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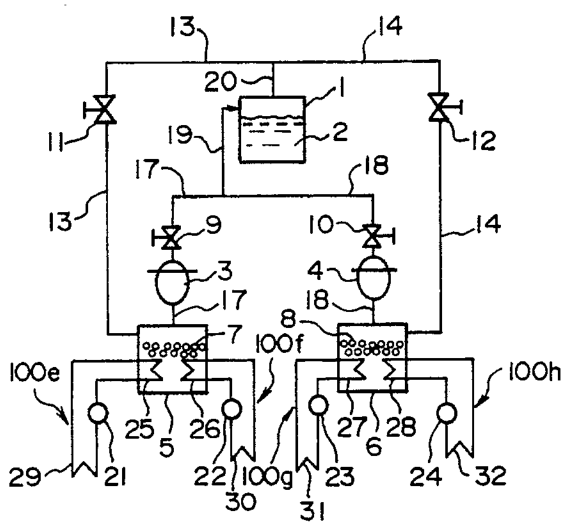
(54) Heat pump.

(57) A heat pump includes a reactor (5) adapted to accommodate a reaction material (7), the reactor (5) including a heat transfer device (100f) for accumulating heat and another heat transfer device (100e) for radiating heat. The reactor (5) communicates to a reservoir (1) adapted to accommodate a reaction medium (2) through a heat accumulation pipe (17, 19) with a compressor (3) and a valve (9) and a heat radiation pipe (13) with a valve (11) to form a circulating loop. Heat pumps having such a construction may be arranged in parallel, and the heat pumps are thereby capable of enhancing efficiency and stabilizing their operation conditions by alternately operating them.

FIG. I



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The present invention relates to a heat pump which is improved in temperature rise and efficiency by connecting a compressor to a chemical heat accumulation type heat pump.

In conventional heat pumps, a reservoir is cooled for reduction in pressure to introduce vapor of a reaction medium to it, the vapor being generated from a reaction material portion of a reactor in the regeneration thereof. Such heat pumps are disclosed in Japanese Patent Unexamined Publications Nos. 63-87564, 61-125561, 62-178857, 55-51295, 52-7057, for example.

The heat pumps of the prior art, however, pay no attention to recovery of heat in regeneration of the reaction material and efficient use of the heat, and hence raise a problem in that they do not provide sufficiently high temperature rise and efficiency.

It is an object of the present invention to provide a heat pump which is capable of providing a high temperature rise and a high efficiency.

In view of this and other objects, the present invention provides a heat pump which includes a reactor and a reservoir communicated to the reactor through a heat accumulation piping means with a compressor and a valve and through a heat radiation piping means with a valve to form a circulating loop. The reactor is adapted to accommodate a reaction material, and includes a heat transfer means for accumulating heat and another heat transfer means for radiating heat. The reservoir is adapted to accommodate a reaction medium. Heat pumps having such a construction may be arranged in parallel, and the heat pumps are thereby capable of enhancing their efficiency and stabilizing their operation states thereof by alternately operating them.

To regenerate the reaction material in the reactor by heating, heat is collected from the outside by the heat transfer means provided to the reactor, and is applied to the reaction material. To assist the regeneration, the heat accumulation pipe of the compressor may be communicated at its suction end to the reactor whereas it may be connected at its discharge end to the reservoir. With such an arrangement, the compressor may be operated to reduce pressure in the reactor. The vapor of the reaction medium which is decomposed from the reaction material by the decompression is compressed by the compressor, and is then passed through the discharge side heat accumulation pipe into the reservoir, where it is liquefied. To introduce vapor of the reaction medium which is generated from a reaction material portion in the reactor into the reservoir, the reservoir is, according to the prior art, depressurized by cooling the inside thereof. For this reason, heat which may be otherwise provided to the reaction material in regeneration is almost wasted outside. According to the present invention, gas generated from the reaction material in regeneration is highly raised in temperature and pressure by the compressor, and is then accumulated in the reservoir without any significant loss. On the other hand, the reaction medium which becomes high in temperature and pressure in the reservoir reaches the reaction material portion in the reactor, where the reaction medium reacts with the reaction material to generate heat with a high temperature. Thus, the heat pump of the present invention is capable of providing a high temperature rise and a high efficiency as compared to the prior art.

The present invention will now be described with reference to the drawings, in which

FIG. 1 is a diagrammatic illustration of one embodiment of the present invention;

FIG. 2 is a diagrammatic view of a modified form of the heat pump of FIG. 1;

FIG. 3 is a diagrammatic view of another embodiment of the present invention;

FIG. 4 is a diagrammatic view of a modified form of the heat pump of FIG. 3;

FIGS. 5 to 8 are diagrammatic views showing how to operate the heat pump of FIG. 4;

FIGS. 9 to 12 are diagrammatic views illustrating how to operate a modified form of the heat pump of FIG. 4;

FIG. 13 is a diagrammatic illustration of a modified form of the heat pump of FIG. 3;

FIG. 14 is a diagrammatic view of a modified form of the heat pump of FIG. 13; and

FIG. 15 is a diagrammatic view of a modified form of the heat pump of FIG. 14.

Referring to FIG. 1, one embodiment of the present invention will be described hereinafter. A reservoir 1 and reactor 5 are interconnected through heat accumulation pipes 17 and 19 and heat radiation pipes 13 and 20 to constitute a circulation loop as shown in FIG. 1. The reservoir 1 contains a reaction medium 2, such as water whereas the reactor accommodates a reaction material 7, such as lime, zeolite and silica gel. The reservoir 1 is a high temperature heat accumulator. It is essential that the reaction medium 2 is a substance such that it is liquefied in the reservoir 1 as a result of its phase change within the operation temperature range. For this reason, water is preferably used as the reaction medium 2 whereas lime, zeolite and silica gel which become high temperature heat by reacting with water may be adopted as the reaction material 7. It is preferable to thermally insulate around the reservoir 1. The heat accumulation pipe 17 is provided with a compressor 3 and a valve 9. The heat radiation pipe 13 has a valve 11 disposed therein. The reactor 5 includes a heat transfer unit 100e for heat radiation and a heat transfer unit 100f for heat accumulation. The heat transfer unit 100e includes a reactor side heat exchanger 25, a heat radiation side heat exchanger 29 and a pump 21, which are connected through a conduit to form a closed circulation passage. In the heat transfer unit 100f, a reactor side heat exchanger 26, a heat collecting side heat exchanger 30 and a pump 22 are connected to form another closed circulation passage. A heat medium, such as an oil and water, is sealed in these closed systems.

One of the essential features of the present invention resides in the closed circulation loops which operates as follows. Heat held in the atmosphere, waste heat and solar heat are collected by actuating the pump 22 of the heat transfer unit 100f for the heat accumulation, and thereby the reaction material 7 in the reactor 5 is heated. This heating causes the reaction medium 2 to be separated from the reaction material 7. Then, the compressor 3 is actuated and the valve 9 is opened, so that gas of the reaction medium 2 generated in the reactor 5 is delivered to the reservoir 1 for pressurization. The reaction medium 2 pressurized in the reservoir 1 is liquefied at a high temperature and pressure. The reservoir 1 is a high temperature heat accumulator.

By such an operation, the reaction material 7 in the reactor 5 is regenerated whilst liquefied reaction medium 2 is accumulated at a high temperature and pressure within the reservoir 1. Then, at an appropriate time, the valve 9 is closed, the compressor 3 is stopped, and the valve 11 is opened. These operations cause the reaction medium 2 in the reservoir 1 to be evaporated, and the generated vapor is passed to the reaction material 7 in the reactor 5 through the heat radiation pipe 13. As a result, the reaction material 7 generates heat and reaches a temperature much higher than the reaction medium 2. In this manner, heat which is provided by the heat collecting side heat exchanger 30 becomes a high temperature in the compressor 3 and is then accumulated in the reservoir 1. From the reservoir 1, heat is then introduced through the heat radiation pipe 13 into the reaction material 7, where it reaches a very high temperature. The heat pump according to the present invention thus enables heat to be derived at a very high temperature from the heat transfer unit 100e for heat radiation.

The heat pump according to the present invention is essentially operated as described but it is preferable that a plurality of (two in FIG. 1) the circulation loops are used in combination for smoothly performing the heat accumulation and heat radiation operations. In FIG. 1, the second circulation loop includes a reactor 6, containing a reaction material 8. The reactor 6 and the reservoir 1 are interconnected in parallel with the first circulation loop through a heat accumulation pipe 18 and a heat radiation pipe 14. The heat accumulation pipe 18 is provided with a compressor 4 and a valve 10, and the heat radiation pipe 14 is provided with a valve 12. The second reactor 6 has a heat transfer unit 100h for heat accumulation and a heat transfer unit 100g for heat radiation connected to it as shown.

The heat transfer unit 100g includes a reactor side heat exchanger 27, a heat radiation side heat exchanger 31 and a pump 23, which are connected through a conduit to form a closed circulation passage.

In the heat transfer unit 100h a reactor side heat exchanger 28, a heat collecting side heat exchanger 32 and a pump 24 are connected to form another closed circulation passage.

Basically, the first and second closed loops are alternately operated. This facilitates adjustment of the reservoir 1 in temperature and pressure, prevents overload operation of the compressors 3 and 4, and lowers the failure rate thereof. In the alternative operation of the loops, the adjustment of the temperature and pressure in the reservoir 1 may be achieved by the rotational speed of the compressor 3 and opening degrees of the valves 9 and 12 or the rotational speed of the compressor 4 and opening degrees of the valves 10 and 11.

In parallel connection operation of the first and second loops, heat flows through the heat transfer unit 100f of heat accumulation, the reactor 5, the compressor 3, the reservoir 1, the valve 12, the reactor 6 and the transfer unit 100g for heat radiation in the first cycle while heat flows through the heat transfer unit 100h for heat accumulation, the reactor 6, the compressor 4, the reservoir 1, the valve 11, the reactor 5 and the heat transfer unit 100e for heat radiation in the second cycle.

FIG. 2 illustrates a modified form of the heat pump of FIG. 1. In the modified heat pump, a heat accumulation pipe 19 is arranged to pass through the reservoir 1 from the bottom of the latter as shown, and communicates to a heat exchanger 15 provided within the reservoir 1. An outlet pipe 16 of the pipe 19 is projected from an upper wall of the reservoir 1 and then communicates at its distal end to the interior of the reservoir 1 through the upper wall. In this manner, it is possible to uniformly and sufficiently heat the liquid and the gas of the reaction medium 2 which is contained in the reservoir 1. The pipe 19 may pass through a side wall of the reservoir 1.

Another modified form of the heat pump is illustrated in FIG. 3. This heat pump is provided with a third loop in addition to the first and second loops. The third loop is constituted by the reservoir 1, a heat radiation pipe 60 with a valve 61, a reactor 50 containing a reaction material 57, a heat accumulation pipe 59 with a valve 58, a heat accumulation pipe 38 with the compressor 3 and the heat exchanger 15, and the outlet pipe 16. The reactor 50 of the third loop has a heat transfer unit 100j for heat accumulation and a heat transfer unit 100i for heat radiation as shown.

The heat transfer unit 100i includes a reactor side heat exchanger 53, a heat radiation side heat exchanger 55 and a pump 51 which are connected through conduits to form a closed circulation passage.

In the heat transfer unit 100j a reactor side heat exchanger 54, a heat collecting side heat exchanger 56 and a pump 52 are connected to form another closed circulation passage.

In this modification, a single compressor 3 is provided, and three loops are switched by valves 9, 10 and 58. That is, the compressor 3 is operated full time. The heat exchanger 15 which is connected to the heat accumulation pipe 38 is arranged to extend along the outer surfaces (side and bottom surfaces) of the reservoir 1 so that the reaction medium 2 within the reservoir 1 may be heated through the walls of the reservoir 1. The three loops may be operated in three different modes. For example, when the reactor 5 of the first loop is in the heat accumulation (regeneration) mode, the reactor 6 of the second loop and the reactor 50 of the third loop are in the heat radiation mode and at a rest, respectively. Alternatively, two of the loops may be overlap in their operation modes for a limited time. More specifically, while the first and second loops are in the heat accumulation (regeneration) mode and the heat radiation mode, respectively, the third loop may be operated for heat accumulation (regeneration) for the first half and for heat radiation for the second half.

FIG. 4 shows a still another modified form of the heat pump of FIG. 3, in which a fourth loop is provided in addition to the first, second and third loops. The fourth loop includes the reservoir 1, a heat radiation pipe 80 with a valve 81, a reactor 70 containing reaction material 77, a heat radiation pipe 80 with a valve 81, a heat accumulation pipe 79 with a valve 78, the heat accumulation pipe 38 with the compressor 3, the heat exchanger 15 and an outlet pipe 16-a. The reactor 70 has a heat transfer unit 1001 for heat accumulation and a heat transfer unit 100k for heat radiation disposed to it as shown. The heat transfer unit 100k includes a reactor side heat exchanger 73, a heat radiation side heat exchanger 75 and a pump 71 which are connected through conduits to form a closed circulation passage.

In the heat transfer unit 100j a reactor side heat exchanger 74, a heat collecting side heat exchanger 76 and a pump 72 are connected to from another closed circulation passage.

In this modified heat pump, the outlet pipe 16-a which extends from the heat exchange 15 opens to an upper space within the reservoir 1 without passing through the upper wall of the latter.

FIGS. 5 to 8 illustrate how to operate the four loops of FIG. 4, and particularly show operation modes of the reactors 5, 6, 50 and 70 of the four loops. In the figures, reference character A designates a reactor in a reaction phase, B a phase in which the reaction is completed and there is waste heat, C a heat accumulation (regeneration) phase, and D a regeneration termination phase. One of the important points to improve in efficiency a chemical heat accumulation type heat pump utilizing reaction heat is to effectively use waste heat when there is waste heat in the reaction termination phase B. In this modified heat pump, efficiency is enhanced by recovering this waste heat in the reactor in a regeneration starting phase or the regeneration phase C. To recover the waste heat, heat transfer units 100m, 100n, 100p and 100q which thermally connect the four reactors 5, 6, 50 and 70 together are arranged as shown. Each of the heat transfer units includes two heat exchangers and a pump. In FIG. 5, the reactor 50 is in the reaction phase A, and the heat transfer unit 100i is under the heat radiation operation; the reactor 5 is in the regeneration phase C with the heat transfer unit 100f under an operation to transfer heat from a heat source 33 to the reactor 5; the reactor 6 is in the regeneration termination phase, in which the heat transfer unit 100m between the reactors 5 and 6 is in a heat transfer mode to recover waste heat of the reactor 6 to the reactor 5. In FIGS. 5 through 8, circles indicates pumps; hollow circles represent pumps at rest while solid circles pumps in operation. The operation mode of each reactor 5, 6, 50, 70 changes as time passes. In FIG. 6, the reactor 70 is in the reaction mode; in FIG. 7, the reactor 5 in the reaction mode; and in FIG. 8, the reactor 6 in the reaction mode.

FIGS. 9 to 12 illustrates a modified form of the four loops of FIGS. 5 to 8. In this modified form, fans 101, 102, 103 and 104 are used for heat transfer forced air convection in place of the heat transfer units 100m, 100n, 100p and 100q to recover heat. Heat transfer between reactors may be achieved via outer surfaces of the reactors 5, 6, 50 and 70 or may be accomplished by introducing air, sent from a fan, into pipes which are arranged to pass through walls of the reactor. In this modified heat pump, a cover 90 having a semi-circular shape in plan view is provided around the heat source 33 so as to open side wards. By rotating the cover 90 as shown, hot air from the heat source 33 is blown against the reactor in the regeneration mode C.

Another modified heat pump is illustrated in FIG. 13. In the modified heat pump, the reservoir is divided into two reservoirs 1 and 1-a which thermally contact through a wall 39. Heat transfer between a reaction medium 2 in the reservoir 1 and a reaction medium 2-a in the reservoir 1-a is achieved through the wall 39. The first and second loops of this modification are basically independent from each other, and the operation of the heat pump is hence stabilized.

The first loop includes the reservoir 1, the heat radiation pipe 13 with the valve 11, the reactor 5, the heat accumulation pipe 17 with the valve 9, the heat accumulation pipe 38 with the compressor 3 and a heat accumulation pipe 36 with a valve 34.

The second loop includes the reservoir 1-a, the heat radiation pipe 14 with the valve 12, the reactor 6, the heat accumulation pipe 18 with the valve 10, the heat accumulation pipe 38 with the compressor 3 commonly with the first loop, and a heat accumulation pipe 37 with a valve 35.

The reservoir 1-a may be disposed within the reservoir 1 or the reverse may be adopted. In such cases, the reservoir 1 or 1-a may have a structure of a coil-shaped heat exchanger. In a case where more than two loops are combined, more than two reservoirs may be arranged to come into thermal contact to each other.

FIG. 14 shows a modification of the heat pump of FIG. 13. In the modified heat pump, the reservoirs 1 and 1-a are separated and thermally combined by a heat transfer unit 100S which includes a heat exchanger 41, a pump 40 and a heat exchanger 42. The amount of heat transfer from the reaction medium 2 in the reservoir 1 to the reaction medium 2-a of the reservoir 1-a or in the reverse direction may be adjusted by varying the operation factor of the pump 40. This enables inner pressure of the reservoir 1 or the reservoir 1-a to be adjusted.

If the heat transfer unit 100S is provided with a heat accumulation tank, the adjustment of inner pressure of the reservoir 1 or the reservoir 1-a is further facilitated. The heat accumulation tank may be located in the heat transfer unit 100S or in a bypass circuit which is switched by a valve provided in the heat transfer unit 100S. In the heat pump of FIG. 14, heaters 43 and 44 are provided within the reservoir 1 and reservoir 1-a, respectively, and inputs to the heaters 43 and 44 may be adjusted by detecting inner pressure and temperature of the reservoir 1 or reservoir 1-a. This also facilitates the adjustment of the inner pressure and temperature of the reservoir 1 or reservoir 1-a. The heaters 43 and 44 may be replaced by heat exchangers which are supplied with cold water (or cold air) or hot water (or hot air). These heat exchangers make such adjustment much easier. A heat accumulation tank may be provided outside each of the heat exchangers to accumulate surplus heat of the reservoir 1 or 1-a. With such a heat accumulation tank, the adjustment of the reservoir 1 or 1-a in inner pressure and temperature is also performed with ease. As the heat accumulation tank, a sensible heat accumulation type tank, a latent heat accumulation type tank, and a chemical heat accumulation type tank may be used. Heat at high or low temperatures may be provided to the heat exchangers by another heat pump.

FIG. 15 illustrates a modified form of the heat pump of FIG. 14. In the modified form, the heat radiation side heat exchanger 29 of the reactor 5 and the radiation side heat exchanger 32 of the reactor 6 are integrated by fins 91 whereas the heat collecting side heat exchanger 30 of the reactor 5 and the heat collection side heat exchanger 31 of the reactor 6 are also integrated by fins 90. With such a construction, the heat pump as a whole may become small sized.

The present invention may adopt a heat flow control heat transfer unit, disclosed in Japanese Patent Examined Publications Nos. 58-53277, 60-37390, etc., as the heat transfer units 100e, 100f, 100g, 100h, 100i, 100j, 100k, 100ℓ, 100m, 100n, 100p, 100q and 100s. High temperature heat collected by other heat pumps may be sent to the heat collection heat exchangers of the heat transfer units 100f, 100h, 100j and 100ℓ for heat accumulation.

The heat pumps according to the present invention is capable of performing a temperature rise twice larger than and is 20% larger in heat efficiency than the conventional heat pumps. The adjustment of pressure in the reservoirs is, according to the present invention, smoothly achieved by the parallel combination of the loops of heat pumps, and the present invention is thus capable of stabilizing the cyclic operation of the heat pumps.

Claims

1. A heat pump which comprises:

a reactor (5) adapted to accommodate a reaction material (7), the reactor (5) including a heat transfer means (100f) for accumulating heat in the reaction material (7) and another heat transfer means (100e) for radiating heat from the reaction material (7);

a reservoir (1) adapted to accommodate a reaction medium (2);

a compressor (3);

first piping means (17, 19) for interconnecting the reactor (5) and the reservoir (1) through the compressor (3) and a valve (9); and second piping means (13) for interconnecting the reactor (7) and the reservoir (1) through another valve (11), whereby the reactor (5), the reservoir (1), the compressor (3), the first (17, 19) and second (13) piping means constitute a circulation loop for circulating the reaction medium (2).

2. A heat pump as recited in claim 1, wherein the first piping means comprises a heat accumulation pipe (17, 19) extending from the compressor (3) to the reservoir (1) having a bottom wall and a side wall, the pipe (19) having one end remote from the compressor (3), the one end passing through one of the bottom walls and the side wall into an interior of the reservoir (1) to open to an upper inner space of the reservoir (1).

3. A heat pump as recited in claim 1, wherein the first piping means comprises a heat accumulation pipe (17, 19) extending from the compressor (3) to the reservoir (1) having a bottom wall and a side wall, the pipe (19) having one end portion remote from the compressor (3), the one end portion externally contacting at least one of the bottom wall and the side wall and opening to an upper inner space of the reservoir (1).

4. A heat pump as recited in claim 1, wherein the reservoir (1) is provided with one of a heater (43, 44) and a heat exchanger (15; 41, 42) for heating the reservoir (1).

5. A heat pump as recited in claim 1, wherein the reaction material (7) comprises one of lime, zeolite and silica gel, and the reaction medium (2) comprises water.

6. A heat pump system comprising a plurality of heat pumps as recited in claim 1, the heat pumps being arranged in parallel.

7. A heat pump which comprises:

a plurality of reactors (5, 6, 50, 70) adapted to accommodate a reaction material (7, 8, 57, 77), each reactor (5, 6, 50, 70) including heat transfer means (100f, 100h, 100j, 100l) for accumulating heat in the reaction material and another heat tranfer means (100e, 100g, 100i, 100k) for radiating heat from the reaction material (7, 8, 57, 77);

a reservoir (1, 1-a) adapted to accommodate a reaction medium (2, 2-a);

a compressor (3); and

first piping means (17, 18, 59, 79) for communicating each reactor (5, 6, 50, 70) to the compressor (3) in parallel through a valve (9, 10, 58, 78);

second piping means (38) for communicating the compressor (3) to the reservoir (1, 1-a); and

third piping means (13, 14, 60, 80) for communicating the reservoir (1, 1-a) to each of the reactors (5, 6, 50, 70) through another valve (11, 12, 61, 81), whereby each reactor (5, 6, 50, 70), the reservoir (1, 1-a), the compressor (3), the corresponding valves (9, 10, 58, 78; 11, 12, 61, 81) and the first (17, 18; 59, 79), second (38) and third (13, 14, 60, 80) piping means constitute a circulation loop for circulating the reaction medium (2, 2-a).

8. A heat pump system as recited in claim 7, wherein there are provided a plurality of the reservoirs (1, 1-a) thermally coupled to each other.

9. A heat pump system as recited in claim 7, wherein the heat transfer means (100f, 100h) for heat accumulation each comprises a heat collection side heat exchanger (30, 31), and the heat transfer means (100e, 100g) for heat radiation each comprises a heat radiation side heat exchanger (29, 32), and further comprising fins (90, 91), part (90) of the fins integrally assembling the heat collection side heat exchangers (30, 31) of the transfer means (100f, 100h) for heat accumulation whereas the rest (91) of the fins integrally assemble the heat radiation side heat exchangers (29, 32) of the transfer means (100e, 100g) for heat radiation.

10. A heat pump as recited in claim 7, further comprising heat recovering means (100m, 100n, 100p, 100q; 101, 102, 103, 104) for recovering surplus heat generated from one of the reactors (5, 6; 50, 70) to another reactor in which regeneration is started, the one reactor having completed a reaction between the heat material and the heat medium.

11. A heat pump which comprises:

a plurality of reactors (5, 6) adapted to accommodate a reaction material (7, 8), the reactor (5, 6) including a heat transfer means (100f, 100h) for accumulating heat in the reaction material (7, 8) and another heat transfer means (100e, 100g) for radiating heat from the reaction material (7, 8);

a reservoir (1) adapted to accommodate a reaction medium (2);

compressors (3, 4);

first piping means (17, 18) for communicating each reactor (5, 6) to the reservoir (1) in parallel through a corresponding ccmpressor (3, 4) and a valve (9, 10); and

second piping means (13, 14) for communicating each reactor (5, 6) to the reservoir (1) through another valve (11, 12), whereby each reactor (5, 6), the reservoir (1), the corresponding compressor (3, 4), the first (17, 18) and second (13, 14) piping means and the corresponding valves (9, 10; 11, 12) constitute a circulation loop for circulating the reaction medium (2).

FIG. 1

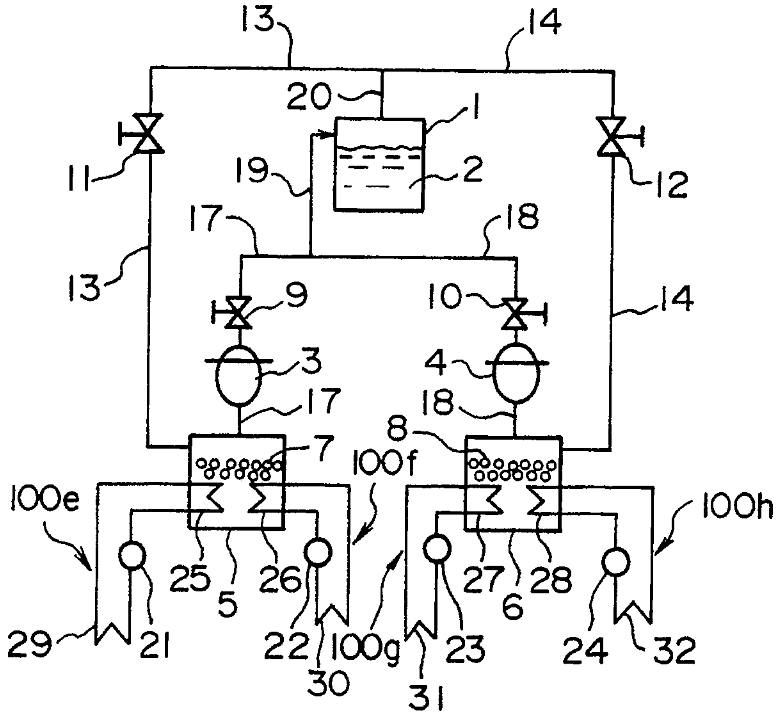
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FIG. 2

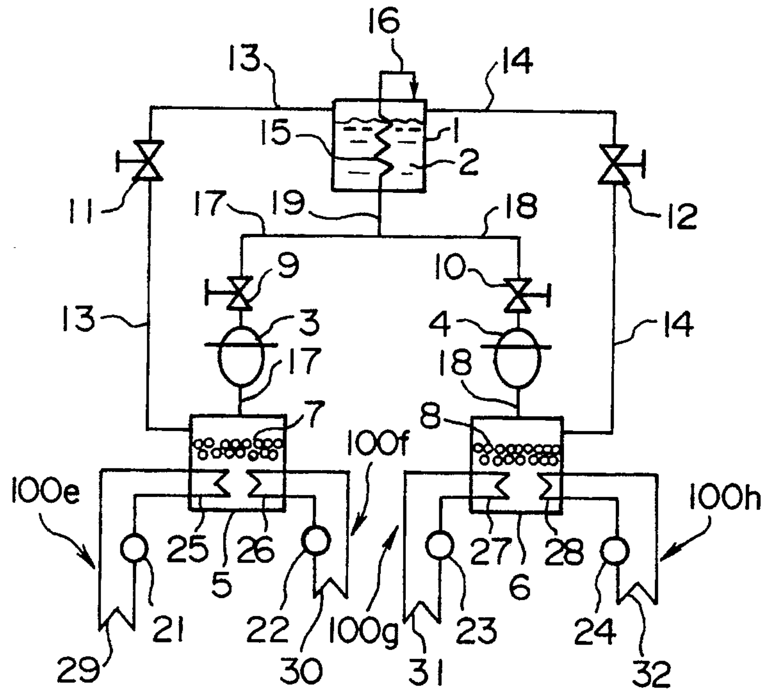
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FIG. 3

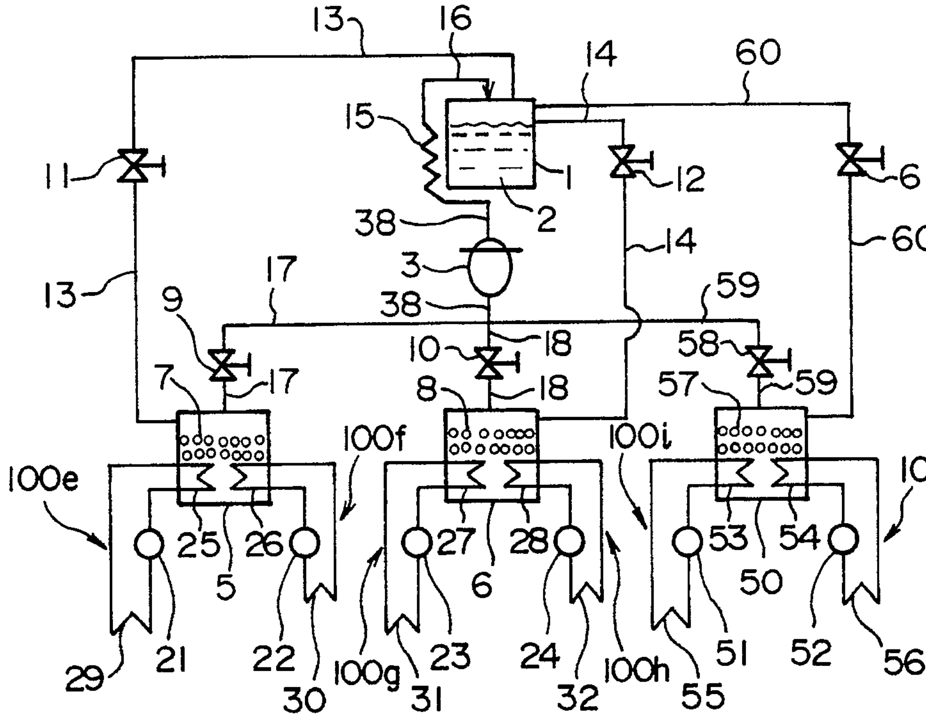
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FIG. 4

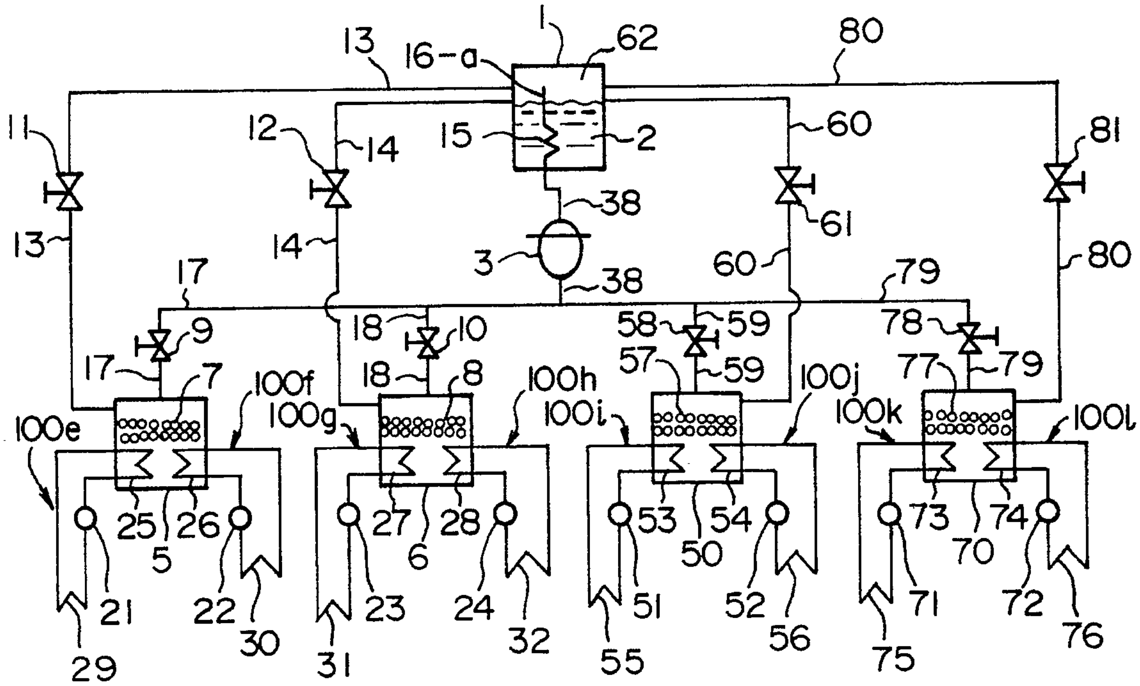
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FIG. 5

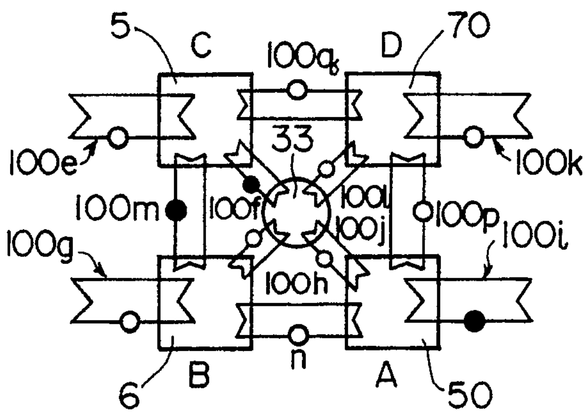

FIG. 7

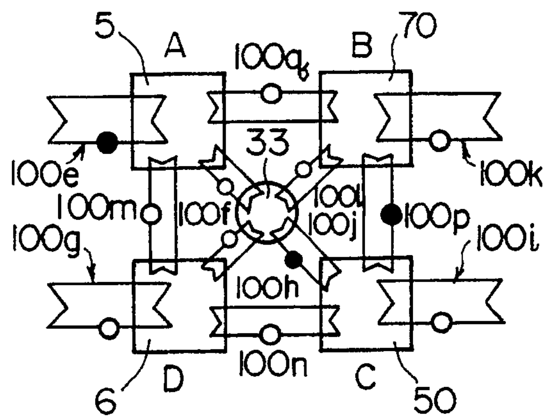

FIG. 6

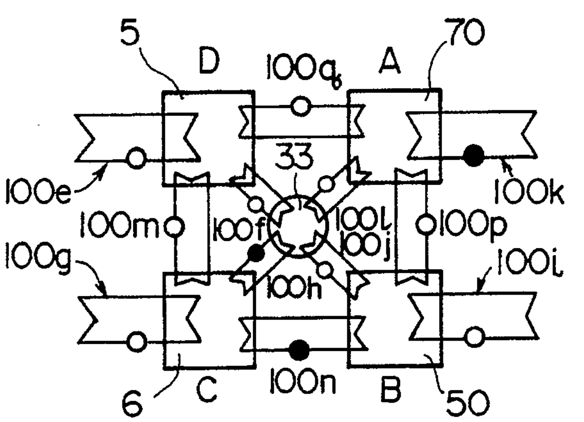

FIG. 8

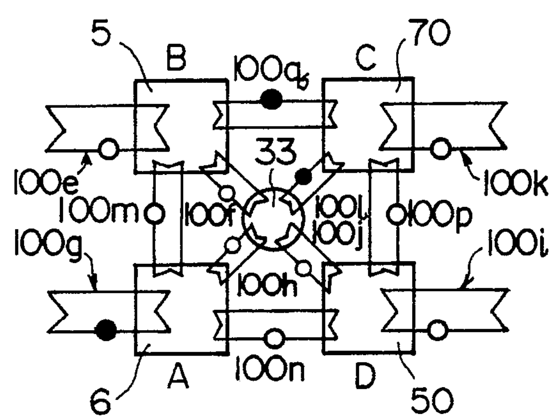

FIG. 9

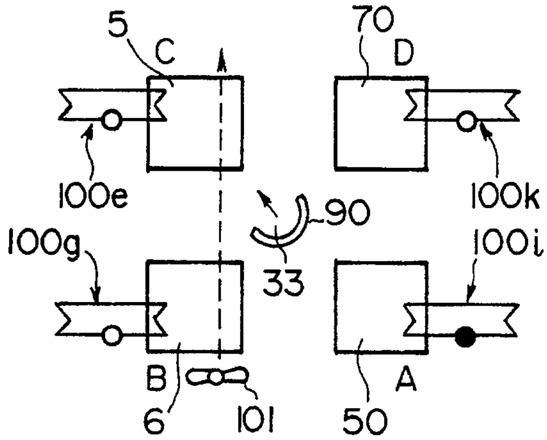

FIG. 11

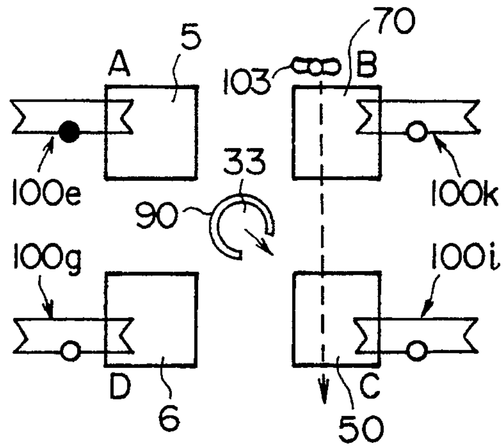

FIG. 10

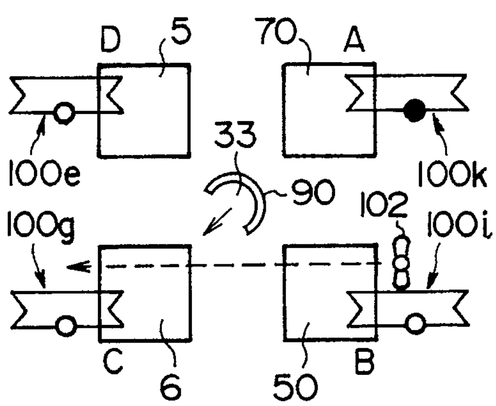

FIG. 12

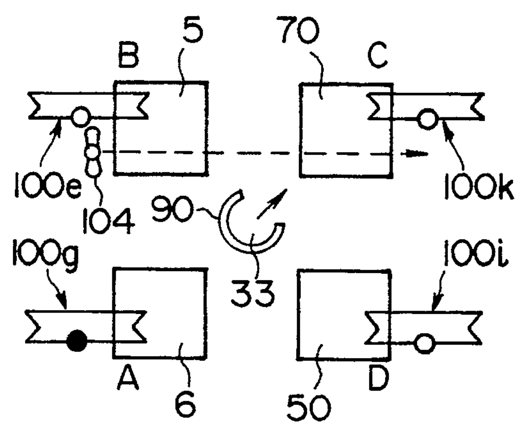

FIG. 13

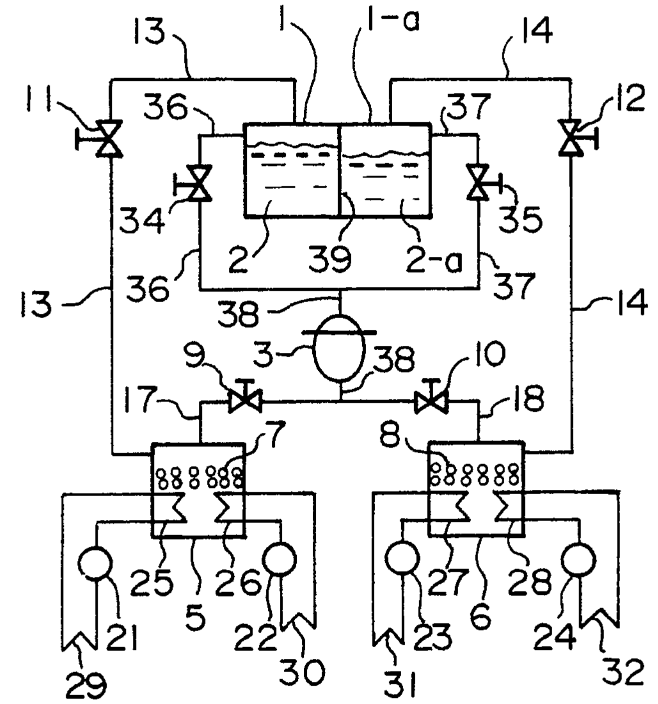
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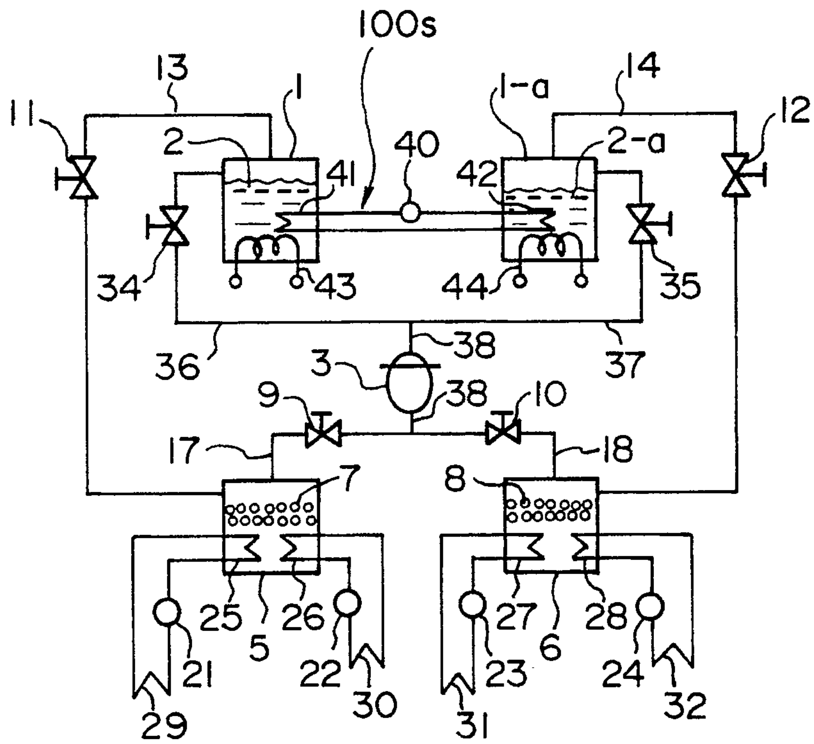
FIG. 14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3
38
9
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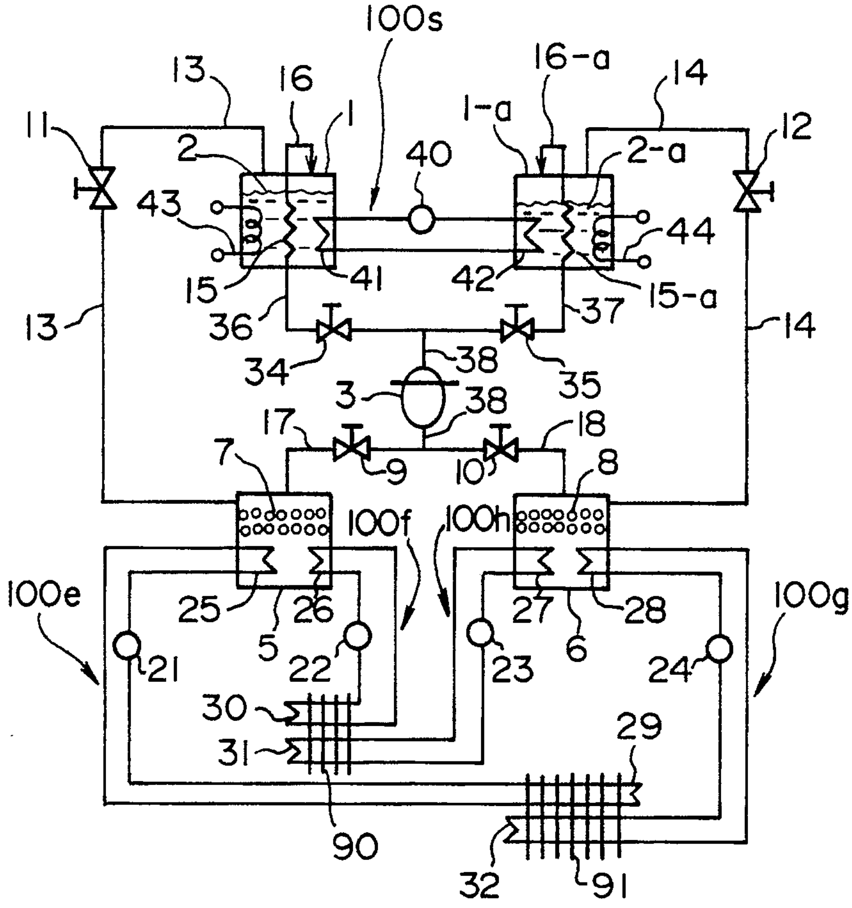
FIG. 15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13
36
37
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35
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17
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8
100f
100h
100e
25
26
5
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28
6
100g
21
22
23
24
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90
32
91