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(54) **A dual-operation mode air conditioning apparatus.**

(57) This apparatus (1), which is designed for operation either as a heater or a cooler by reversing the flow of thermal fluid, comprises an indoor unit (2), an outdoor unit (3), a flexible connection element (4) between the indoor unit and the outdoor unit, an indoor heat exchanger (5) within the indoor unit (2), an outdoor heat exchanger (16) within the outdoor unit (3), a compressor (7) internal to the indoor unit (2), and an expansion device (33,34). The apparatus (1) also includes connective ducting comprising, inside the connection element (4), three flexible lines: a main flexible line (32) for the thermal fluid to flow between the outdoor heat exchanger (16) and the compressor (7) in either directions, a heating mode flexible line (33) for the thermal fluid to flow from the indoor heat exchanger (5) to the outdoor heat exchanger (16) during operation in the heating mode, and a cooling mode flexible line (34) for the thermal fluid to flow from the outdoor heat exchanger (16) to the indoor heat exchanger (5) during operation in the cooling mode. The flexible connection element (4) comprises a sleeve (26) defining two separate longitudinal cavities (27,28), of which one cavity (27) accommodates the main flexible line (32) together with the heating mode flexible line (33), and the other cavity (28) accommodates the cooling mode flexible line (34).

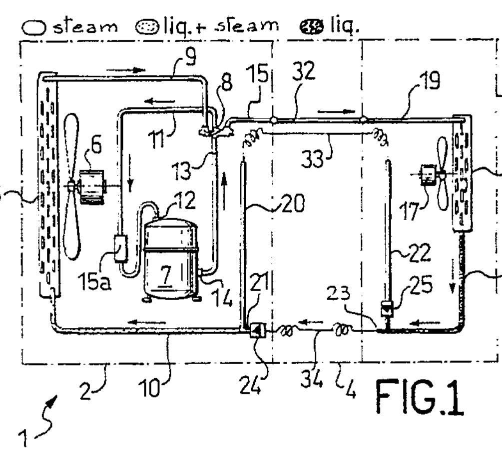

FIG.1

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This invention relates to an air-conditioner refrigerating apparatus comprising two separate units intended, the one for installation within a room to be air conditioned and the other for outdoor installation.

More particularly, the invention relates to an air-conditioner refrigerating apparatus having dual operation mode features, i.e. a cooling mode and a heating mode by reversal of the thermal fluid flow, which apparatus comprises an indoor unit, an outdoor unit, a flexible element interconnecting the indoor and outdoor units, an indoor heat exchanger within the indoor unit, an outdoor heat exchanger within the outdoor unit, a compressor within the indoor unit, an expansion device, and connection ducts between the outdoor heat exchanger, the expansion device, the indoor heat exchanger, and the compressor.

Apparatus of this general type have been known and used especially as portable air conditioners, that is air conditioners for non-permanent installation. In this case, much valued is indeed the possibility they afford of installing them without bores having to be provided through the window panes, it being sufficient that a window be kept ajar or that a cutout be formed in the window frame and/or jamb for the connection element.

The connection element is provided, in fact, in the form of a thick flattened cable. It has an outer sleeve enclosing the electrical connections (three electrical cables), the two-way refrigerating liquid lines (two lines), and usually a drain line for taking to the outdoor heat exchanger the condensation water which forms over the indoor heat exchanger during operation in the cooling mode.

In order to switch the mode of operation over from cooling to heating, the direction of flow of the thermal fluid is just reversed. In the cooling mode, the flow direction is from the compressor to the outdoor heat exchanger (which then operates as the system condenser), the filming device, the indoor heat exchanger (which operates then as the evaporator), and back to the compressor; in the heating mode, the flow direction is from the compressor to the indoor heat exchanger (then operating as the system condenser) to the expansion device, the outdoor heat exchanger (then operating as the evaporator), and back to the compressor.

Thus, fluids at different temperatures would be normally flown through the lines in the connection element. To avoid heat exchange between the fluids within the lines, it is common practice to hold the two lines as far apart as possible, or to provide them with individual thermal insulation.

This invention is directed to an air-conditioner refrigerating apparatus of the kind outlined above, which is characterized in that the connection ducts comprise three flexible lines within the connection element, namely a main flexible line for the thermal fluid to flow between the outdoor heat exchanger and the compressor in either directions, a heating mode flexible line for conveying the thermal fluid flow from the indoor heat exchanger to the outdoor heat exchanger during operation in the heating mode, and a cooling mode flexible line for conveying the thermal fluid flow from the outdoor heat exchanger to the indoor heat exchanger during operation in the cooling mode.

Advantageously, the main flexible line would be located adjacent to the heating mode flexible line and at a spacing from the cooling mode flexible line.

Further to advantage, the flexible connection element comprises a sleeve defining two separate longitudinal cavities, with the main and heating mode flexible lines housed within one of the cavities and the cooling mode flexible line housed in the other of said cavities.

Further features and the advantages of a refrigerating apparatus according to the invention will be more clearly understood from the following detailed description of a preferred embodiment thereof, given with reference to the accompanying drawings.

In the drawings:

Figure 1 shows in schematic form an apparatus according to the invention while operated in the cooling mode;

Figure 2 shows in schematic form the apparatus of Figure 1, while operated in the heating mode;

Figure 3 is a sectional view of the connection element in the apparatus of Figure 1; and

Figure 4 is a temperature vs. entropy state diagram which depicts the thermodynamic cycle occurring in the apparatus shown in Figure 1.

In the drawing views, generally shown at 1 is a refrigerating apparatus for air conditioning, being of a type which can operate in a dual mode (i.e , either in the cooling or heating modes). The apparatus 1 comprises an indoor unit 2, an outdoor unit 3, and a flexible connection element 4 extending between the indoor unit 2 and the outdoor unit 3.

The indoor unit 2 comprises an indoor heat exchanger 5 having conventional air forcing means, only shown schematically at 6 in the drawings, associated therewith.

The indoor unit 2 further comprises a compressor 7 and a change-over valve 8, as well as a line 9 between the change-over valve 8 and the indoor heat exchanger 5, a line 10 between the indoor heat exchanger 5 and the connection element 4, a line 11 between the change-over valve 8 and an intake port 12 of the compressor 7, a line 13 between the change-over valve 8 and a delivery port 14 of the compressor 7, and a line 15 between the change-over valve 8 and the connection element 4. Included with the line 11, at a location close to the intake port 12 of the compressor 7, is a liquid/steam separator 15a effective to prevent the liquid-phase thermal fluid from entering the compressor 7 and damaging it.

The outdoor unit 3 comprises an outdoor heat exchanger 16, having conventional air forcing means associated therewith, as only shown schematically at 17 in the drawings. The outdoor unit 3 also comprises two lines 18 and 19 extending between the outdoor heat exchanger 16 and the connection element 4.

The line 10 in the indoor unit 2 and line 18 in the outdoor unit 3, leading to the connection element 4, are both split, the former into two sub-lines 20 and 21 and the latter into two sub-lines 22 and 23. The sub-line 21 includes a one-way valve 24 which only allows the thermal fluid to flow toward the line 10, and the sub-line 22 includes a one-way valve 25 which only allows the thermal fluid to flow toward the line 18.

The connection element 4 comprises a sleeve or outer sheath 26 having two longitudinal cavities 27 and 28 defined therein which are separated by a partition 29.

The connection element 4 further comprises a main flexible line or duct 32 connected, at one end, to the line 15 of the indoor unit 2, and at the other end, to the line 19 going to the outdoor unit 3; a heating mode flexible line or duct 33 connected, at one end, to the sub-line 20 of the indoor unit 2, and at the other end, to the sub-line 22 of the outdoor unit 3; and a cooling mode flexible line or duct 34 connected, at one end, to the sub-line 21 of the indoor unit 2, and at the other end, to the sub-line 23 of the outdoor unit 3.

The main flexible line 32 is formed essentially by a pipe positioned inside the cavity 27 in the sleeve 26; the heating mode flexible line 33 consists instead of at least one capillary tube, preferably two capillary tubes placed in parallel with each other within the cavity 27, and therefore at a location substantially adjacent to the main line 32. The cooling mode flexible line 34 also consists of at least one capillary tube, preferably two capillary tubes in parallel, positioned inside the cavity 28, that is at a location substantially removed from the main flexible line 32.

The operation of the apparatus 1 will be now described with particular reference to Figures 1 and 2, and to the state diagram of Figure 4.

When the apparatus is operated as a cooler, i.e. in the cooling mode, the switching or changeover valve 8 is set to communicate the line 13 to the line 15, and the line 9 to the line 11. In this way, the following circuit is established for the thermal fluid in this order: compressor 7, line 13, line 15, main flexible line 32, line 19, outdoor heat exchanger 16, line 18, sub-line 23, cooling mode flexible line 34, sub-line 21, line 10, indoor heat exchanger 5, line 9, line 11, compressor 7. The one-way valve 25 in the sub-line 22 will cut off the heating mode flexible line 33.

The thermal fluid undergoes the following thermodynamic cycle in the cooling mode.

Within the compressor 7, the thermal fluid will enter at dry saturated steam conditions at a temperature T1 (point A in Figure 4) and be compressed iso-entropically up to a temperature T4 (segment AB). Under this condition of superheated steam (point B), the thermal fluid will flow through the lines 13 and 15, the main flexible line 32, and line 19 to the outdoor heat exchanger 16. At the outdoor heat exchanger 16 (now serving as the condenser), the thermal fluid will give forth heat to the surroundings, to be cooled and liquefied; more specifically, vapor phase cooling would initially (segment BC) take place from temperature T4 down to temperature T3, followed by a gradual iso-thermobaric change of state at temperature T3 (segment CD), and finally by further liquid phase cooling (referred to as subcooling) from temperature T3 to temperature T2 (segment DE).

The thermal fluid, therefore, will leave the outdoor heat exchanger 16 in a liquid state subcooled to temperature T2 (point E) and flow through the lines 18 and 23 to the cooling mode flexible line 34. This line 34 provides a choke, and accordingly, will serve as an expansion device wherein the thermal fluid undergoes iso-enthalpic filming (segment EF) and be cooled down to temperature T1 and partly evaporated. In the two-phase condition of liquid plus vapor at temperature T1 (point F), the thermal fluid will flow through lines 21 and 10 to the indoor heat exchanger 5.

Within the heat exchanger 5 (presently serving as the evaporator), the thermal fluid will take in heat from the space to be cooled and undergo a gradual iso-thermobaric change of state (segment FA) to a condition of dry saturated steam at temperature T1 (point A). It is in this condition that the thermal fluid will flow through lines 9 and 11 to compressor 7.

It should be noted, in the respect of the cooling mode of operation, that steam at temperature T4 (point B) will be present in the main flexible line 32, whilst liquid at temperature T2 (point E) is present within the cooling mode flexible line 34. Note should also be taken of that the amount of heat removed from the space being cooled is directly proportional to the length of segment FA. Thus, thermal exchange between the lines 32 and 34 would result in the gas within the line 32 (segment BB′) being cooled and the liquid within the line 34 (point EE′) being heated. Accordingly, iso-enthalpic expansion by the expansion device would lead to condition F′, with an evident decrease of the amount of heat to be removed from the space being cooled (F′A instead of FA).

It should be further noted that the situation would remain substantially unchanged where the expansion device, rather than being comprised of the capillary tubes of the cooling mode flexible line 34, were comprised of a conventional expansion valve provided on the outdoor unit 3 (e.g , on sub-line 23) or on the indoor unit 2 (e.g., on sub-line 21). With the expansion device incorporated to the indoor unit 2, within the cooling mode flexible line 34 there would still be thermal fluid under condition E; in the other case, within the cooling mode flexible line 34 there would be fluid under condition F, i.e. at a lower temperature T1 than temperature T2, which would aggravate the problems due to transfer of heat between lines 32 and 34.

The advantage may therefore be appreciated of having heat transfer between the main flexible line 32 and the cooling mode flexible line 34 prevented, which is accomplished, according to the invention, by placing the former inside the cavity 27 of sleeve 26 and the latter inside the cavity 28 of sleeve 26, that is separated by the partition 29.

When the apparatus is operated as a heater, i.e. in the heating mode, the switching of change-over valve 8 is set to communicate line 13 with line 9, and line 15 with line 11. In this way, the following circuit path is established for the thermal fluid: compressor 7, line 13, line 9, indoor heat exchanger 5, line 10, sub-line 20, heating mode flexible line 33, sub-line 22, line 18, outdoor heat exchanger 16, line 19, main flexible line 32, line 15, line 11, compressor 7. The one-way valve 24 will cut off the cooling mode flexible line 34

The thermal fluid undergoes the following thermodynamic cycle in the heating mode.

Within the compressor 7, the thermal fluid will enter a condition of dry saturated steam at temperature T1 (point A) and be compressed iso-enthropically to temperature T4 (segment AB). Under this superheated steam condition (point B), the thermal fluid flows through the lines 13 and 9 to the indoor heat exchanger 5. At the heat exchanger 5 (now serving as the condenser), the thermal fluid will transfer heat iso-barically to the space to be heated, and hence be cooled and liquefied; specifically, vapor phase cooling (segment BC) will first take place from temperature T4 down to temperature T3, followed by a gradual iso-thermobaric change of state at temperature T3 (segment CD), and finally by further liquid phase cooling (subcooling) from temperature T3 to temperature T2 (segment DE).

The thermal fluid then exits the indoor heat exchanger 5 in a condition of subcooled liquid at temperature T2 (point E), and flows through the lines 10 and 20 to the heating mode flexible line 33. This line 33 provides a choke, and accordingly, will function as an expansion device whereby the thermal fluid, in flowing through it, undergoes iso-enthalpic filming (segment EF) and cooling to temperature T1 while evaporating in part. In the condition of a two-phase fluid comprising liquid plus vapor at temperature T1 (point F), the thermal fluid will flow through the lines 22 and 18 to the outdoor heat exchanger 16.

Inside the heat exchanger 16 (now serving as the evaporator), the thermal fluid will take in heat from the surroundings and undergo a gradual iso-thermobaric change of state (segment FA) to the condition of dry saturated steam at temperature T1 (point A). It is in this condition that the thermal fluid flows then through the line 19, main flexible line 32, line 15, and line 11 to the compressor 7.

With respect to the heating mode, note should be taken of that in operation the main flexible line will contain dry saturated steam at temperature T1 (point A), and the heating mode flexible line 33 contain liquid at temperature T2 (point E). It should be also noted that the amount of heat delivered to the space being heated is directly proportional to the length of segment BG.

Thus, a transfer of heat between the lines 32 and 33 would result in the dry saturated steam within the line 32 (segment AA″) becoming heated and the liquid in the line 33 (segment EE″) cooled. The net result would evidently be an increase in the amount of heat available for delivery to the space being heated (B″G″ instead of BG). In addition, the steam within the line 32 would be relieved of the risk to partly liquefy, and the liquid within the line 33 from that of undergoing partial vaporization; reduced would therefore be both the risk of passing liquid into the compressor 7 and damage it, and the risk of vapor bubbles being formed inside lines 10 and 20, with attendant emission of objectionable noise.

Also noteworthy is that the situation would remain virtually unchanged if the expansion device, instead of comprising the capillary tubes of the heating mode flexible line 33, consists of a traditional expansion valve incorporated to the outdoor unit 3 (e.g. to line 18) or to the indoor unit 2 (e.g. to sub-line 21). With the expansion device at the outdoor unit 3, inside the heating mode flexible line 33 there would be present thermal fluid under condition E all the same; in the other case, inside the heating mode flexible line 33 there would be present fluid under condition F, that is at the same temperature T1 as that of the fluid within the main flexible line 32, thereby any transfer of heat between the lines 32 and 33 would be prevented.

Evident is therefore the advantage of enhancing the heat thermal exchange between the main flexible line 32 and the heating mode flexible line 33, as obtained with the invention by placing both inside the cavity 27 of sleeve 26.

To summarize, it can be concluded that this apparatus 1 will operate

- in the cooling mode, in accordance with cycle A B C D E F A,
- in the heating mode, according to cycle A A″ B″ C D E″ F″ A.

Notice should be taken lastly, of that the concurrent provision of the main flexible line 32 and heating mode flexible line 33 within the same cavity 27 in the sleeve 26 is apt to fight the formation of condensation water over the sleeve 26, along the section thereof located inside the space to be heated. In fact, lacking the line 33, the low temperature of the fluid in the line 30 (T1, point A in Figure 4) would cool the cavity 27 and cause condensation water to form over the sleeve 26. By contrast, the warmer fluid present in the line 33 (T2, point E in Figure 4) is effective to compensate for and limit the cooling of cavity 27.

Advantageously, to also resist the formation of condensation water over the sleeve 26 at the line 32, the interior wall of cavity 27 is formed with ribs 35. These hold the line 32 suspended and prevent full contact of the line 32 with the sleeve 26, thereby preventing direct thermal exchange therebetween such as would harm the benefit from arranging the line 33 within the same cavity 27.

Claims

1. An air-conditioner refrigerating apparatus for dual operation in either heating mode or cooling mode by reversal of the thermal fluid flow, comprising an indoor unit (2), an outdoor unit (3), a flexible connection element (4) interconnecting the indoor and outdoor units, an indoor heat exchanger (5) within the indoor unit (2), an outdoor heat exchanger (16) within the outdoor unit (3), a compressor (7) within the indoor unit (2), an expansion device (33,34), and connection ducts between the outdoor heat exchanger (16), the filming device (33,34), the indoor heat exchanger (5), and the compressor (7), characterized in that said connection ducts comprise three flexible lines within the connection element (4), namely a main flexible line (32) for the thermal fluid to flow between the outdoor heat exchanger (16) and the compressor (7) in either directions, a heating mode flexible line (33) for conveying the thermal fluid flow from the indoor heat exchanger (5) to the outdoor heat exchanger (16) during operation in the heating mode, and a cooling mode flexible line (34) for conveying the thermal fluid flow from the outdoor heat exchanger (16) to the indoor heat exchanger (5) during operation in the cooling mode.

2. An apparatus according to Claim 1, characterized in that said main flexible line (32) is located adjacent to the heating mode flexible line (33) and apart from the cooling mode flexible line (34).

3. An apparatus according to Claim 2, characterized in that said flexible connection element (4) comprises a sleeve (26) defining two separate longitudinal cavities (27,28), said main (32) and heating mode (33) flexible lines being located within one (27) of said cavities and said cooling mode flexible line (34) being located within the other (28) of said cavities.

4. An apparatus according to Claim 3, characterized in that said one cavity (27) of the sleeve (26) accomodating the main flexible line (32) has its interior wall provided with rib formations (35).

5. An apparatus according to Claim 1, characterized in that said heating mode (33) and cooling mode (34) flexible lines are respectively formed by first and second capillary tubes, said first and second capillary tubes constituting said expansion device during operation in the heating mode and the cooling mode, respectively.

6. An apparatus according to Claim 1, characterized in that said heating mode (33) and cooling mode (34) flexible lines are respectively formed by first and second pluralities of capillary tubes in parallel, said first and second pluralities of capillary tubes constituting said expansion device during operation in the heating mode and the cooling mode, respectively.

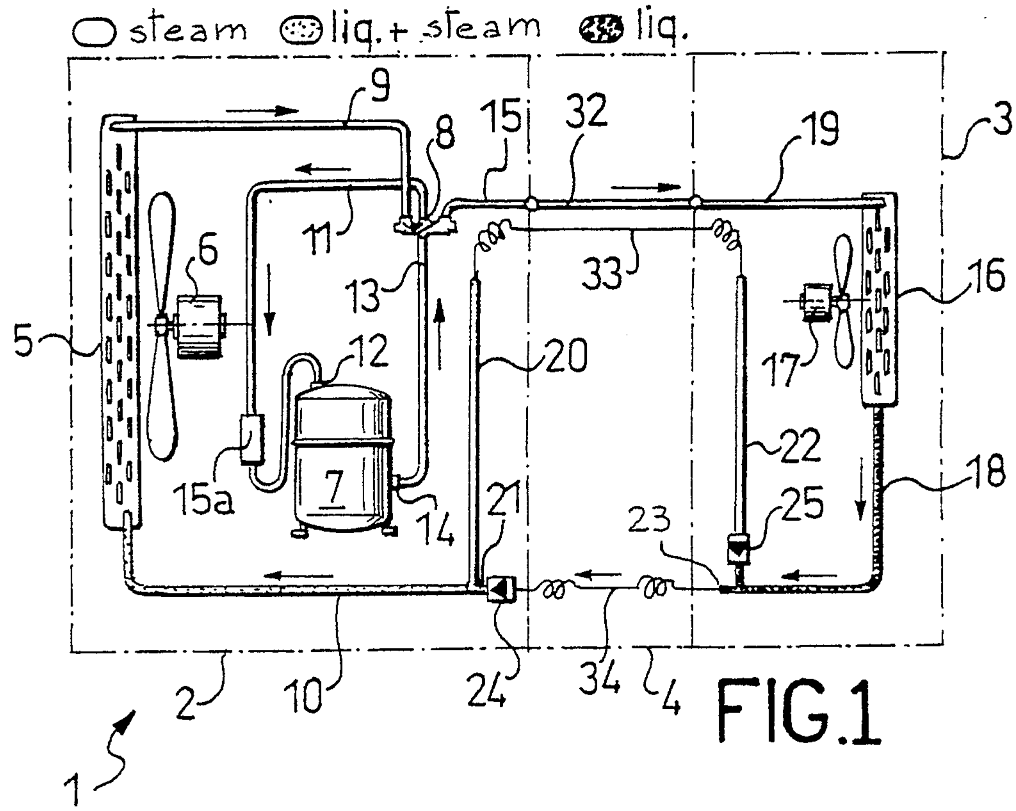
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FIG.1

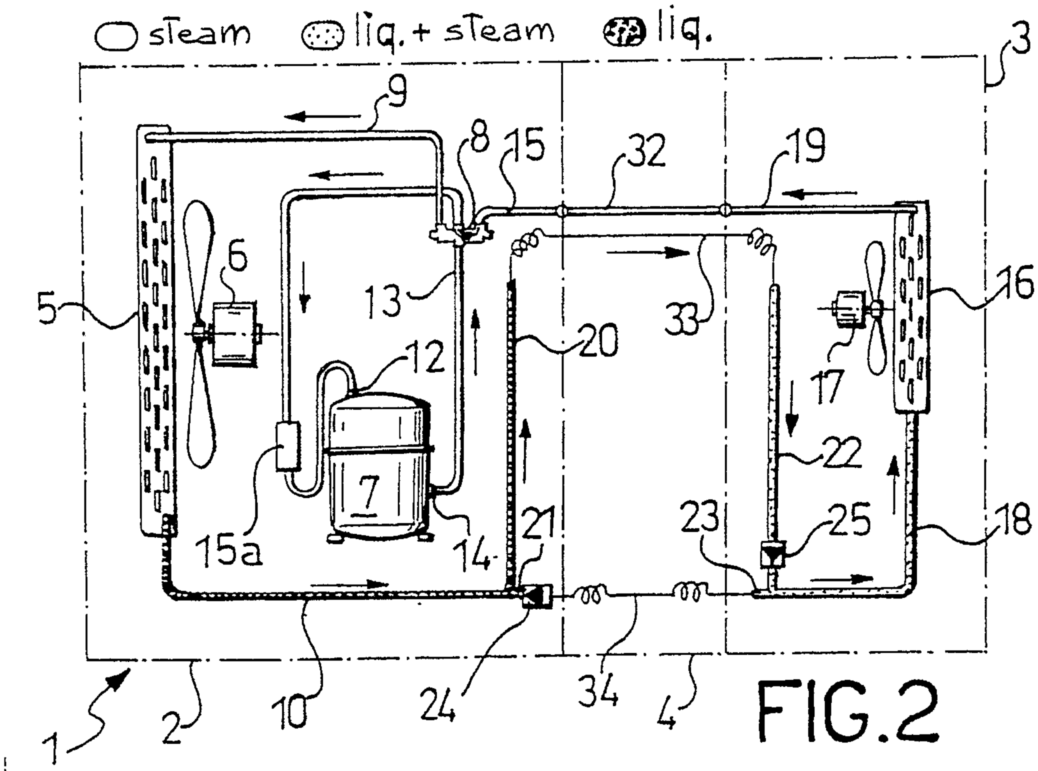
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FIG.2

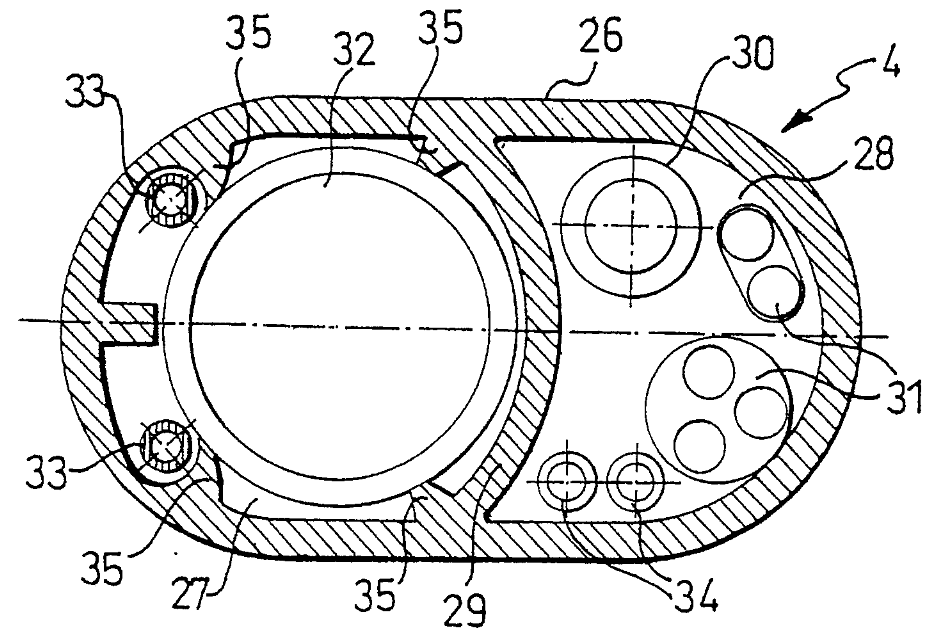
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FIG.3

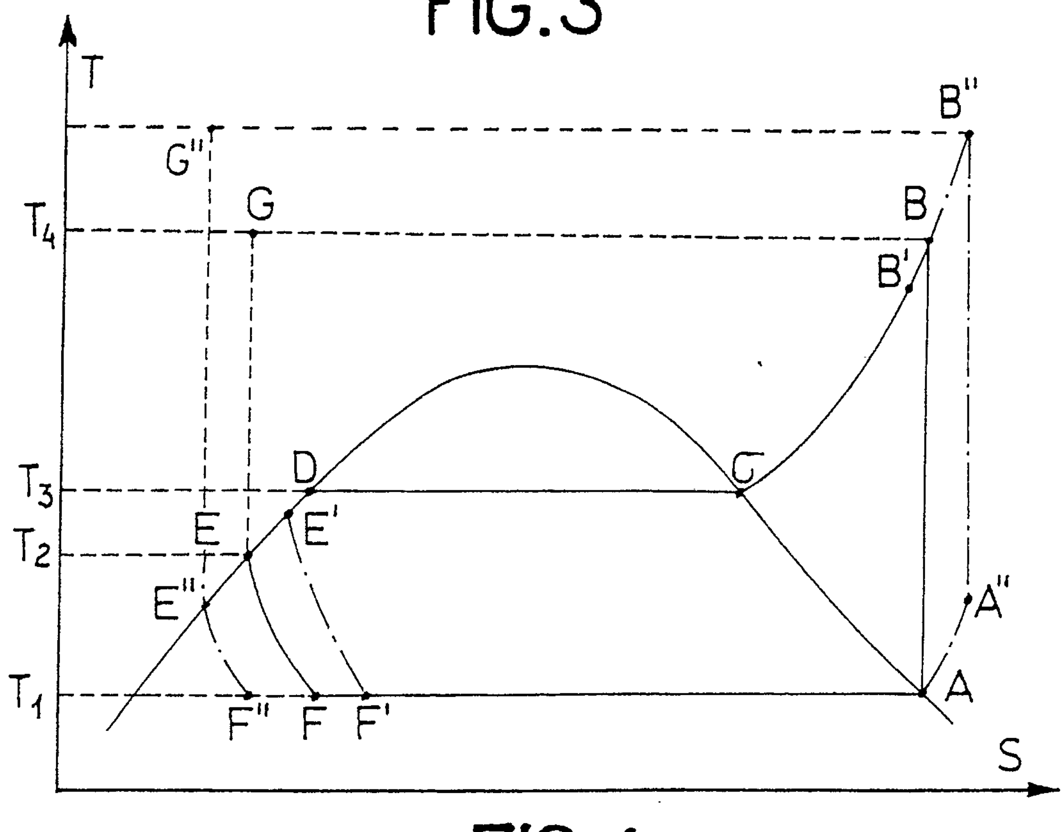
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FIG.4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 11 2829

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	DE-A-2 826 813 (BRAUN) * Page 7, line 18 - page 9, line 10; figures 1-4 * ---	1	F 25 B 13/00 F 25 B 41/00 F 24 F 1/02
A	EP-A-0 162 720 (MITSUBISHI DENKI) * Page 4, line 3 - page 12, line 6; figures 1,2 * ---	1,5	
A	US-A-4 057 975 (DEL TORO) * Column 2, line 10 - column 6, line 24; figures 1-6 * ---	1,6	
A	US-A-3 611 743 (MANGANARO) * Column 3, line 2 - column 4, line 24; figures 1-5 * ---	1	
A	US-A-2 760 354 (BRADY) * Column 1, line 61 - column 3, line 50; figures 1-3 * ---	1	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	US-A-2 388 314 (EISINGER) ---		F 25 B F 24 F
A	US-A-2 708 835 (NIGRO) ---		
A	EP-A-0 145 114 (HALLETT) -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22-10-1990	BOETS A.F.J.

CATEGORY OF CITED DOCUMENTS

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