



(11) **EP 2 005 079 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
07.12.2016 Bulletin 2016/49

(51) Int Cl.:
F25B 41/00 (2006.01) **F25B 49/00** (2006.01)
F25B 47/00 (2006.01) **F25B 39/04** (2006.01)
F25B 11/00 (2006.01) **F25B 9/00** (2006.01)

(21) Application number: **06739730.7**

(86) International application number:
PCT/US2006/011097

(22) Date of filing: **27.03.2006**

(87) International publication number:
WO 2007/111594 (04.10.2007 Gazette 2007/40)

(54) **REFRIGERATING SYSTEM WITH PARALLEL STAGED ECONOMIZER CIRCUITS AND A SINGLE OR TWO STAGE MAIN COMPRESSOR**

KÜHLSYSTEM MIT PARALLELSTUFENECONOMISERSCHALTUNGEN UND EINEN EIN- ODER ZWEISTUFIGEN KOMPRESSOR

SYSTÈME DE RÉFRIGÉRATION AVEC CIRCUITS D'ÉCONOMISEUR ÉTAGÉS EN PARALLÈLE ET COMPRESSEUR PRINCIPAL À UN OU DEUX ÉTAGES

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

• **BUSH, James, W.**
Farmington, CT 06034-4015 (US)

(43) Date of publication of application:
24.12.2008 Bulletin 2008/52

(74) Representative: **Taylor, Adam David**
Dehns
St Bride's House
10 Salisbury Square
London EC4Y 8JD (GB)

(73) Proprietor: **Carrier Corporation**
Farmington, CT 06034-4015 (US)

(56) References cited:
EP-A1- 1 775 531 **WO-A1-2006/022829**
US-A- 2 024 323 **US-A- 5 095 712**
US-A- 5 103 650 **US-A- 5 768 901**
US-A- 6 113 358 **US-A1- 2002 050 149**
US-B1- 6 694 750

(72) Inventors:
• **MITRA, Biswajit**
Farmington, CT 06034-4015 (US)
• **BEAGLE, Wayne, P.**
Farmington, CT 06034-4015 (US)

EP 2 005 079 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to refrigerating systems used for cooling. More particularly, the present invention relates to a refrigerating system that incorporates economizer circuits to increase system efficiency.

[0002] A typical refrigerating system includes an evaporator, a compressor, a condenser, and a throttle valve. A refrigerant, such as a hydrofluorocarbon (HFC), typically enters the evaporator as a two-phase liquid-vapor mixture. Within the evaporator, the liquid portion of the refrigerant changes phase from liquid to vapor as a result of heat transfer into the refrigerant. The refrigerant is then compressed within the compressor, thereby increasing the pressure of the refrigerant. Next, the refrigerant passes through the condenser, where it changes phase from a vapor to a liquid as it cools within the condenser. Finally, the refrigerant expands as it flows through the throttle valve, which results in a decrease in pressure and a change in phase from a liquid to a two-phase liquid-vapor mixture.

[0003] While natural refrigerants such as carbon dioxide have recently been proposed as alternatives to the presently used HFCs, the high side pressure of carbon dioxide typically ends up in the supercritical region where there is no transition from vapor to liquid as the high pressure refrigerant is cooled. For a typical single stage vapor compression cycle, this leads to poor efficiency due to the loss of the subcritical constant temperature condensation process and to the relatively high residual enthalpy of supercritical carbon dioxide at normal high side temperatures.

[0004] WO 2006/022829 A1 discloses a CO₂ refrigerant circuit. The circuit is provided with a receiver comprising a liquid portion and a flash gas portion. A flash gas line is connected to the flash gas portion, and a liquid line is connected to the liquid portion. Heat is transferred from the liquid flowing in the liquid line to the flash gas flowing through the flash gas line in an internal heat exchanger. The flash gas is returned to an inlet of a low temperature compressor set. The refrigerant circuit is also provided with further sub-cooling in the outlet line of a heat rejecting heat exchanger. A portion of the refrigerant is diverted through an expansion valve and sub-cools the remainder of the refrigerant in another heat exchanger.

[0005] US-A- 6 113 358 discloses a refrigeration system according to the preamble of claim 1.

[0006] Thus, there exists a need for a refrigerating system that is capable of utilizing any refrigerant, including a transcritical refrigerant, while maintaining a high level of system efficiency.

BRIEF SUMMARY OF THE INVENTION

[0007] According to a first aspect of the present invention, there is provided a refrigeration system comprising: a main refrigerant path; an evaporator; a plurality of compressors for compressing a refrigerant, each of the compressors having a suction port and a discharge port; a heat rejecting heat exchanger for cooling the refrigerant; and a plurality of economizer circuits each comprising a heat exchanger, wherein each of the economizer circuits is configured to inject a portion of the refrigerant into the suction port of one of the compressors, wherein an economizer path of each of the economizer circuits is in a heat exchanger relationship with the main refrigerant path for cooling the main refrigerant path in the respective economizer heat exchanger, and wherein the discharge port of each of the compressors is directly connected to the heat rejecting heat exchanger.

[0008] According to a second aspect of the present invention, there is provided a method of operating a refrigeration system, the method comprising: evaporating a refrigerant; compressing the refrigerant from a lower pressure to a higher pressure in a plurality of compressors, the plurality of compressors including a two-stage compressor and at least two single-stage compressors, wherein the two-stage compressor includes an intercooler configured to cool the refrigerant between a first stage of compression and a second stage of compression; injecting the refrigerant from the discharge port of each of the compressors directly into a heat rejecting heat exchanger and cooling the refrigerant in the heat rejecting heat exchanger; directing the refrigerant in a main refrigerant path through a plurality of economizer heat exchangers each provided in a respective economizer circuit, and, in the economizer heat exchangers, cooling the refrigerant in the main refrigerant path using the refrigerant in an economizer path of the respective economizer circuit; injecting a first portion of the refrigerant from a first economizer circuit into a suction port of one of the single-stage compressors; and injecting a second portion of the refrigerant from a second economizer circuit into a suction port of another one of the single-stage compressors; and wherein, optionally, the compressors are part of a single, multi-cylinder compressor unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1A illustrates a schematic diagram of a refrigeration system employing a pair of economizer circuits.

FIG. 1B illustrates a graph relating enthalpy to pressure for the refrigeration system of FIG. 1A.

FIG. 2A illustrates a schematic diagram of a refrigeration system employing three economizer circuits. FIG. 2B illustrates a graph relating enthalpy to pressure for the refrigeration system of FIG. 2A.

FIG. 3A illustrates a schematic diagram of a refrigeration system employing four economizer circuits. FIG. 3B illustrates a graph relating enthalpy to pressure for the refrigeration system of FIG. 3A.

FIG. 4A illustrates a schematic diagram of a refrigeration system employing five economizer circuits. FIG. 4B illustrates a graph relating enthalpy to pressure for the refrigeration system of FIG. 4A.

FIG. 5A illustrates a schematic diagram of a second embodiment of a refrigeration system employing a pair of economizer circuits.

FIG. 5B illustrates a graph relating enthalpy to pressure for the refrigeration system of FIG. 5A.

FIG. 6 illustrates a schematic diagram of an alternative embodiment of the refrigeration system of FIG. 1A.

FIG. 7 illustrates a schematic diagram of another embodiment of the refrigeration system of FIG. 1A.

DETAILED DESCRIPTION

[0010] FIG. 1A illustrates a schematic diagram of refrigeration system 20A, which includes compressor unit 22, heat rejecting heat exchanger 24, first economizer circuit 25A, second economizer circuit 25B, main expansion valve 26, evaporator 27, and sensor 31. First economizer circuit 25A includes first economizer heat exchanger 28A, expansion valve 30A, and sensor 31A, while second economizer circuit 25B includes second economizer heat exchanger 28B, expansion valve 30B, and sensor 31B. As shown in FIG. 1A, first economizer heat exchanger 28A and second economizer heat exchanger 28B are parallel flow tube-in-tube heat exchangers.

[0011] Compressor unit 22 includes two-stage compressor 32, single-stage compressor 34, and single-stage compressor 35. Two-stage compressor 32 includes cylinders 36A and 36B connected in series, single-stage compressor 34 includes cylinder 36C, and single-stage compressor 35 includes cylinder 36D. Two-stage compressor 32, single-stage compressor 34, and single-stage compressor 35 may be stand-alone compressor units, or they may be part of a single, multi-cylinder compressor unit. In addition, two-stage compressor 32, single-stage compressor 34, and single-stage compressor 35 are preferably reciprocating compressors, although other types of compressors may be used including, but not limited to, scroll, screw, rotary vane, standing vane, variable speed, hermetically sealed, and open drive compressors.

[0012] In refrigeration system 20A, three distinct refrigerant paths are formed by connection of the various elements in the system. A main refrigerant path is defined by the route between points 1, 2, 3, 4, 5, and 6. A first economized refrigerant path is defined by the route between points 5A, 6A, 7A, and 8A. Finally, a second economized refrigerant path is defined by the route between points 5B, 6B, 7B, and 8B. It should be understood that

the paths are all closed paths that allow for continuous flow of refrigerant through refrigeration system 20A.

[0013] In reference to the main refrigerant path, after refrigerant exits two-stage compressor 32 at high pressure and enthalpy through discharge port 39 (point 4), the refrigerant loses heat in heat rejecting heat exchanger 24, exiting heat rejecting heat exchanger 24 at low enthalpy and high pressure (point 5A). The refrigerant then splits into two flow paths 40A and 42A prior to entering first economizer heat exchanger 28A. The main path continues along paths 40A and 40B through first economizer heat exchanger 28A (point 5B) and second economizer heat exchanger 28B (point 5), respectively. As the refrigerant in path 40A flows through first economizer heat exchanger 28A, it is cooled by the refrigerant in path 42A of the first economized path. Similarly, as the refrigerant in path 40B flows through second economizer heat exchanger 28B, it is cooled by the refrigerant in path 42B of the second economized path.

[0014] Refrigerant from path 40B is then throttled in main expansion valve 26. Main expansion valve 26, along with economizer expansion valves 30A and 30B, are preferably thermal expansion valves (TXV) or electronic expansion valves (EXV). After going through an expansion process within main expansion valve 26 (point 6), the refrigerant is a two-phase liquid-vapor mixture and is directed toward evaporator 27. After evaporation of the remainder of the liquid (point 1), the refrigerant enters two-stage compressor 32 through suction port 37. The refrigerant is compressed within cylinder 36A, which is the first stage of two-stage compressor 32, and is then directed out discharge port 50 (point 2), where it flows through intercooler 48 prior to a second stage of compression in cylinder 36B. Intercooler 48 is configured to cool down the refrigerant discharged from cylinder 36A prior to the second stage of compression within cylinder 36B. After the second stage of compression, the refrigerant is discharged through discharge port 39 (point 4).

[0015] In reference to the first economized path, after refrigerant exits heat rejecting heat exchanger 24 at low enthalpy and high pressure (point 5A) and splits into two flow paths 40A and 42A, the first economized path continues along path 42A. In path 42A, the refrigerant is throttled to a lower pressure by economizer expansion valve 30A (point 6A) prior to flowing through first economizer heat exchanger 28A. The refrigerant from path 42A that flowed through first economizer heat exchanger 28A (point 7A) is then directed along economizer return path 46A and injected into suction port 52 of single-stage compressor 34 for compression in single-stage compressor 34. After compression within single-stage compressor 34, the refrigerant is discharged through discharge port 54 (point 8A) where it merges with the refrigerant discharged from two-stage compressor 32 and single-stage compressor 35.

[0016] In reference to the second economized path, after being cooled in the higher pressure first economizer heat exchanger 28A (point 5B), the refrigerant in path

40A splits into two flow paths 40B and 42B. The second economized path continues along flow path 42B where the refrigerant is throttled to a lower pressure by economizer expansion valve 30B (point 6B) prior to flowing through second economizer heat exchanger 28B. The refrigerant from path 42B that flowed through second economizer heat exchanger 28B (point 7B) is then directed along economizer return path 46B and injected into suction port 56 of single-stage compressor 35 for compression in single-stage compressor 35. After compression within single-stage compressor 35, the refrigerant is discharged through discharge port 58 (point 8B) where it merges with the refrigerant discharged from two-stage compressor 32 and single-stage compressor 34.

[0017] Refrigeration system 20A also includes sensor 31 disposed between evaporator 27 and compressor unit 22 along the main refrigerant path. In general, sensor 31 acts with expansion valve 26 to sense the temperature of the refrigerant leaving evaporator 27 and the pressure of the refrigerant in evaporator 27 to regulate the flow of refrigerant into evaporator 27 to keep the combination of temperature and pressure within some specified bounds. In a preferred embodiment, expansion valve 26 is an electronic expansion valve and sensor 31 is a temperature transducer such as a thermocouple or thermistor. In another embodiment, expansion valve 26 is a mechanical thermal expansion valve and sensor 31 includes a small tube that terminates in a pressure vessel filled with a refrigerant that differs from the refrigerant running through refrigeration system 20A. As refrigerant from evaporator 27 flows past sensor 31 on its way toward compressor unit 22, the pressure vessel will either heat up or cool down, thereby changing the pressure within the pressure vessel. As the pressure in the pressure vessel changes, sensor 31 sends a signal to expansion valve 26 to modify the pressure drop caused by the valve. Similarly, in the case of the electronic expansion valve, sensor 31 sends an electrical signal to expansion valve 26 which responds in a similar manner to regulate refrigerant flow. For example, if a return gas coming from evaporator 27 is too hot, sensor 31 will then heat up and send a signal to expansion valve 26, causing the valve to open further and allow more refrigerant per unit time to flow through evaporator 27, thereby reducing the heat of the refrigerant exiting evaporator 27.

[0018] Economizer circuits 25A and 25B also include sensors 31A and 31B, respectively, that operate in a similar manner to sensor 31. However, sensors 31A and 31B sense temperature along economizer return paths 46A and 46B and act with expansion valves 30A and 30B to control the pressure drops within expansion valves 30A and 30B instead. It should also be noted that various other sensors may be substituted for sensors 31, 31A, and 31B without departing from the scope of the present invention, which is defined by the appended claims.

[0019] By controlling the expansion valves 26, 30A, and 30B, the operation of refrigeration system 20A can be adjusted to meet the cooling demands and achieve

optimum efficiency. In addition to adjusting the pressures associated with expansion valves 26, 30A, and 30B, the displacements of cylinders 36A, 36B, 36C, and 36D may also be adjusted to help achieve optimum efficiency of refrigeration system 20A.

[0020] FIG. 1B illustrates a graph relating enthalpy to pressure for the refrigeration system 20A of FIG. 1A. Vapor dome V is formed by a saturated liquid line and a saturated vapor line, and defines the state of the refrigerant at various points along the refrigeration cycle. Underneath vapor dome V, all states involve both liquid and vapor coexisting at the same time. At the very top of vapor dome V is the critical point. The critical point is defined by the highest pressure where saturated liquid and saturated vapor coexist. In general, compressed liquids are located to the left of vapor dome V, while superheated vapors are located to the right of vapor dome V.

[0021] In FIG. 1B, the main refrigerant path is defined by the route between points 1, 2, 3, 4, 5, and 6; the first economized path is defined by the route between points 5A, 6A, 7A, and 8A; and the second economized path is defined by the route between points 5B, 6B, 7B, and 8B. The cycle begins in the main path at point 1, where the refrigerant is at a low pressure and high enthalpy prior to entering compressor unit 22. After a first stage of compression within cylinder 36A of two-stage compressor 32, both the enthalpy and pressure increase as shown by point 2. Next, the refrigerant is cooled down as it flows through intercooler 48, as shown by point 3. After a second stage of compression within cylinder 36B, the refrigerant exits compressor unit 22 at high pressure and even higher enthalpy, as shown by point 4. Then, as the refrigerant flows through heat rejecting heat exchanger 24, enthalpy decreases while pressure remains constant. Prior to entering first economizer heat exchanger 28A, the refrigerant splits into a main portion and a first economized portion as shown by point 5A. Similarly, prior to entering second economizer heat exchanger 28B, a second economized portion is diverted from the main portion as shown by point 5B. The first and second economized portions will be discussed in more detail below. The main portion is then throttled in main expansion valve 26, decreasing pressure as shown by point 6. Finally, the main portion of the refrigerant is evaporated, exiting evaporator 27 at a higher enthalpy as shown by point 1.

[0022] As stated previously, the first economized portion splits off of the main portion as indicated by point 5A. The first economized portion is throttled to a lower pressure in expansion valve 30A as shown by point 6A. The first economized portion of the refrigerant then exchanges heat with the main portion in first economizer heat exchanger 28A, cooling down the main portion of the refrigerant as indicated by point 5B, and heating up the first economized portion of the refrigerant as indicated by point 7A. The first economized portion is then compressed within single-stage compressor 34 and merged with the refrigerant discharged from two-stage compressor 32 and single-stage compressor 35, as shown by

point 8A.

[0023] As stated previously, the second economized portion splits off of the main portion as indicated by point 5B. The second economized portion is throttled to a lower pressure in expansion valve 30B as shown by point 6B. The second economized portion of the refrigerant then exchanges heat with the main portion within second economizer heat exchanger 28B, cooling down the main portion of the refrigerant to its lowest temperature as indicated by point 5, and heating up the second economized portion of the refrigerant as indicated by point 7B. The second economized portion is then compressed within single-stage compressor 35 and merged with the refrigerant discharged from two-stage compressor 32 and single-stage compressor 34, as shown by point 8B.

[0024] In a refrigeration system, the specific cooling capacity, which is the measure of total cooling capacity divided by refrigerant mass flow, may typically be represented on a graph relating pressure to enthalpy by the length of the evaporation line. Furthermore, when the specific cooling capacity is divided by the specific power input to the compressor, the result is the system efficiency. In general, a high specific cooling capacity achieved by inputting a low specific power to the compressor will yield a high efficiency.

[0025] As shown in FIG. 1B, the specific cooling capacity of refrigeration system 20A is represented by the length of evaporation line E1 from point 6 to point 1. Lines A1 and A2 represent the increased specific cooling capacity due to the addition of the first economizer circuit 25A and second economizer circuit 25B, respectively. This indicates that refrigeration system 20A, which includes two economizer circuits, has a larger specific cooling capacity than a refrigeration system with no economizer circuits. Along with the increase in specific cooling capacity also comes an increase in specific power consumption. The increase in specific power consumption is a result of the additional compression of the economized flow shown between points 7A and 8A as well as between points 7B and 8B. However, since the economized vapor is compressed over a smaller pressure range than the main portion of refrigerant, the added compression power is less than the added capacity. Therefore, the ratio of capacity to power (the efficiency) is increased by the addition of the two economizer circuits.

[0026] FIG. 2A illustrates a schematic diagram of refrigeration system 20B of the present invention employing three economizer circuits. Refrigeration system 20B is similar to refrigeration system 20A, except that single-stage compressor 70 is added to compressor unit 22, and third economizer circuit 25C is added to the system. Single-stage compressor 70 includes cylinder 36E.

[0027] In refrigeration system 20B, four distinct refrigerant paths are formed by connection of the various elements in the system. The main refrigerant path, the first economized refrigerant path, and the second economized refrigerant path are similar to those described above in reference to FIG. 1A. A third economized refrigerant

path is defined by the route between points 5C, 6C, 7C, and 8C.

[0028] In reference to the third economized path, after being cooled in the higher pressure second economizer heat exchanger 28B, the refrigerant in path 40B splits into two flow paths 40C and 42C (point 5C). The third economized path continues along flow path 42C where the refrigerant is throttled to a lower pressure by economizer expansion valve 30C prior to flowing through third economizer heat exchanger 28C (point 6C). The refrigerant from path 42C that flowed through third economizer heat exchanger 28C (point 7C) is then directed along economizer return path 46C and injected into suction port 72 of single-stage compressor 70 for compression in single-stage compressor 70. After compression within single-stage compressor 70, the refrigerant is discharged through discharge port 74 (point 8C) where it merges with the refrigerant discharged from two-stage compressor 32 and single-stage compressors 34 and 35.

[0029] FIG. 2B illustrates a graph relating enthalpy to pressure for the refrigeration system 20B of FIG. 2A. In FIG. 2B, the main refrigerant path is defined by the route between points 1, 2, 3, 4, 5, and 6; the first economized path is defined by the route between points 5A, 6A, 7A, and 8A; the second economized path is defined by the route between points 5B, 6B, 7B, and 8B; and the third economized path is defined by the route between points 5C, 6C, 7C, and 8C. As shown in FIG. 2B, evaporation line E2 of refrigeration system 20B is longer than evaporation line E1 of refrigeration system 20A (FIG. 1B). This indicates that refrigeration system 20B, which includes three economizer circuits, has a larger specific cooling capacity than refrigeration system 20A, which includes two economizer circuits. In particular, line A3 represents the increased specific cooling capacity due to the addition of the third economizer circuit.

[0030] FIG. 3A illustrates a schematic diagram of refrigeration system 20C of the present invention employing four economizer circuits. Refrigeration system 20C is similar to refrigeration system 20B, except that single-stage compressor 80 is added to compressor unit 22, and fourth economizer circuit 25D is added to the system. Single-stage compressor 80 includes cylinder 36F.

[0031] In refrigeration system 20C, five distinct refrigerant paths are formed by connection of the various elements in the system. The main refrigerant path, the first economized refrigerant path, the second economized refrigerant path, and the third economized refrigerant path are similar to those described above in reference to FIGS. 1A and 2A. A fourth economized refrigerant path is defined by the route between points 5D, 6D, 7D, and 8D.

[0032] In reference to the fourth economized path, after being cooled in the higher pressure third economizer heat exchanger 28C, the refrigerant in path 40C splits into two flow paths 40D and 42D (point 5D). The fourth economized path continues along flow path 42D where the refrigerant is throttled to a lower pressure by economizer expansion valve 30D prior to flowing through fourth econ-

omizer heat exchanger 28D (point 6D). The refrigerant from path 42D that flowed through fourth economizer heat exchanger 28D is then directed along economizer return path 46D (point 7D) and injected into suction port 82 of single-stage compressor 80 for compression in single-stage compressor 80. After compression within single-stage compressor 80 (point 8D), the refrigerant is discharged through discharge port 84 where it merges with the refrigerant discharged from two-stage compressor 32 and single-stage compressors 34, 35, and 70.

[0033] FIG. 3B illustrates a graph relating enthalpy to pressure for the refrigeration system 20C of FIG. 3A. In FIG. 3B, the main refrigerant path is defined by the route between points 1, 2, 3, 4, 5, and 6; the first economized path is defined by the route between points 5A, 6A, 7A, and 8A; the second economized path is defined by the route between points 5B, 6B, 7B, and 8B; the third economized path is defined by the route between points 5C, 6C, 7C, and 8C; and the fourth economized path is defined by the route between points 5D, 6D, 7D, and 8D. As shown in FIG. 3B, evaporation line E3 of refrigeration system 20C is longer than evaporation line E2 of refrigeration system 20B (FIG. 2B). This indicates that refrigeration system 20C, which includes four economizer circuits, has a larger specific cooling capacity than refrigeration system 20B, which includes three economizer circuits. In particular, line A4 represents the increased specific cooling capacity due to the addition of the fourth economizer circuit.

[0034] FIG. 4A illustrates a schematic diagram of refrigeration system 20D of the present invention employing five economizer circuits. Refrigeration system 20D is similar to refrigeration system 20C, except that single-stage compressor 90 is added to compressor unit 22, and fifth economizer circuit 25E is added to the system. Single-stage compressor 90 includes cylinder 36G.

[0035] In refrigeration system 20D, six distinct refrigerant paths are formed by connection of the various elements in the system. The main refrigerant path, the first economized refrigerant path, the second economized refrigerant path, the third economized refrigerant path, and the fourth economized refrigerant path are similar to those described above in reference to FIGS. 1A, 2A, and 3A. A fifth economized refrigerant path is defined by the route between points 5E, 6E, 7E, and 8E.

[0036] In reference to the fifth economized path, after being cooled in the higher pressure fourth economizer heat exchanger 28D, the refrigerant in path 40D splits into two flow paths 40E and 42E (point 5E). The fifth economized path continues along flow path 42E where the refrigerant is throttled to a lower pressure by economizer expansion valve 30E prior to flowing through fifth economizer heat exchanger 28E (point 6E). The refrigerant from path 42E that flowed through fifth economizer heat exchanger 28E is then directed along economizer return path 46E (point 7E) and injected into suction port 92 of single-stage compressor 90 for compression in single-stage compressor 90. After compression within sin-

gle-stage compressor 90, the refrigerant is discharged through discharge port 94 (point 8E) where it merges with the refrigerant discharged from two-stage compressor 32 and single-stage compressors 34, 35, 70, and 80.

[0037] FIG. 4B illustrates a graph relating enthalpy to pressure for the refrigeration system 20D of FIG. 4A. In FIG. 4B, the main refrigerant path is defined by the route between points 1, 2, 3, 4, 5, and 6; the first economized path is defined by the route between points 5A, 6A, 7A, and 8A; the second economized path is defined by the route between points 5B, 6B, 7B, and 8B; the third economized path is defined by the route between points 5C, 6C, 7C, and 8C; the fourth economized path is defined by the route between points 5D, 6D, 7D, and 8D; and the fifth economized path is defined by the route between points 5E, 6E, 7E, and 8E. As shown in FIG. 4B, evaporation line E4 of refrigeration system 20D is longer than evaporation line E3 of refrigeration system 20C (FIG. 3B). This indicates that refrigeration system 20D, which includes five economizer circuits, has a larger specific cooling capacity than refrigeration system 20C, which includes four economizer circuits. In particular, line A5 represents the increased specific cooling capacity due to the addition of the fifth economizer circuit.

[0038] FIG. 5A illustrates a schematic diagram of refrigeration system 20E of the present invention employing two economizer circuits. Refrigeration system 20E is similar to and an alternative embodiment of refrigeration system 20A. In refrigeration system 20E, intercooler 48 has been removed and two-stage compressor 32 has been replaced by single-stage compressor 100. Single-stage compressor 100 includes cylinder 36H.

[0039] In refrigeration system 20E, three distinct refrigerant paths are formed by connection of the various elements in the system. A main refrigerant path is defined by the route between points 1, 2, 3, and 4. A first economized refrigerant path is defined by the route between points 3A, 4A, 5A, and 6A. Finally, a second economized refrigerant path is defined by the route between points 3B, 4B, 5B, and 6B.

[0040] In reference to the main refrigerant path, after refrigerant exits single-stage compressor 100 at high pressure and enthalpy through discharge port 104 (point 2), the refrigerant loses heat in heat rejecting heat exchanger 24, exiting heat rejecting heat exchanger 24 at low enthalpy and high pressure (point 3A). The refrigerant then splits into two flow paths 40A and 42A prior to entering first economizer heat exchanger 28A. The main path continues along paths 40A and 40B through first economizer heat exchanger 28A (point 3B) and second economizer heat exchanger 28B (point 3), respectively. As the refrigerant in path 40A flows through first economizer heat exchanger 28A, it is cooled by the refrigerant in path 42A of the first economized path. Similarly, as the refrigerant in path 40B flows through second economizer heat exchanger 28B, it is cooled by the refrigerant in path 42B of the second economized path.

[0041] Refrigerant from path 40B is then throttled in

main expansion valve 26. After going through an expansion process within main expansion valve 26 (point 4), the refrigerant is a two-phase liquid-vapor mixture and is directed toward evaporator 27. After evaporation of the remainder of the liquid (point 1), the refrigerant enters single-stage compressor 100 through suction port 102. The refrigerant is then compressed within cylinder 36H and discharged through discharge port 104 (point 2).

[0042] In reference to the first economized path, after refrigerant exits heat rejecting heat exchanger 24 at low enthalpy and high pressure (point 3A) and splits into two flow paths 40A and 42A, the first economized path continues along path 42A. In path 42A, the refrigerant is throttled to a lower pressure by economizer expansion valve 30A (point 4A) prior to flowing through first economizer heat exchanger 28A. The refrigerant from path 42A that flowed through first economizer heat exchanger 28A (point 5A) is then directed along economizer return path 46A and injected into suction port 52 of single-stage compressor 34 for compression in single-stage compressor 34. After compression within single-stage compressor 34, the refrigerant is discharged through discharge port 54 (point 6A) where it merges with the refrigerant discharged from single-stage compressors 100 and 35.

[0043] In reference to the second economized path, after being cooled in the higher pressure first economizer heat exchanger 28A (point 3B), the refrigerant in path 40A splits into two flow paths 40B and 42B. The second economized path continues along flow path 42B where the refrigerant is throttled to a lower pressure by economizer expansion valve 30B (point 4B) prior to flowing through second economizer heat exchanger 28B. The refrigerant from path 42B that flowed through second economizer heat exchanger 28B (point 5B) is then directed along economizer return path 46B and injected into suction port 56 of single-stage compressor 35 for compression in single-stage compressor 35. After compression within single-stage compressor 35, the refrigerant is discharged through discharge port 58 (point 6B) where it merges with the refrigerant discharged from single-stage compressors 34 and 100.

[0044] FIG. 5B illustrates a graph relating enthalpy to pressure for the refrigeration system 20E of FIG. 5A. In FIG. 5B, the main refrigerant path is defined by the route between points 1, 2, 3, and 4; the first economized path is defined by the route between points 3A, 4A, 5A, and 6A; and the second economized path is defined by the route between points 3B, 4B, 5B, and 6B.

[0045] As shown in FIG. 5B, the specific cooling capacity of refrigeration system 20E is represented by the length of evaporation line E5 from point 4 to point 1. Lines A1' and A2' represent the increased specific cooling capacity due to the addition of first economizer circuit 25A and second economizer circuit 25B, respectively. When compared with evaporation line E1 of FIG. 1B, evaporation line E5 is substantially equivalent in length to evaporation line E1. This indicates that refrigeration system 20E has a specific cooling capacity that is substantially

equivalent to the specific cooling capacity of refrigeration system 20A. Thus, a two-stage compressor and an intercooler may be replaced by a single-stage compressor in a refrigeration system such as that shown in FIG. 1A without a substantial change in specific cooling capacity. It should be noted that although refrigeration system 20E is shown as a modified version of refrigeration system 20A, refrigeration systems 20B, 20C, and 20D may also be modified in the same manner without a substantial change in specific cooling capacity.

[0046] FIG. 6 illustrates a schematic diagram of refrigeration system 20A', which is an alternative embodiment of refrigeration system 20A. In the embodiment shown in FIG. 6, first economizer heat exchanger 28A' and second economizer heat exchanger 28B' comprise flash tanks. Thus, as used in refrigeration system 20A', flash tanks are an alternative type of heat exchanger. As stated previously, in the embodiment shown in FIG. 1A, first and second economizer heat exchangers 28A and 28B are parallel flow tube-in-tube heat exchangers. However, parallel flow tube-in-tube heat exchangers may be replaced with flash tank type heat exchangers, as depicted in FIG. 6, without departing from the scope of the present invention, which is defined by the appended claims.

[0047] FIG. 7 illustrates a schematic diagram of refrigeration system 20A", which is another alternative embodiment of refrigeration system 20A. In the embodiment shown in FIG. 7, first economizer heat exchanger 28A" and second economizer heat exchanger 28B" form a brazed plate heat exchanger. However, substituting a brazed plate heat exchanger for parallel flow tube-in-tube heat exchangers does not substantially affect the overall system efficiency. Thus, a refrigeration system using a brazed plate heat exchanger is also within the intended scope of the present invention.

[0048] In addition to the parallel flow tube-in-tube heat exchangers, flash tanks, and brazed plate heat exchangers, numerous other heat exchangers may be used for the economizers without departing from the scope of the present invention. The list of alternative heat exchangers includes, but is not limited to, counter-flow tube-in-tube heat exchangers, parallel flow shell-in-tube heat exchangers, and counter-flow shell-in-tube heat exchangers.

[0049] Although the refrigeration system of the present invention is useful to increase system efficiency in a system using any type of refrigerant, it is especially useful in refrigeration systems that utilize transcritical refrigerants, such as carbon dioxide. Because carbon dioxide is such a low critical temperature refrigerant, refrigeration systems using carbon dioxide typically run transcritical. Furthermore, because carbon dioxide is such a high pressure refrigerant, there is more opportunity to provide multiple pressure steps between the high and low pressure portions of the circuit to include multiple economizers, each of which contributes to increase the efficiency of the system. Thus, the present invention may be used to increase the efficiency of systems utilizing transcritical

refrigerants such as carbon dioxide, making their efficiency comparable to that of typical refrigerants. However, the refrigeration system of the present invention is useful to increase the efficiency in systems using any refrigerant, including those that run subcritical as well as those that run transcritical.

[0050] While the alternative embodiments of the present invention have been described as including a number of economizer circuits ranging from two to five, it should be understood that a refrigeration system with more than five economizer circuits is within the intended scope of the present invention. Furthermore, the economizer circuits may be connected to the compressors in various other combinations without decreasing system efficiency. Thus, refrigeration systems that utilize a greater number of economizer circuits or connect the economizer circuits in various other combinations are within the scope defined by the appended claims.

[0051] Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the scope of the invention, which is defined by the appended claims.

Claims

1. A refrigeration system (20A; 20B; 20C; 20D; 20E; 20A'; 20A'') comprising:

a main refrigerant path;
 an evaporator (27);
 a plurality of compressors (32, 34, 35; 70; 80; 90; 100) for compressing a refrigerant, each of the compressors having a suction port (37, 52, 56; 72; 82; 92; 102) and a discharge port (39, 54, 58; 74; 84; 94; 104);
 a heat rejecting heat exchanger (24) for cooling the refrigerant; and
 a plurality of economizer circuits (25A, 25B; 25C; 25D; 25E) each comprising an economizer heat exchanger (28A, 28B; 28A', 28B'; 28A'', 28B''), wherein each of the economizer circuits is configured to inject a portion of the refrigerant into the suction port of one of the compressors, **characterised in that** an economizer path (42A, 42B) of each of the economizer circuits is in a heat exchanger relationship with the main refrigerant path (40A, 40B) for cooling the main refrigerant path in the respective economizer heat exchanger, and **in that** the discharge port (39, 54, 58; 74; 84; 94; 104) of each of the compressors is directly connected to the heat rejecting heat exchanger (24).

2. The refrigeration system of claim 1, wherein one of the compressors is a two-stage compressor (32) having a first compressor cylinder (36A) and a sec-

ond compressor cylinder (36B).

3. The refrigeration system of claim 2, wherein an intercooler (48) is disposed between the first and second compressor cylinders (36A, 36B) of the two-stage compressor (32) to cool the refrigerant prior to a second stage of compression.

4. The refrigeration system of claim 1, wherein each of the compressors is a single-stage compressor.

5. The refrigeration system of any preceding claim, wherein the heat rejecting heat exchanger (24) is a condenser or a gas cooler.

6. The refrigeration system of any preceding claim, wherein the economizer heat exchangers are flash tanks (28A', 28B').

7. The refrigeration system of claim 1 comprising:

a two-stage compressor (32) for compressing the refrigerant, the two-stage compressor having a first compressor cylinder (36A) and a second compressor cylinder (36B);

a first single-stage compressor (34) for compressing the refrigerant,

a second single-stage compressor (35) for compressing the refrigerant,

a first economizer circuit (25A) configured to inject a first portion of the refrigerant into the suction port (52) of the first single-stage compressor; and

a second economizer circuit (25B) configured to inject a second portion of the refrigerant into the suction port (56) of the second single-stage compressor.

8. The refrigeration system of claim 7, wherein the plurality of compressors or the two-stage compressor (32), the first single-stage compressor (34), and the second single-stage compressor (35) are part of a single, multi-cylinder compressor unit.

9. The refrigeration system of claims 7 and 8, wherein an intercooler (48) is disposed between the first compressor cylinder (36A) and the second compressor cylinder (36B) to cool the refrigerant between a first stage of compression and a second stage of compression.

10. The refrigeration system of claim 9, and further comprising:

a third single-stage compressor (70) having a suction (72) port and a discharge port (74); and
 a third economizer circuit (25C) configured to inject a third portion of the refrigerant into the

suction port of the third single-stage compressor.

11. The refrigeration system of claim 10, and further comprising:

a fourth single-stage compressor (80) having a suction port (82) and a discharge port (84); and a fourth economizer circuit (25D) configured to inject a fourth portion of the refrigerant into the suction port of the fourth single-stage compressor.

12. The refrigeration system of claim 11, and further comprising:

a fifth single-stage compressor (90) having a suction port (92) and a discharge port (94); and a fifth economizer circuit (25E) configured to inject a fifth portion of the refrigerant into the suction port of the fifth single-stage compressor.

13. The refrigeration system of any preceding claim, wherein the refrigerant is carbon dioxide.

14. A method of operating a refrigeration system, the method comprising:

evaporating a refrigerant;
 compressing the refrigerant from a lower pressure to a higher pressure in a plurality of compressors, the plurality of compressors including a two-stage compressor and at least two single-stage compressors, wherein the two-stage compressor includes an intercooler configured to cool the refrigerant between a first stage of compression and a second stage of compression;
 injecting the refrigerant from the discharge port of each of the compressors directly into a heat rejecting heat exchanger and cooling the refrigerant in the heat rejecting heat exchanger;
 directing the refrigerant in a main refrigerant path through a plurality of economizer heat exchangers each provided in a respective economizer circuit, and, in the economizer heat exchangers, cooling the refrigerant in the main refrigerant path using the refrigerant in an economizer path of the respective economizer circuit;
 injecting a first portion of the refrigerant from a first economizer circuit into a suction port of one of the single-stage compressors; and
 injecting a second portion of the refrigerant from a second economizer circuit into a suction port of another one of the single-stage compressors; and

wherein, optionally, the compressors are part of a single, multi-cylinder compressor unit.

15. The method of claim 14, wherein the refrigerant is carbon dioxide.

5 Patentansprüche

1. Kühleystem (20A; 20B; 20C; 20D; 20E; 20A'; 20A"), umfassend:

10 einen Hauptkältemittelweg;
 einen Verdampfer (27);
 eine Vielzahl von Verdichtern (32, 34, 35; 70; 80; 90; 100) zum Verdichten eines Kältemittels, wobei jeder der Verdichter einen Ansauganschluss (37, 52, 56; 72; 82; 92; 102) und einen Auslassanschluss (39, 54, 58; 74; 84; 94; 104) aufweist;
 einen Wärme ableitenden Wärmetauscher (24) zum Kühlen des Kältemittels; und
 20 eine Vielzahl von Economiserkreisläufen (25A, 25B; 25C; 25D; 25E), die jeweils einen Economiserwärmetauscher (28A, 28B; 28A', 28B'; 28A", 28B") umfassen, wobei jede der Economiserkreisläufe dazu konfiguriert ist, einen Teil des Kältemittels in den Ansauganschluss von einem der Verdichtern einzuspritzen,

dadurch gekennzeichnet, dass ein Economiserweg (42A, 42B) jeder der Economiserkreisläufe in einer Wärmetauscherbeziehung zum Hauptkältemittelweg (40A, 40B) steht, um den Hauptkältemittelweg in dem jeweiligen Economiserwärmetauscher zu kühlen, und
 30 dass der Auslassanschluss (39, 54, 58; 74; 84; 94; 104) eines jeden der Verdichtern direkt mit dem Wärme ableitenden Wärmetauscher (24) verbunden ist.

2. Kühleystem nach Anspruch 1, wobei einer der Verdichter ein zweistufiger Verdichter (32) mit einem ersten Verdichterzylinder (36A) und einem zweiten Verdichterzylinder (36B) ist.
3. Kühleystem nach Anspruch 2, wobei ein Ladeluftkühler (48) zwischen dem ersten und zweiten Verdichterzylinder (36A, 36B) des zweistufigen Verdichters (32) angeordnet ist, um das Kältemittel vor einer zweiten Verdichtungsstufe zu kühlen.
4. Kühleystem nach Anspruch 1, wobei jeder der Verdichter ein einstufiger Verdichter ist.
5. Kühleystem nach einem der vorangehenden Ansprüche, wobei der Wärme ableitende Wärmetauscher (24) ein Kondensator oder ein Gaskühler ist.
6. Kühleystem nach einem der vorangehenden Ansprüche, wobei die Economiserwärmetauscher Entspanner (28A', 28B') sind.

7. KÜHLSYSTEM NACH ANSPRUCH 1, UMFASSEND:

einen zweistufigen Verdichter (32) zum Verdichten des Kältemittels, wobei der zweistufige Verdichter einen ersten Verdichterzylinder (36A) und einen zweiten Verdichterzylinder (36B) aufweist;

einen ersten einstufigen Verdichter (34) zum Verdichten des Kältemittels, einen zweiten einstufigen Verdichter (35) zum Verdichten des Kältemittels, einen ersten Economiserkreislauf (25A), der dazu konfiguriert ist, einen ersten Teil des Kältemittels in den Ansauganschluss (52) des ersten einstufigen Verdichters einzuspritzen; und einen zweiten Economiserkreislauf (25B), der dazu konfiguriert ist, einen zweiten Teil des Kältemittels in den Ansauganschluss (56) des zweiten einstufigen Verdichters einzuspritzen.

8. KÜHLSYSTEM NACH ANSPRUCH 7, WOBEI DIE VIELZahl VON Verdichtern ODER DER ZWEIFLUGIGE Verdichter (32), DER ERSTE einstufige Verdichter (34) UND DER ZWEIFLUGIGE Verdichter (35) TEIL EINER EINZELNEN Verdichtereinheit MIT MEHREREN ZYLINDERN SIND.

9. KÜHLSYSTEM NACH DEN ANSPRÜCHEN 7 UND 8, WOBEI EIN LADELUFTKÜHLER (48) ZWISCHEN DEM ERSTEN Verdichterzylinder (36A) UND DEM ZWEIFLUGIGEN Verdichterzylinder (36B) ANGEORDNET IST, UM DAS Kältemittel ZWISCHEN EINER ERSTEN Verdichtungsstufe UND EINER ZWEIFLUGIGEN Verdichtungsstufe ZU KÜHLEN.

10. KÜHLSYSTEM NACH ANSPRUCH 9, UND FERNER UMFASSEND:

einen dritten einstufigen Verdichter (70) mit einem Ansauganschluss (72) und einem Auslassanschluss (74); und einen dritten Economiserkreislauf (25C), der dazu konfiguriert ist, einen dritten Teil des Kältemittels in den Ansauganschluss des dritten einstufigen Verdichters einzuspritzen.

11. KÜHLSYSTEM NACH ANSPRUCH 10, UND FERNER UMFASSEND:

einen vierten einstufigen Verdichter (80) mit einem Ansauganschluss (82) und einem Auslassanschluss (84); und einen vierten Economiserkreislauf (25D), der dazu konfiguriert ist, einen vierten Teil des Kältemittels in den Ansauganschluss des vierten einstufigen Verdichters einzuspritzen.

12. KÜHLSYSTEM NACH ANSPRUCH 11, UND FERNER UMFASSEND:

einen fünften einstufigen Verdichter (90) mit einem Ansauganschluss (92) und einem Auslassanschluss (94); und einen fünften Economiserkreislauf (25E), der dazu konfiguriert ist, einen fünften Teil des Kältemittels in den Ansauganschluss des fünften einstufigen Verdichters einzuspritzen.

13. KÜHLSYSTEM NACH EINEM DER VORANGEHENDEN ANSPRÜCHE, WOBEI DAS Kältemittel Kohlendioxid IST.

14. VERFAHREN ZUM BETREIBEN EINER KÜHLSYSTEMS, WOBEI DAS VERFAHREN FOLGENDES UMFASST:

Verdampfen eines Kältemittels;
Verdichten des Kältemittels von einem niedrigeren Druck auf einen höheren Druck in einer Vielzahl von Verdichtern, wobei die Vielzahl von Verdichtern einen zweistufigen Verdichter und wenigstens zwei einstufige Verdichtern beinhaltet, wobei der zweistufige Verdichter einen Ladeluftkühler beinhaltet, der dazu konfiguriert ist, das Kältemittel zwischen einer ersten Verdichtungsstufe und einer zweiten Verdichtungsstufe zu kühlen;

Einspritzen des Kältemittels von dem Auslassanschluss eines jeden der Verdichtern direkt in einen Wärme ableitenden Wärmetauscher und Kühlen des Kältemittels in dem Wärme ableitenden Wärmetauscher;

Leiten des Kältemittels auf einem Hauptkältemittelweg durch eine Vielzahl von Economiserwärmetauschern, die jeweils in einem jeweiligen Economiserkreislauf vorgesehen sind, und, in den Economiserwärmetauschern, Kühlen des Kältemittels auf dem Hauptkältemittelweg mithilfe des Kältemittels in einem Economiserweg des jeweiligen Economiserkreislaufs;

Einspritzen eines ersten Teils des Kältemittels von einem ersten Economiserkreislauf in einen Ansauganschluss von einem der einstufigen Verdichtern; und

Einspritzen eines zweiten Teils des Kältemittels von einem zweiten Economiserkreislauf in einen Ansauganschluss von einem anderen der einstufigen Verdichter; und

wobei die Verdichter wahlweise Teil einer einzelnen Verdichtereinheit mit mehreren Zylindern sind.

15. VERFAHREN NACH ANSPRUCH 14, WOBEI DAS Kältemittel Kohlendioxid IST.

55 **Revendications**

1. Système de réfrigération (20A ; 20B ; 20C ; 20D ; 20E ; 20A' ; 20A") :

- une voie principale de réfrigérant ;
 un évaporateur (27) ;
 une pluralité de compresseurs (32, 34, 35 ; 70 ; 80 ; 90 ; 100) servant à comprimer un réfrigérant, chacun des compresseurs comportant un orifice d'aspiration (37, 52, 56 ; 72 ; 82 ; 92 ; 102) et un orifice d'évacuation (39, 54, 58 ; 74 ; 84 ; 94 ; 104) ;
 un échangeur de chaleur à rejet de chaleur (24) servant à refroidir le réfrigérant ; et
 une pluralité de circuits économiseurs (25A, 25B ; 25C ; 25D ; 25E) donc chacun comprend un échangeur de chaleur économiseur (28A, 28B ; 28A', 28B' ; 28A'', 28B'') où chacun des circuits économiseurs est conçu pour injecter une partie du réfrigérant dans l'orifice d'aspiration d'un des compresseurs,
- caractérisé en ce qu'**une voie d'économiseur (42A, 42B) de chacun des circuits économiseurs est dans une relation d'échange de chaleur avec la voie principale de réfrigérant (40A, 40B) pour refroidir la voie principale de réfrigérant dans l'échangeur de chaleur économiseur respectif, et **en ce que** l'orifice d'évacuation (39, 54, 58 ; 74 ; 84 ; 94 ; 104) de chacun des compresseurs est directement raccordé à l'échangeur de chaleur à rejet de chaleur (24).
2. Système de réfrigération selon la revendication 1, dans lequel un des compresseurs est un compresseur à deux étages (32) comportant un premier cylindre de compresseur (36A) et un deuxième cylindre de compresseur (36B).
 3. Système de réfrigération selon la revendication 2, dans lequel un interrefroidisseur (48) se trouve entre les premier et deuxième cylindres de compresseur (36A, 36B) du compresseur à deux étages (32) pour refroidir le réfrigérant avant un deuxième étage de compression.
 4. Système de réfrigération selon la revendication 1, dans lequel chacun des compresseurs est un compresseur à un seul étage.
 5. Système de réfrigération selon l'une quelconque des revendications précédentes, dans lequel l'échangeur de chaleur à rejet de chaleur (24) est un condenseur ou un refroidisseur à gaz.
 6. Système de réfrigération selon l'une quelconque des revendications précédentes, dans lequel les échangeurs de chaleur économiseurs sont des cuves de décompression (28A', 28B').
 7. Système de réfrigération selon la revendication 1, comprenant :
 - un compresseur à deux étages (32) servant à comprimer le réfrigérant, le compresseur à deux étages comportant un premier cylindre compresseur (36A) et un deuxième cylindre compresseur (36B) ;
 - un premier compresseur à un seul étage (34) servant à comprimer le réfrigérant,
 - un deuxième compresseur à un seul étage (35) servant à comprimer le réfrigérant,
 - un premier circuit économiseur (25A) conçu pour injecter une première partie du réfrigérant dans l'orifice d'aspiration (52) du premier compresseur à un seul étage ; et
 - un deuxième circuit économiseur (25B) conçu pour injecter une deuxième partie du réfrigérant dans l'orifice d'aspiration (56) du deuxième compresseur à un seul étage.
 8. Système de réfrigération selon la revendication 7, dans lequel la pluralité de compresseurs ou de compresseur à deux étages (32), le premier compresseur à un seul étage (34) et le deuxième compresseur à un seul étage (35) font partie d'une unité de compresseur simple et à cylindre multiples.
 9. Système de réfrigération selon la revendication 7 ou 8, dans lequel un interrefroidisseur (48) est disposé entre le premier cylindre de compresseur (36A) et le deuxième cylindre de compresseur (36B) pour refroidir le réfrigérant entre un premier étage de compression et un deuxième étage de compression.
 10. Système de réfrigération selon la revendication 9, comprenant en outre :
 - un troisième compresseur à un seul étage (70) comportant un orifice d'aspiration (72) et un orifice d'évacuation (74) ; et
 - un troisième circuit économiseur (25C) conçu pour injecter une troisième partie du réfrigérant dans l'orifice d'aspiration du troisième compresseur à un seul étage.
 11. Système de réfrigération selon la revendication 10, comprenant en outre :
 - un quatrième compresseur à un seul étage (80) comportant un orifice d'aspiration (82) et un orifice d'évacuation (84) ; et
 - un quatrième circuit économiseur (25D) conçu pour injecter une quatrième partie du réfrigérant dans l'orifice d'aspiration du quatrième compresseur à un seul étage.
 12. Système de réfrigération selon la revendication 11, comprenant en outre :
 - un cinquième compresseur à un seul étage (90)

- comportant un orifice d'aspiration (92) et un orifice d'évacuation (94) ; et
 un cinquième circuit économiseur (25E) conçu pour injecter une cinquième partie du réfrigérant dans l'orifice d'aspiration du cinquième compresseur à un seul étage. 5
- 13.** Système de réfrigération selon l'une quelconque des revendications précédentes, dans lequel le réfrigérant est du dioxyde de carbone. 10
- 14.** Procédé d'utilisation d'un système de réfrigération, ce procédé comprenant :
- la vaporisation d'un réfrigérant ; 15
 - la compression du réfrigérant d'une pression relativement basse à une pression plus élevée dans une pluralité de compresseurs, la pluralité de compresseurs comprenant un compresseur à deux étages et au moins deux compresseurs à un seul étage, le compresseur à deux étages comprenant un interrefroidisseur conçu pour refroidir le réfrigérant entre un premier étage de compression et un deuxième étage de compression ; 20
 - l'injection du réfrigérant depuis l'orifice d'évacuation de chacun des compresseurs directement dans un échangeur de chaleur à rejet de chaleur et le refroidissement du réfrigérant dans l'échangeur de chaleur à rejet de chaleur ; 25
 - l'acheminement du réfrigérant dans une voie principale de réfrigérant à travers une pluralité d'échangeurs de chaleur à économiseur, dont chacun se trouve dans un circuit économiseur respectif et, dans les échangeurs de chaleur économiseurs, le refroidissement du réfrigérant dans la voie principale de réfrigérant grâce au réfrigérant dans une voie d'économiseur du circuit économiseur respectif ; 30
 - l'injection d'une première partie du réfrigérant d'un premier circuit économiseur vers un orifice d'aspiration d'un des compresseurs à un seul étage ; et 35
 - l'injection d'une deuxième partie du réfrigérant d'un deuxième circuit économiseur vers un orifice d'aspiration d'un autre des compresseurs à un seul étage ; et 40
- où, en option, les compresseurs font partie d'une unité de compresseur simple et cylindres multiples. 45
- 15.** Procédé selon la revendication 14, dans lequel le réfrigérant est du dioxyde de carbone. 50
- 55

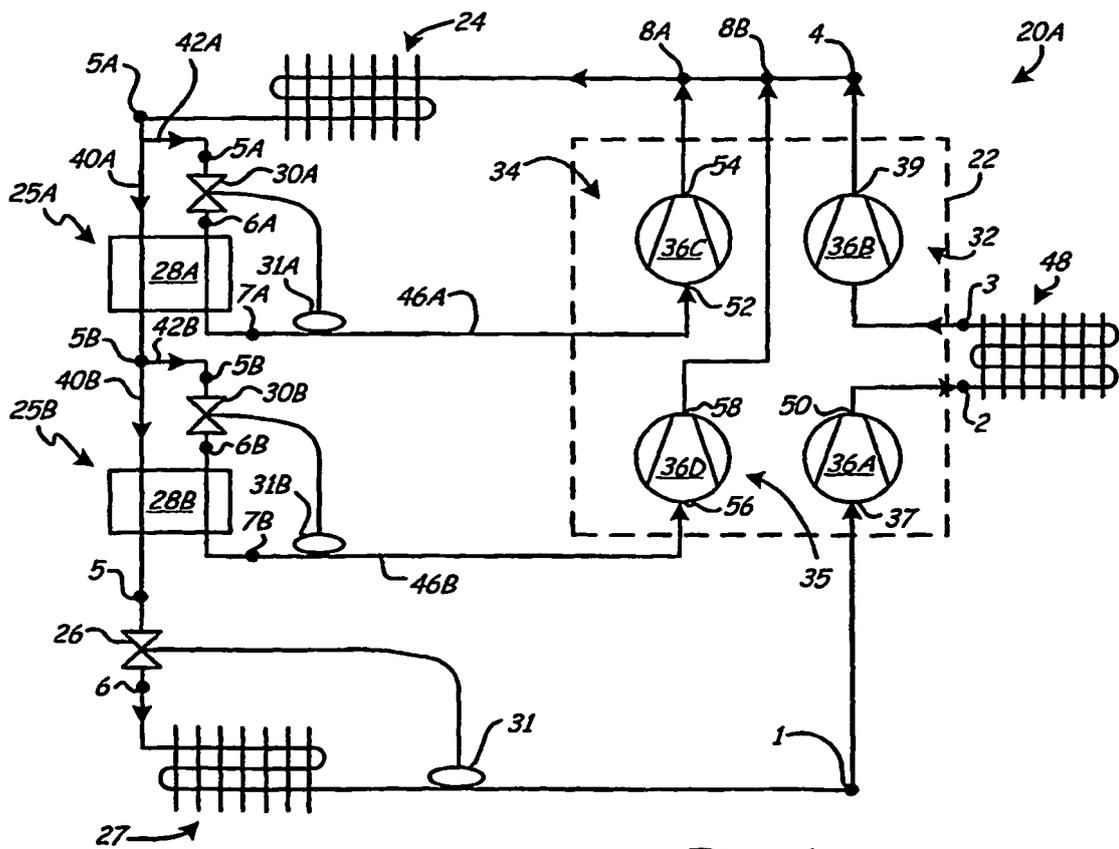


Fig. 1A

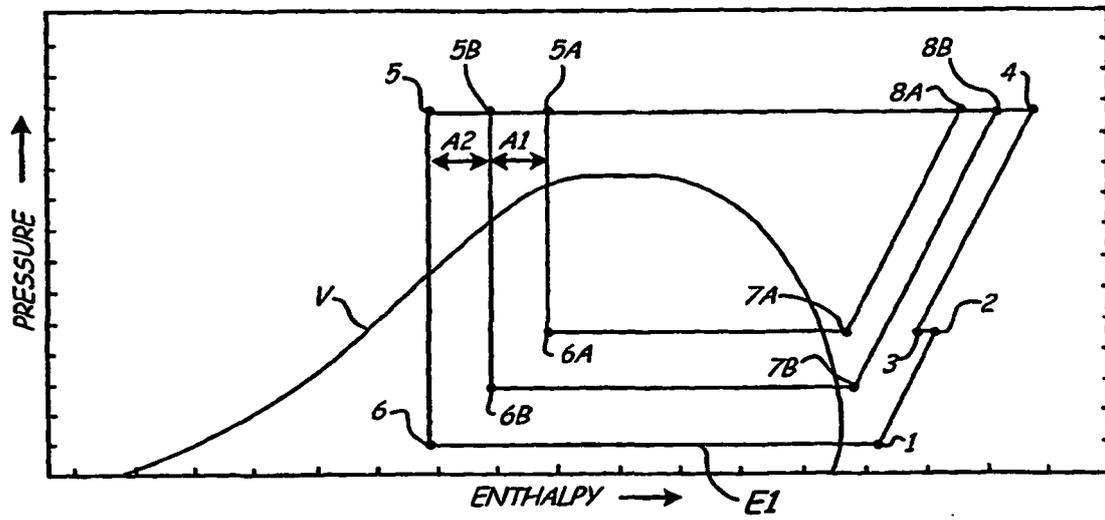


Fig. 1B

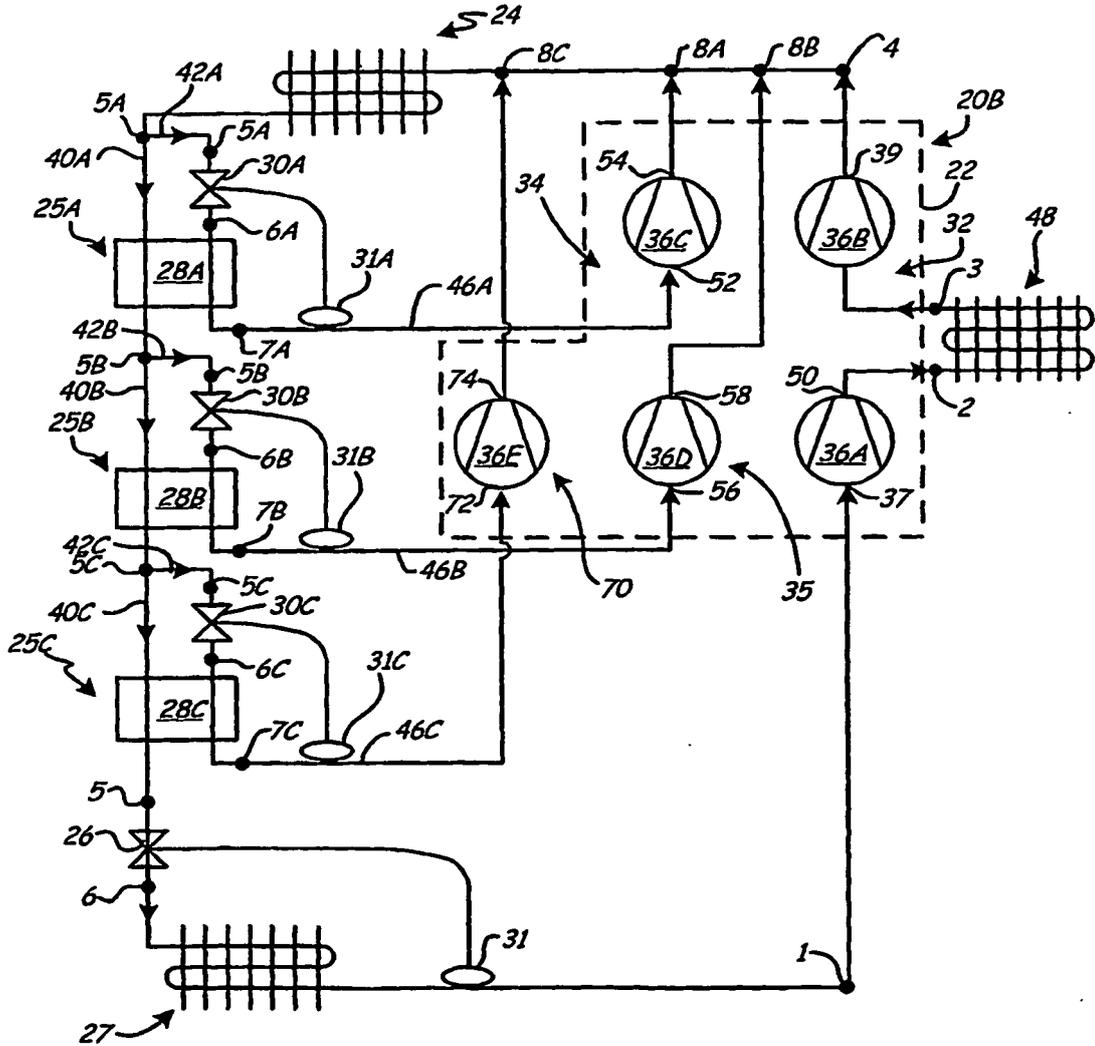


Fig. 2A

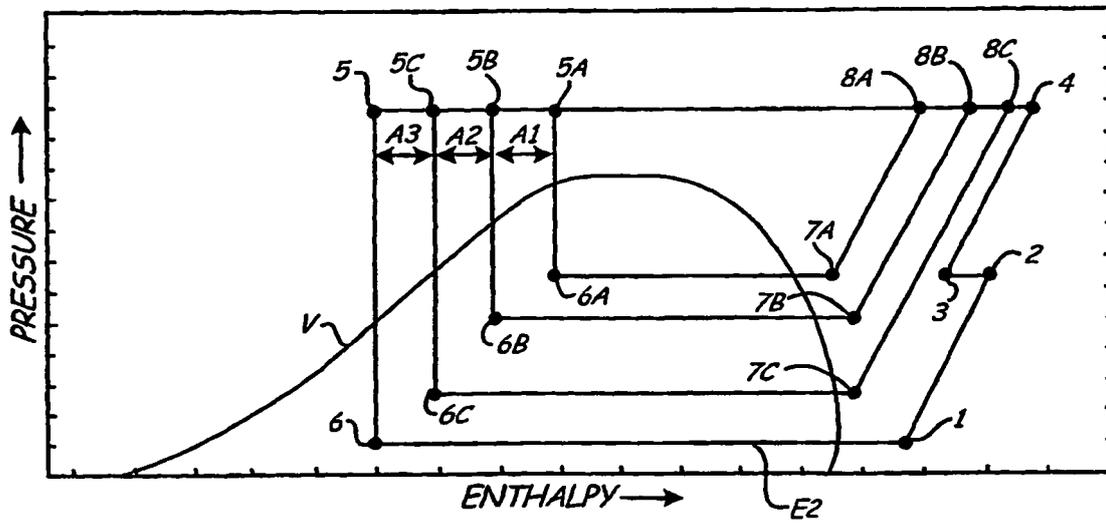


Fig. 2B

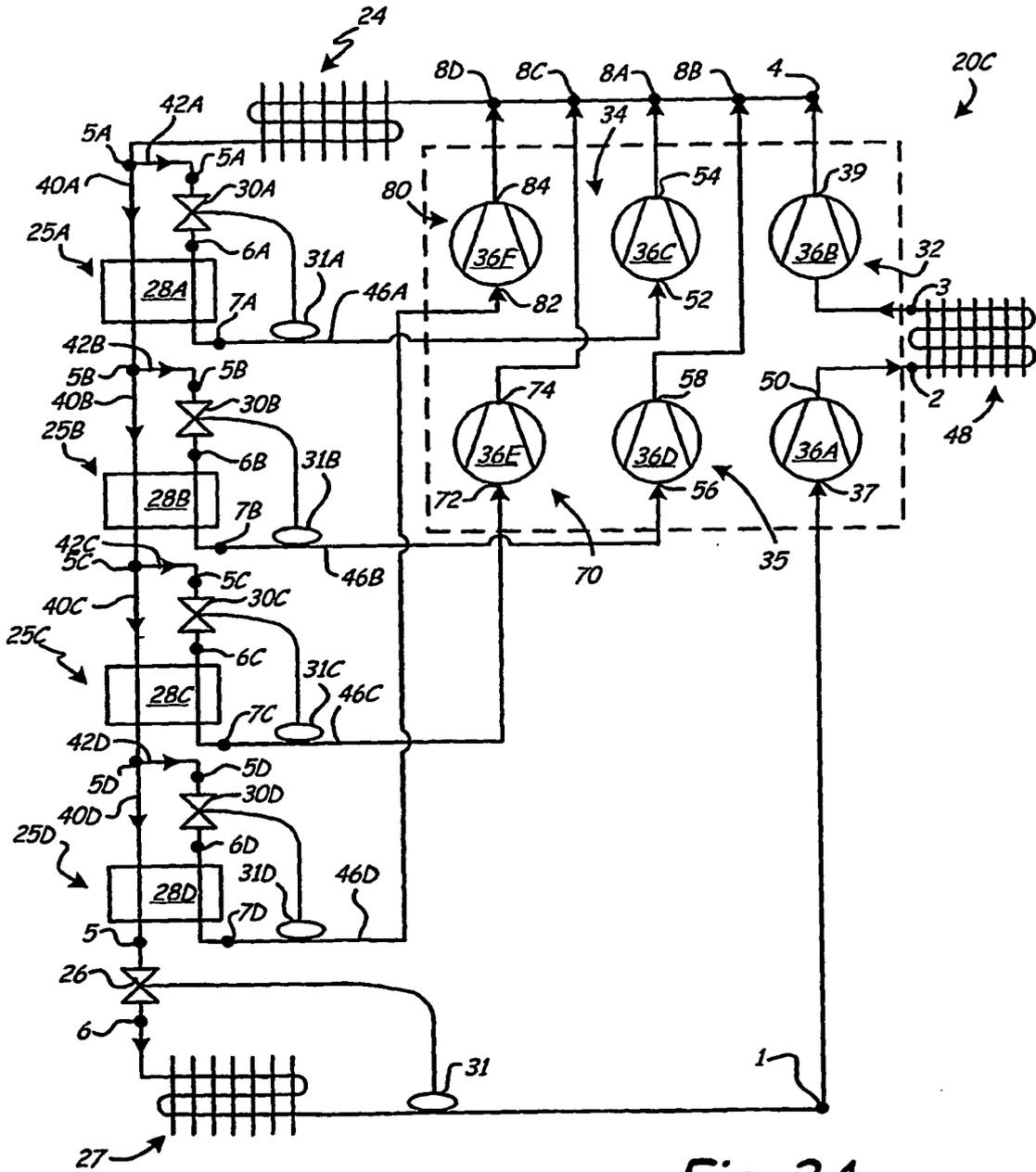


Fig. 3A

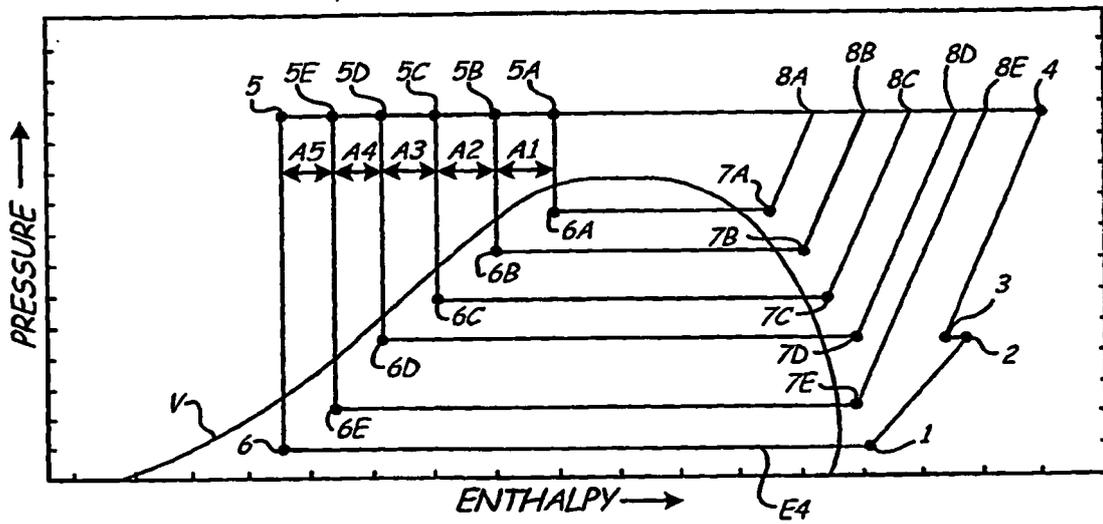


Fig. 4B

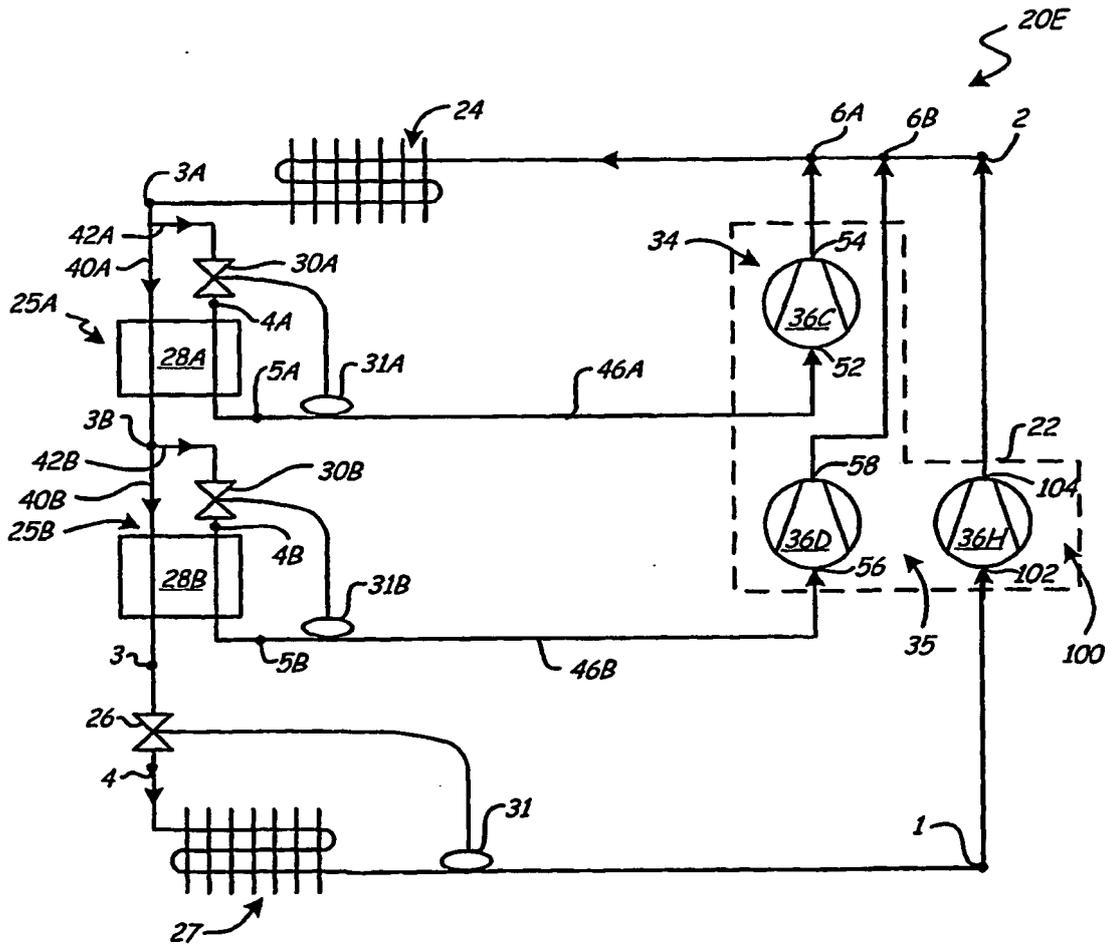


Fig. 5A

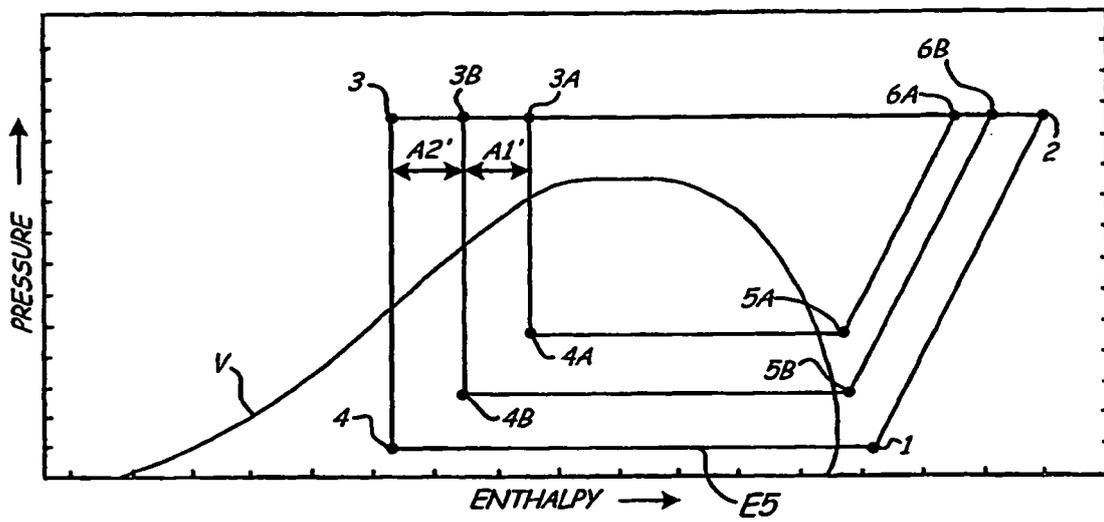


Fig. 5B

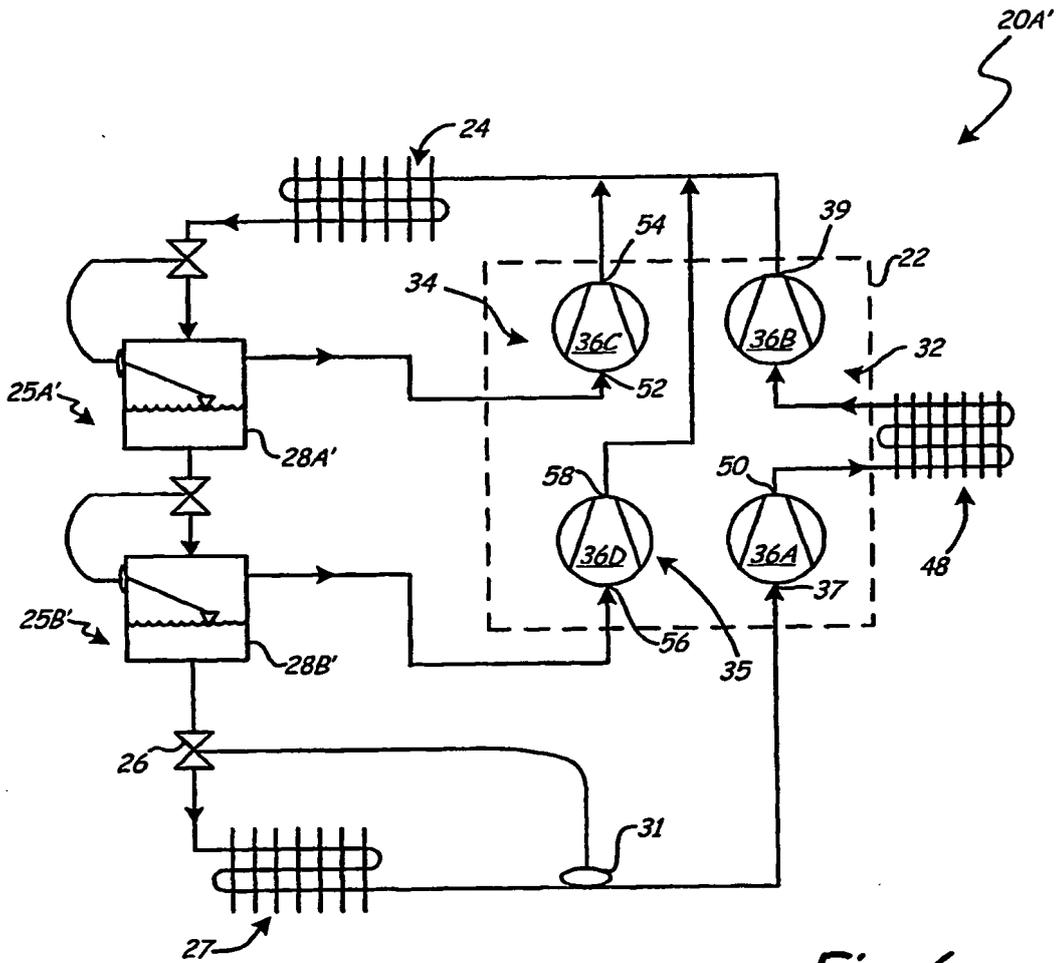


Fig. 6

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2006022829 A1 [0004]
- US 6113358 A [0005]