of the cooling efficiency during the cooling operation.

The present invention has been achieved with a view to overcoming such disadvantages of the conventional air conditioner.

Now, the present invention will be described in detail hereinafter with reference to embodiments thereof shown in FIGS. 3–11. With reference to the first embodiment shown in FIGS. 3 and 4, the air conditioner comprises a compressor **1**, an outdoor heat exchanger **2**, a first capillary tube **3**, a second capillary tube **4**, a third capillary tube **5**, a first valve **6**, a first indoor heat exchanger **7**, a second indoor heat exchanger **8**, a second valve **9**, an outdoor fan **10** and an indoor fan **11**. During the cooling operation, the first valve **6** is held closed and the second valve **9** is held opened, so that a cooling cycle is formed in the air conditioner along two paths, one extending from the compressor **1** through the outdoor heat exchanger **2**, the first capillary tube **3**, the first indoor heat exchanger **7** to the compressor **1**, and another extending from the compressor **1** through the outdoor heat exchanger **2**, the second capillary tube **4**, the second indoor heat exchanger **8**, the second valve **9** to the compressor **1**, as indicated by the dotted line arrows in FIG. 3. The airs exterior and interior of a room are circulated by the fans **10** and **11** as indicated by the solid line arrows respectively, whereby the refrigerant cools the air interior of the room during passage through the first and second indoor heat exchangers **7, 8** and releases its heat to the outside during passage through the outdoor heat exchanger **2**.

Now, during the dehumidifying operation, the first valve **6** is held opened and the second valve **9** is held closed, and further the outdoor fan **10** is driven at a relatively low rate of rotation, whereby a dehumidifying cycle is formed in the air conditioner, extending from the compressor **1** through the outdoor heat exchanger **2**, the first valve **6** (substantially no refrigerant flows through the first and second capillary tubes **3, 4** as the flow resistances of said capillary tubes are large), the second indoor heat exchanger **8**, the third capillary tube **5**, the first indoor heat exchanger **7** to the compressor **1**, as indicated by the dotted line arrows in FIG. **4**. The airs exterior and interior of the room are circulated as indicated by the solid line arrows respectively, whereby the refrigerant cools the air interior of the room during passage through the first indoor heat exchanger **7** and thereby the water present in the air is removed therefrom by said first indoor heat exchanger, and the refrigerant releases its heat during passage through the outdoor heat exchanger **2**. The air cooled by the refrigerant is heated again by the second indoor heat exchanger **8** and returned into the room. Thus, the air interior of the room is dehumidified.

As described above, according to the present invention the individual indoor heat exchangers **7, 8**, during the cooling operation, are connected with each other in parallel by the two capillary tubes **3, 4**. Therefore, the flow resistance of the refrigerant passage can be decrease to one-fourth to one-third of that in the case when said heat exchangers are connected in series, and hence the loss of cooling capacity due to flow resistance can be substantially decreased.

Furthermore, according to the present invention there can be provided an air conditioner capable of heating operation in addition to the cooling and dehumidifying operations.



The air conditioner shown in FIGS. **3** and **4** is capable of cooling and dehumidifying operations by using the two valves **6, 9** in the cooling cycle, but in FIGS. **5, 6** and **7** there is shown an air conditioner as the second embodiment of the invention, which comprises a four-way valve **12** in addition to the valves **6, 9** and is capable of not only cooling and dehumidifying operations but also heating operation. Namely, during the cooling operation, the first valve **6** is held closed and the second valve **9** is held opened and further the four-way valve **12** is held in the position shown in FIG. **5**, whereby a cooling cycle is formed in the air conditioner along two paths, one extending from the compressor **1** through the four-way valve **12**, the outdoor heat exchanger **2**, the first capillary tube **3**, the first indoor heat exchanger **7**, the four-way valve **12** to the compressor **1**, and another extending from the compressor **1** through the four-way valve **12**, the outdoor heat exchanger **2**, the second capillary tube **4**, the second indoor heat exchanger **8**, the second valve **9**, the four-way valve **12** to the compressor **1**, as indicated by the dotted line arrows in FIG. **5**. The airs exterior and interior of the room are circulated by the fans **10, 11** as indicated by the solid line arrows respectively, whereby the refrigerant cools the air interior of the room during passage through the first and second indoor heat exchangers **7, 8** and releases its heat to the outside during passage through the outdoor heat exchanger **1**.

Now, during the dehumidifying operation, the first valve **6** is held opened and the second valve **9** is held closed and further the outdoor fan **10** is driven at a relatively low rate of rotation, whereby a dehumidifying cycle is formed in the air conditioner, extending from the compressor **1** through the four-way valve **12**, the outdoor heat exchanger **2**, the first valve **6** (substantially no refrigerant flows through the first and second capillary tubes **3, 4** as the flow resistances of said capillary tubes are large), the second indoor heat exchanger **8**, the third capillary tube **5**, the first indoor heat exchanger **7**, the four-way valve **12** to the compressor **1**, as indicated by the dotted line arrows in FIG. **6**. The airs exterior and the interior of the room are circulated by the fans **10, 11** respectively as indicated by the solid line arrows, whereby the air interior of the room is cooled by the refrigerant at the first indoor heat exchanger **7** and at the same time the water present therein is removed therefrom, and then re-heated by the second indoor heat exchanger **8**, while the refrigerant releases its heat to the outside during passage through the outdoor heat exchanger **2**. Thus, the air interior of the room is dehumidified.

During the heating operation, the four-way valve **12** is placed in the position shown in FIG. **7** and the first valve **6** is held closed and the second valve **9** opened, whereby a heating cycle is formed in the air conditioner along two paths, one extending from the compressor **1** through the four-way valve **12**, the first indoor heat exchanger **7**, the first capillary tube **3**, the outdoor heat exchanger **2**, the four-way valve **12** to the compressor **1**, and another extending from the compressor **1** through the four-way valve **12**, the second valve **9**, the second indoor heat exchanger **8**, the second capillary tube **4**, the outdoor heat exchanger **2**, the four-way valve **12** to the compressor **1** as indicated by the dotted line arrows in FIG. **7**. The airs exterior and interior of the room are circulated by the fans **10, 11** respectively as indicated by the solid line arrows, whereby the refrigerant absorbs heat from the outside during passage through the outdoor heat exchanger **2** and heats the air interior of the room during passage through the first and second indoor heat exchangers **7, 8.**

As described above on the second embodiment, according to the present invention it is possible to render the air conditioner capable of heating operation, which comprises two valves and is capable of cooling and dehumidifying operations, merely by adding a four-way valve to said air conditioner.

The third embodiment of the invention will be described with reference to FIGS. **8, 9, 10** and **11.** In the first and second embodiments described above, there are provided two valves **6, 9** and these valves must be operated individually. However, the third embodiment of the air conditioner shown in FIGS. **8, 9, 10** and **11** comprises means by which one of the two valves in the preceding embodiments is automatically opened or closed when the other one is operated. Where the valves are electromagnetic valves, the incorporation of such means is advantageous in simplifying an electric circuit to operate the valves and simplifying the operation of said valves since both valves can be operated by operating only one of them.

The air conditioner according to this embodiment, as shown in FIGS. **8** and **9**, comprises a compressor **1**, an outdoor heat exchanger **2**, a first capillary tube **3**, a second capillary tube **4**, a third capillary tube **5**, a first operating valve **6** such as an electromagnetic valve, a first indoor heat exchanger **7**, a second indoor heat exchanger **8**, a three-way valve **19** that is a second valve not comprising operating parts such as electromagnetically controlled parts, an outdoor fan **10** and an indoor fan **11**. The details of the three-way valve **19** are shown in FIGS. **10** and **11** in which reference numerals **40, 41, 42** designate pipes connected to the three-way valve **19**; **43** a piston slidably received in said valve; and **44** a fine channel axially bored through said piston.

During the cooling operation, the first operating valve **6** such as an electromagnetic valve is held closed, whereby the piston **44** in the three-way valve **19** that is the second valve is held in the position shown in FIG. **10** (the piston **44** moves down under gravity when the three-way valve **19** is mounted in such a manner that the pipe **40** extends upwardly therefrom), so that the refrigerant flows from the pipe **40** into the pipe **41.** Thus, a cooling cycle is formed along two paths, one extending from the compressor **1** through the outdoor heat exchanger **2**, the first capillary tube **3**, the first indoor heat exchanger **7** to the compressor **1**, and another extending from the compressor **1** through the outdoor heat exchanger **2**, the second capillary tube **4**, the second indoor heat exchanger **8**, the three-way valve **19** to the compressor **1**, as indicated by the dotted line arrows in FIG. **8.** The airs exterior and interior of the room are circulated by the fans **10, 11** respectively as indicated by the solid line arrows, whereby the refrigerant cools the air interior of the room during passage through the first and second indoor heat exchangers **7, 8** and releases its heat to the outside during passage through the outdoor heat exchanger **2.**

On the other hand, during the dehumidifying operation the operating valve **6** such as an electromagnetic valve is held opened and hence the piston **44** is the three-way valve **19** is held in the elevated position shown in FIG. **11** since the pressure of the refrigerant in the pipe **42** becomes higher than that in the pipes **40, 41.** Thus, the communication between the pipes **42, 40** and the pipe **41** is shut down and the refrigerant flows from the pipe **42** into the pipe **40** through the axial channel **44** in the piston **43.** Namely, a dehumidifying cycle is formed in the air conditioner, extending from the compressor **1** through the outdoor heat exchanger **2**, the electromagnetic valve **6**, the three-way valve **19**, the second indoor heat exchanger **8**, the third capillary tube **5**, the first indoor heat exchanger **7** to the compressor **1**, as indicated by the dotted line arrows in FIG. **9.** The airs exterior and interior of the room are circulated by the fans **10, 11** respectively as indicated by the solid line arrows, whereby the air interior of the room is cooled and at the same time the water present therein is removed by the first indoor heat exchanger **7**, and reheated by the second indoor heat exchanger **8** and returned into the room, while the heat of the refrigerant is slightly released to the outside at the outdoor heat exchanger **2.** Thus, the air interior of the room is dehumidified. A further embodiment of the invention is described with reference to FIGS. **12, 13,** and **14,** wherein the same reference numerals are used to describe similar parts as above. In this embodiment, as described with the second embodiment above in FIGS. **5–7,** a four-way valve **12** is provided which allows a heating operation, together with cooling and dehumidifying operations. Furthermore, a second valve **19,** which is a three-way valve, as described in FIGS. **10** and **11,** is used as the second valve. As discussed above with regard to FIGS. **8** and **9,** this three-way valve provides the advantage of having its operation effected by the operation of valve **6.** Therefore, when valve **6** is open, the three-way valve **19** is automatically closed by the action of the refrigerant pressure entering pipe **42.** On the other hand, when valve **6** is closed, the piston **43** (as seen in FIG. **10**) moves down under gravity, allowing the flow of the refrigerant through pipe **40** into pipe **41.**

Accordingly, in the cooling operation, the valve **6** is closed, and the three-way valve **19** is in the position shown in FIG. **10,** since the piston **43** is in its lower position under the action of gravity. The refrigerant in the pipe **40** flows into the pipe **41,** with the result that the refrigerant in the cycle flows, as indicated by the dotted line arrow in FIG. **12.**

In the dehumidifying operation, as shown in FIG. **13,** the valve **6** is open, so that the pressure of refrigerant in the pipe **42** becomes higher than that in the pipes **40** and **41** and the piston **43** in the three-way valve **19** is pushed up to the operative position shown in FIG. **11.** The refrigerant in the pipe **42** flows into the pipe **40** through the channel **44** at the center of the piston **43.** The refrigerant in this cycle flows as indicated by the dotted line arrow in FIG. **13.**

In the heating operation, the four-way valve is shifted to the position shown in FIG. **14.** The valve **6** is closed. In this case, the piston **43** of the three-way valve **19** moves down under gravity to the position shown in FIG. **10,** and the refrigerant in the pipe **41** flows into the pipe **40.** The refrigerant in this cycle then flows as indicated by the dotted line arrow in FIG. **14.**

We claim:

**1.** An air conditioner comprising a compressor, an outdoor heat exchanger, a first indoor heat exchanger, a second indoor heat exchanger, a first capillary tube, a second capillary tube, a third capillary tube, a first valve, a second valve and a piping communicating said elements with each other, said compressor communicating with one side of said outdoor heat exchanger and said first indoor heat exchanger, the other side of said outdoor heat exchanger communicating with one side of said first capillary tube and said second capillary tube, the other side of said first capillary tube tibe communicating with the other side of said first indoor heat exchanger, the other side of said second capillary tube communicating with one side of said second indoor heat exchanger, the other side of said second indoor heat exchanger and said compressor communicating with each other by said second valve, a series circuit of said second capillary tube and said second indoor heat exchanger and said first valve being connected in parallel with each other, said third capillary tube being connected between the side of said first indoor heat exchanger closer to said first capillary tube and the side of said second indoor heat exchanger closer to said second capillary tube, said first valve being closed and said second valve being opened during a cooling operation, and said first valve being opened and said second valve being closed during a dehumidifying operation.

**2.** An air conditioner as defined in claim **1,** wherien a four-way valve is disposed between the compressor, and the outdoor heat exchanger and the first indoor heat exchanger.



**3.** An air conditioner as defined in claim **2,** wherein said second valve is a three-way valve including a first pipe communicating with said first valve; a second pipe communicating with said second indoor heat exchanger; a third pipe, operatively connected to said compressor; and a piston, operatively movable by pressure differential of a refrigerant, such that said refrigerant flows between said first pipe and said second pipe, when said first valve is open, and said refrigerant flows between said second pipe and said third pipe, when said first valve is closed.

**4.** An air conditioner as defined in claim **1,** wherein said second valve is a three-way valve including a first pipe communicating with said first valve; a second pipe communicating with said second indoor heat exchanger; a third pipe, operatively connected to said compressor; and a piston, operatively movable by pressure differential of a refrigerant, such that said refrigerant flows between said first pipe and said second pipe, when said first valve is open, and said refrigerant flows between said second pipe and said third pipe, when said first valve is closed.

* * * * *