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DIRECT EXPANSION AIR-CONDITIONING UNIT FOR COOLING A TUNNEL

(57)

An air-conditioning unit (1) on a train car (4) for cooling a tunnel where trains run comprising: an inlet (10) for sucking air (HOT AIR) from exterior of the train car (4); a refrigerant circuit (7) having a first heat exchanger (12, 12s) operating as an evaporator when the train car (4) runs in a tunnel (3), a second heat exchanger (16, 16s) operating as a condenser when the train car (4) runs in a tunnel (3), an expansion device (29, 29s) which permits the expansion of the condensed fluid by the second

heat exchanger (16, 16s), and a compressor (25, 25s); an outlet (13) for cooled air supplied to the exterior of the train car (4) in the tunnel (3); a fan (50) coupled with the first heat exchanger (12, 12s) and blowing the sucked air passed through the first heat exchanger (12, 12s) from the inlet (10) towards the outlet (13); and a heat collector (20) that receives air passing through the second heat exchanger (16, 16s) and stores the received thermal energy. (figure 1)

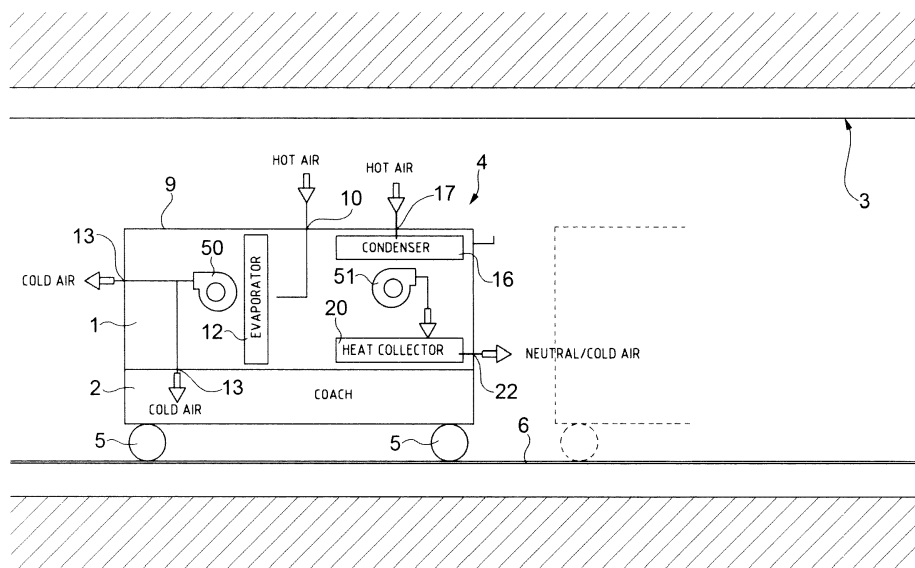


FIG. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to a direct expansion air-conditioning unit for cooling a tunnel.

BACKGROUND ART

[0002] The operation of trains in undergrounds tunnels produces a large quantity of heat that is delivered to the air inside the tunnel producing a serious increase of the air temperature.

[0003] About 80% of the heat produced comes from the operation of the trains (brakes, motors, etc.), 15% comes from the equipments of the tunnels (lighting systems, signaling and control for instance) and the remaining 5% of heat comes from people using the underground; to that regard, it has been calculated that underground passengers account for about 56 GW-Hours of heat energy emitted in an average year.

[0004] Underground system is carrying more people than ever before; this intense use of the systems has caused a great increase of the heat delivered inside the tunnels.

[0005] Accordingly the temperatures inside the tunnels have slowly and constantly increased over about the last thirty years of about 10 or 15 degrees while also the temperatures of the ground around the underground tunnels have increased.

Accordingly cooling equipments have to be installed inside the underground tunnels in order to control the increase of temperature.

[0006] In several underground system, however, it is extremely difficult to install the above equipments as the available free space is limited.

[0007] For instance in some underground systems the old tunnels were designed and built with enough room for allowing the service of trains carriages only. This limitation of space is especially evident in deep-level underground tunnels (the tunnels below the surface level of about 20m - 65ft 7in) wherein the space for air-conditioning units to be installed either inside of the train or outside in the tunnel is limited.

[0008] In order to cool underground stations it has been proposed to use heat exchangers where air is cooled using the cold water that is pumped from the ground; this water has an almost constant temperature that is enough low to cool the air.

[0009] In year 2006 groundwater cooling trials were carried out at Victoria Station of the London Underground. The above system uses the Underground's existing pumps which are designed to prevent a rising water table from flooding the area. Water is extracted from boreholes at about 14C° and pumped to heat exchangers located between platforms. Fans blow hot air from the station across the pipes of the heat exchanges; the cooled air is then blown onto platforms and driven along

by trains.

[0010] The warmed water delivered from heat exchangers is pumped back into the water table.

The above cooling solution needs a complicated construction and is almost expensive. Moreover the above cooling system is not suitable for all stations, because groundwater could not be adequate for cooling purposes at some places. Finally, measures have to be taken to prevent the ejected warm water from heating up the aquifer.

[0011] Other solutions for cooling underground tunnel are described in the patents JP-A-2007-247269, EP 2216504 A2, GB 2404245 and GB 2406902.

[0012] Patent application JP-A-2007-247269 describes a cooling system where a carriage is arranged at the rear side of a vehicle running in a tunnel and is provided with a fan for generating swirl flow at the vicinity of the vehicle toward the inner wall of the tunnel. The carriage is also provided with an exhaust duct for sucking the polluted air.

[0013] Patent application EP 2216504 A2 describes a cooling system for an underground space like a subway where a liquefied cryogenic gas is introduced into the underground space through one or more nozzles arranged in the roof and walls of the underground space. During the introduction of the liquefied cryogenic gas into the underground space it is desirable to avoid extreme cooling of any machinery or other equipment in the underground space which could over time lead to it failing.

[0014] Patent application GB 2404245 describes a cooling system for cooling an underground rail network where a carriage provided with a fan having an impeller of a size to fit the cross section of the tunnel is used to drawn air from surface entrances of some train stations upstream of the fan and for expelling warm air from the tunnels via surface entrances of other train stations downstream of the fan. Turbulence vanes on rolling stock may be temporarily positioned at intervals along the tunnels to increase the rate of heat transfer from the walls.

[0015] Patent application GB 2406902 A describes a cooling system for an underground transit system where liquid oxygen is used as cooling medium for heat exchangers. The use of cryogenic gas is complex and may be potentially dangerous while other proposed cooling systems may be used only when trains are not running in the tunnels subject to cooling.

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0016] The scope of the present invention is to provide a cooling system for an underground tunnel.

SOLUTION TO THE PROBLEM

[0017] The present scope is obtained by the present invention as it relates to an air-conditioning unit on a train

that is designed to move along the tunnel for cooling the tunnel where trains run characterized by comprising: an inlet for sucking air from exterior of the train car; a refrigerant circuit having a first heat exchanger operating as an evaporator when the train car runs in a tunnel, a second heat exchanger operating as a condenser when the train car runs in a tunnel, an expansion device which permits the expansion of the condensed fluid by the second heat exchanger, and a compressor; an outlet for cooled air supplied to the exterior of the train car in the tunnel; a fan coupled with the first heat exchanger and blowing the sucked air passed through the first heat exchanger from the inlet towards the outlet; and a heat collector that receives air passing through the second heat exchanger and stores the received thermal energy.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0018] According to the present invention, an air-conditioning unit on a train car that is designed to move along a tunnel is possible to cool the tunnel.

BRIEF DESCRIPTION OF DRAWINGS

[0019] The invention will be described with reference to the attached drawings wherein:

Figure 1 shows schematically an air-conditioning unit for cooling an underground tunnel where trains run realized according to a first embodiment;
 Figure 2 shows a first preferred non limiting example of an air-conditioning unit for cooling an underground tunnel according to a first embodiment;
 Figure 3 shows a first operation mode of the air-conditioning unit of figure 2;
 Figure 4 shows a second operation mode of the air-conditioning unit of figure 2; and
 Figure 5 shows a second example of an air-conditioning unit for cooling an underground tunnel according to a second embodiment.

First Embodiment

[0020] Figure 1 shows schematically a direct expansion air-conditioning unit 1 (in the following air-conditioning unit) for cooling an underground tunnel 3 (shown schematically) where underground trains run. The air-conditioning unit 1 is installed on a train car 4 movable in the tunnel 3, for instance the train car 4 is self-propelled or the train car 4 may be attached to an underground train (shown with dotted lines). More specifically, the air-conditioning unit 1 can be installed on a special train that can travel alone into the tunnel 3 or be attached to a circulating passengers train. The special train may run during the time out of service or during the normal operation of passengers trains.

[0021] In this embodiment, the air-conditioning unit 1 is installed in/on the roof 9 of the train car 4 which is

located over a coach 2. The installed place is not confined in/on the roof 9 and it may be installed under floor of the coach 2 or in the coach 2. The train car 4 is provided with wheels 5 to move along a rail 6 that extends in the tunnel 3.

[0022] The air-conditioning unit 1 has air inlets 10,17 for sucking air from the exterior of the train car 4, air outlets 13,22, heat exchangers 12,16, fans 50,51, and a heat collector 20. Preferably the air-conditioning unit 1 has a ventilation hole through the roof 9 and the coach 2.

[0023] The first embodiment shows two inlets but the number of the inlet is not limited to two, and this invention can provide the air-conditioning unit 1 for cooling a tunnel only with one inlet.

[0024] The heat collector 20 may preferably contain a phase-change material (of known kind), PCM, that stores the received heat energy changing its state. The heat collector 20 may also comprise a material that may store a lot of thermal energy in its volume (water for instance) other than PCM.

[0025] The air blown by the fan 51 comes into contact with the energy changing material of the heat collector 20 and the air output from the outlet 22 may be cooled or have a temperature close to the temperature of the air that has been sucked (NEUTRAL/COLD AIR).

[0026] As it is known a phase-change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) units.

[0027] Examples of Organic PCMs are Paraffin (C_nH_{2n+2}) and fatty acids ($CH_3(CH_2)_{2n}COOH$).

Examples of Inorganic PCMs are Salt hydrates (M_nH_2O). Phase-change materials having a biological base that may be used in building industry may also be used.

The recovered thermal energy is stored in the heat collector 20 that may be substituted or regenerated during a successive phase that is performed when the train car 4 is outside of the tunnel 3. This phase will be described in detail as following.

[0028] Figure 2 shows a diagram of a refrigerant circuit 7 (shown in detail in the following) which is provided to the air-conditioning unit 1.

In the preferred example shown as figure 2, the refrigerant circuit 7 comprises tubes in which fluid refrigerant flows, a first heat exchanger 12, a second heat exchanger 16, a four-way valve 24, an accumulator 41, a compressor 25, and thermostatic expansion valves 29,33. It is noted that in a most simplified version (not shown) each thermostatic valves 29,33 may be substituted with a capillary tube that works as an expansion device.

[0029] The first fan 50 is coupled with the first heat exchanger 12 and blows heat exchanged air by the first heat exchanger 12. In the same manner, the second fan 51 is coupled with the second heat exchanger 16 and blows heat exchanged air by the second heat exchanger

16. And the heat collector 20 which collects heat energy from the second fan 51 which blows air passed through the second heat exchanger 16. Preferably the refrigerant circuit 7 has non-return valves 29-a,34,35,37, a solenoid valve 39, a dehydrator filter 40, and a liquid viewer and moisture indicator 45.

[0030] The compressor 25 having an inlet 25-a and an outlet 25-b is connected to the four-way valve 24 with tubes. The inlet 25-a is connected with a first port 24-a of the valve 24 through a first tube 26, and the outlet 25-b is connected with a second port 24-b of the valve 24 through a second tube 27.

[0031] Between the first port 24-a and the inlet 25-a, there are a LP (Low Pressure)/HP (High Pressure) Transmitter 42 sensing the pressure of the working fluid at the inlet 25-a of the compressor 25, a LP (Low Pressure)/HP (High Pressure) switch 43 communicating with the first tube 26, and a LP (Low Pressure)/HP (High Pressure) connection 44 suitable for refrigerant (working fluid) charge in series along the first tube 26.

[0032] In the same manner, between the outlet 25-b and the second port 24-b, there are a LP /HP connection 44-b suitable for refrigerant (working fluid) charge in series along the first tube 26, a LP /HP switch 43-b communicating with the second tube 27, and a LP (Low Pressure)/HP (High Pressure) Transmitter 42-b sensing the pressure of the working fluid at the outlet 25-b of the compressor 25.

[0033] The first heat exchanger 12 has a first side connected with a third port 24-c of the valve 24 through a third tube 28 and a second side connected with a first end of a thermostatic expansion valve 29.

[0034] The second heat exchanger 16 has a first side connected with a fourth port 24-d of the valve 24 through a fourth tube 30 and a second side communicating with a fifth tube 31 that also communicates with a second end of the thermostatic expansion valve 29.

[0035] A sixth tube 32 operating as a by-pass tube has a first end connected to the fifth tube 31 at a branching point 32-a and a second end connected to the fifth tube 31 at another branching point 32-b. A second thermostatic expansion valve 33 is placed along the by-pass tube 32 close to the branching point 32-a. Moreover, the solenoid valve 39, the dehydrator filter 40, the liquid viewer and moisture indicator 45, and the accumulator 41 are placed in series along the sixth by-pass tube 32.

[0036] The first non-return valve 34 is placed along the fifth tube 31 between the branching points 32-a and 32-b, and a second non-return valve 35 is placed along the fifth tube 31 between branching point 32-b and the second end of the thermostatic expansion valve 29. The first non-return valve 34 inhibits further movement of the fluid from the point 32-b to the point 32-a, and the second non-return valve 35 inhibits further movement of the fluid from the point 32-b to the second end of the thermostatic expansion valve 29.

[0037] A seventh tube 36 has a first end connected with the sixth by-pass tube 32, between the thermostatic

valve 33 and the solenoid coil 39, and a second end communicating with the second end of the thermostatic expansion valve 29. A third non return valve 37 is placed along the seventh tube 36 to inhibit further movement of the fluid from the second first end to the second end of the seventh tube 36. Additionally, there is a fourth non-return valve 29-a placed in parallel to the expansion valve 29 by-passing the expansion valve 29.

[0038] A eighth optional tube 38 has a first end connected with the fifth tube 31, between the second heat exchanger 16 and the branching point 32-a, and a second end communicating with the second tube 27, between the outlet 25-b of the compressor 25 and the four-way valve 24. A solenoid valve 46 is placed along the eighth by-pass tube 38. Normally the solenoid valve 46 is closed, and it opens for several tens of seconds at the time of startup. In the following description of the first/second operating mode we suppose that the solenoid valve 46 is closed so that no working fluid passes through by-pass tube 38.

[0039] The four-way valve 24 may be moved by an actuator 60 controlled by an electronic unit 61 and set in a first/ second working position for performing different operation mode shown in figures 3 and 4.

[0040] In the first embodiment, the air-conditioning unit 1 is designed to switch between two alternative operation modes, i.e.:

- (i) A first operation mode: The first operation mode is performed when the train car 4 runs in the tunnel 3 and is shown with reference to figure 3. The first heat exchanger 12 operates as an evaporator for cooling the air (see HOT AIR in figure 1) that is sucked from the exterior of the train car 4 and the second heat exchanger 16 operates as a condenser.
- (ii) A second operation mode: The second operation mode is performed when the train car 4 is outside of the tunnel 3, for example the train car 4 runs on the ground, and is shown with reference to figure 4. The second heat exchanger 16 operates as an evaporator for cooling the air sucked from the exterior of the train car 4 and the first heat exchanger 12 operates as a condenser.

[0041] In the first operation mode shown as figure 3, the four-way valve 24 works on the first working position wherein the second port 24-b communicates with the fourth port 24-d and the first port 24-a communicates with the third port 24-c.

[0042] The working fluid compressed by the compressor 25 is supplied to the first side of the second heat exchanger 16 through the second tube 27 and the fourth tube 30. As explained above, the second heat exchanger 16 works as a condenser and transfers the thermal energy of the working fluid to the heat collector 20 using the second fan 51 which blows the air in the air-conditioning unit 1 passed through the second heat exchanger 16.

[0043] The condensed working fluid that is present at the second side of the heat exchanger 16 is supplied to the fifth tube 31 (the expansion valve 33 is closed), and at the branching point 32-b the condensed working fluid moves to the sixth by-pass tube 32; no further movement of the condensed working fluid along tube 31 is possible as the second non-return valve 35 inhibits further movement of the fluid.

[0044] The condensed working fluid reaches the seventh tube 36 and the thermostatic expansion valve 29 (that is opened) that permits the expansion of the condensed fluid in the first heat exchanger 12. The state change of the fluid cools the tubes of the first heat exchanger 12 that works as an evaporator, so that the hot air sucked through the inlet 10 from the exterior of the train car 4 is cooled and the cooled air (COLD AIR in figure 1), which is cooled by the first heat exchanger 12, is supplied to the tunnel 3 through the outlet 13 under the thrust of fan 50.

[0045] The working fluid coming out from the first heat exchanger 12 is supplied to the inlet 25-a of the compressor 25 through the tubes 28 and 26.

[0046] In the second operation mode shown as figure 4, the four-way valve 24 works on the second working position wherein the second port 24-b communicates with the third port 24-c and the first port 24-a communicates with the fourth port 24-d.

[0047] The working fluid compressed by the compressor 25 is supplied to the first side of the first heat exchanger 12 through the second tube 27 and the third tube 28. As explained above, the first heat exchanger 12 works as a condenser and transfers the thermal energy of the working fluid to the exterior of the train car 4 via the outlet 13 using the first fan 50 which blows the air in the air-conditioning unit 1 passed through the first heat exchanger 12.

[0048] The condensed working fluid that is present at the second side of the first heat exchanger 12 is supplied to the fifth tube 31 (the expansion valve 29 is closed and the fluid passes through the fourth non-return valve 29-a). The condensed fluid moving along tube 31 reaches the branching point 32-b where the fluid is diverted to the sixth by-pass tube 32 as the non-return valve 34 inhibits further movement of the condensed working fluid through fifth tube 31.

[0049] The condensed working fluid reaches the second heat exchanger 16 through the thermostatic expansion valve 33 and the fifth tube 31, when the thermostatic expansion valve 33 is opened and permits the expansion of the condensed fluid in the second heat exchanger 16. The state change of the fluid cools the tubes of the second heat exchanger 16 that works as an evaporator, so that the air sucked through the inlet 17 from the exterior of the train car 4 is cooled. The cooled air by the second heat exchanger 16 is supplied by the second fan 51 towards the state changing material of the heat collector 20 so that the PCM may return to its original state regenerating the heat collector 20.

[0050] This second operation is performed when the train car 4 with the air-conditioning unit 1 runs outside of the tunnel 3, the air in the air-conditioning unit 1 moved by fan 51 is supplied to the outside of the train car 4 through the outlet 22 after having cooled the heat collector 20. Then the cooled air will not be blown into the coach 2.

[0051] The working fluid coming out from the second side of the second heat exchanger 16 is supplied to the inlet 25-a of the compressor 25 through the fourth tube 30 and the first tube 26 via the fourth port 24-d and the first port 24-a. As aforementioned, the heat collector 20 may be regenerated by the cooled air in the second operation mode. When the expiration cycle for use comes, the heat collector 20 may also be replaced with new one during driving suspension. On the situation, the cooled air may be supplied into the coach 2 via the inlet 13 between the roof 9 and the coach 2.

[0052] The first embodiment shown with reference to figures 2, 3 and 4 does not require the substitution of the heat collector 20 at the end of an operating cycle as the heat collector may be regenerated as above described.

[0053] Moreover, in the first embodiment, the train car 4 with the air-conditioning unit 1 has been described as a passenger train. Of course the invention, it is not confined to the passenger train, and the train car 4 may be a special train that travels alone or attached to a circulating passenger train into the tunnel. As the special train may run during the time out of service or during the normal operation of the passenger trains, the air-conditioning unit 1 may reduce the temperature increase of the air inside the tunnel 3, independent of time. Preferably the maximum train speed is set compatibly with an effective heat exchange.

[0054] Accordingly, the air-conditioning unit 1 is able to absorb a part of the heat produced by the trains and other equipment inside the underground tunnel 3, and it is able to cool the air inside the tube tunnel 3. Then the air-conditioning unit 1 may reduce the temperature increase of the air or the ground around the underground tunnel 3.

[0055] On this cooling action, the air-conditioning unit 1 does not require the construction of any infrastructure inside the underground tunnel 3, for example stations or around rails. The air-conditioning unit 1 may run along the entire underground tunnel 3 so that the air-conditioning unit 1 is able to cool the air along the entire route of an underground train car 4 also when other trains are in service.

[0056] Accordingly, it is possible to condition the whole tunnel where is not only the area reached by any ducts or communicated with openings to the outside as proposed by some prior art documents.

55 Second Embodiment

[0057] The embodiment shows a simplified version of the air-conditioning unit 1. In the second embodiment,

the heat exchangers 12 and 16 cannot be inverted.

[0058] Figure 5 shows a simplified refrigerant circuit 7a that has a closed loop tubing 55 comprising portions (tubes) 55a, 55b, 55c where working fluid refrigerant circulates. The difference of the first and second embodiments is the structure of the air-conditioning unit 1, specifically the refrigerant circuits 7 and 7a. The refrigerant circuit 7a comprises a number of units connected in series comprising at least the following:

- a compressor 25s having an inlet 25s-a and an outlet 25s-b;
- two heat exchangers 16s and 12s;
- a thermostatic expansion valve 29s (or a capillary).

Preferably the refrigerant circuit 7a also has a solenoid valve 39s, a dehydrator filter 40s, an accumulator 41s, and a liquid viewer and moisture indicator 45s.

[0059] The inlet 25s-a is connected with a first side of the heat exchanger 16s via the portion 55b of the tubing 55. A second side of the heat exchanger 16s is connected with a first side of the heat exchanger 12s via the portion 55c of the tubing 55. Between the second side of the heat exchanger 16s and the first side of the heat exchanger 12s, the solenoid valve 39s, the dehydrator filter 40s, the accumulator 41s, the liquid viewer and moisture indicator 45s, and a first end of the thermostatic expansion valve 29s are placed in series along the portion 55c. The thermostatic expansion valve 29s may be substituted with a capillary tube that works as an expansion device. A second side of the heat exchanger 12s is connected with the inlet 25s-a via the portion 55a of the tubing 55, and a second end of the thermostatic expansion valve 29s is placed along the portion 55a.

[0060] The air-conditioning unit 1 of the second embodiment also has the heat collector 20, the fans 50, 51, the inlets 10, 17, the outlets 13, 22 explained as in the first embodiment.

[0061] In use as shown in figure 5, the working fluid compressed by the compressor 25s is supplied to the first side of the second heat exchanger 16s and the condensed working fluid that is present at the second side of the heat exchanger 16s is supplied to the thermostatic expansion valve 29s (that is opened) permitting the expansion of the condensed fluid in the heat exchanger 12s.

[0062] The state change of the fluid cools the tubes of the heat exchanger 12s that works only as an evaporator, so that the air (hot air) sucked through the inlet 10 from the exterior of the train car 4 is cooled and the cooled air (COLD AIR in figure 1), which is cooled by the heat exchanger 12s, is supplied to the tunnel 3 through the outlet 13 under the thrust of fan 50. The working fluid coming out from the heat exchanger 12s is supplied to the inlet 25s-a of the compressor 25s through the portion 55a of the tubing 55.

[0063] The second heat exchanger 16s works only as a condenser and transfers the thermal energy of the working fluid to the heat collector 20 using the second

fan 51 which blows the air in the air-conditioning unit 1 passed through the second heat exchanger 16s.

[0064] When the expiration cycle of the material in the heat collector 20, the heat collector 20 is substituted with a new one while the train car 4 is outside of the tunnel 3 during driving suspension.

[0065] To that regard, the heat collector 20 is designed to be movable with respect to the train car 4. The heat collector 20 may be placed in a train body as a first working position where it receives the air passing through the second heat exchanger 16s, and the heat collector 20 may be replaced with a new one as a second discharge position where it is extracted from the train body during driving suspension for the replacement.

[0066] As aforementioned in the first embodiment, the air-conditioning unit 1 is installed in the roof 9 of the train car 4 which is located over a coach 2. The installed place is not confined in the roof 9 and it may be installed under floor of the coach 2 or in the coach 2.

Moreover, the train car 4 with the air-conditioning unit 1 may be a passenger train or a special train that travels alone or attached to a circulating passenger train into the tunnel. As the special train may run during the time out of service or during the normal operation of the passenger trains, the air-conditioning unit 1 may reduce the temperature increase of the air inside the tunnel 3, independent of time. Preferably the maximum train speed is set compatibly with an effective heat exchange.

[0067] Accordingly, the air-conditioning unit 1 is able to absorb a part of the heat produced by the trains and other equipment inside the tube tunnel 3, and it is able to cool the air inside the tunnel 3. Then the air-conditioning unit 1 may reduce the temperature increase of the air or the ground around the underground tunnel 3.

[0068] On this cooling action, the air-conditioning unit 1 does not require the construction of any infrastructure inside the underground tunnel 3, for example stations or around rails. The air-conditioning unit 1 may run along the entire underground tunnel 3 so that the air-conditioning unit 1 is able to cool the air along the entire route of an underground train car 4 also when other trains are in service.

[0069] Accordingly, it is possible to condition the whole tunnel where is not only the area reached by any ducts or communicated with openings to the outside as proposed by some prior art documents.

CITATION LIST

PATENT LITERATURE

[0070]

- Patent document 1: JP-A-2007-247269
- Patent document 2: EP 2216504 A2
- Patent document 3: GB 2404245
- Patent document 4: GB 2406902

Claims

1. An air-conditioning unit (1) on a train car (4) for cooling a tunnel where trains run **characterized by** comprising:
 - an inlet (10) for sucking air (HOT AIR) from exterior of the train car (4) ;
 - a refrigerant circuit (7) having:
 - a first heat exchanger (12, 12s) operating as an evaporator when the train car (4) runs in a tunnel (3),
 - a second heat exchanger (16, 16s) operating as a condenser when the train car (4) runs in a tunnel (3),
 - an expansion device (29, 29s) which permits the expansion of the condensed fluid by the second heat exchanger (16, 16s), and
 - a compressor (25, 25s);
 - an outlet (13) for cooled air supplied to the exterior of the train car (4) in the tunnel (3);
 - a fan (50) coupled with the first heat exchanger (12, 12s) and blowing the sucked air passed through the first heat exchanger (12, 12s) from the inlet (10) towards the outlet (13); and
 - a heat collector (20) that receives air passing through the second heat exchanger (16, 16s) and stores the received thermal energy.
2. An air-conditioning unit as defined in claim 1, wherein the refrigerant circuit (7) is designed to switch between two alternative operation modes and has:
 - a four-way valve (24) that is alternatively placed in a first working position on a first operation mode wherein the first heat exchanger (12) operates as an evaporator and the second heat exchanger (16) operates as a condenser, or a second working position on a second operation mode wherein the first heat exchanger (12) operates as a condenser, the second heat exchanger (16) operates as an evaporator, and the heat collector (20) is regenerated by cooled air through the second heat exchanger (16); and
 - a second expansion device (33) which permits the expansion of the condensed fluid by the first heat exchanger (12) in the second operation mode.
3. An air-conditioning unit as defined in claim 2, wherein the expansion devices comprise respectively first and second expansion valves; in the first operation mode the first expansion valve (29) is opened and the second expansion valve (33) is closed, and in the second operation mode the first expansion valve (29) is closed and the second expansion valve (33) is opened.
4. An air-conditioning unit as claimed in claim 1, wherein the refrigerant circuit (7) is designed to switch between two alternative operation modes:
 - (i) a first operation mode that is performed when the train car (4) is in the tunnel (3); the first heat exchanger (12) operates as an evaporator for cooling the air that is sucked from the exterior of the train car (4) and is returned as cooled air into the tunnel (3); and the second heat exchanger (16) operates as a condenser; and
 - (ii) a second operation mode that is performed when the train car (4) is outside of the tunnel (3); the second heat exchanger (16) operates as an evaporator for cooling the air that is sucked from the exterior of the train car (4) and blown by a second fan (51) towards the heat collector (20); and the first heat exchanger (12) operates as a condenser.
5. An air-conditioning unit (1) as defined in claim 1, wherein the heat collector (20) is designed to be replaced after use and may be alternatively placed with respect to a train body:
 - in a first working position where the heat collector (20) is placed in the train car (4) where it receives the air passing through the second heat exchanger (16s); and
 - in a second discharge position where the heat collector (20) is extracted from the train body to be substituted with a new heat collector (20).
6. An air-conditioning unit (1) as defined in any of the preceding claims 1-5, wherein the heat collector (20) contains a phase changing material that stores the received heat energy changing its state.

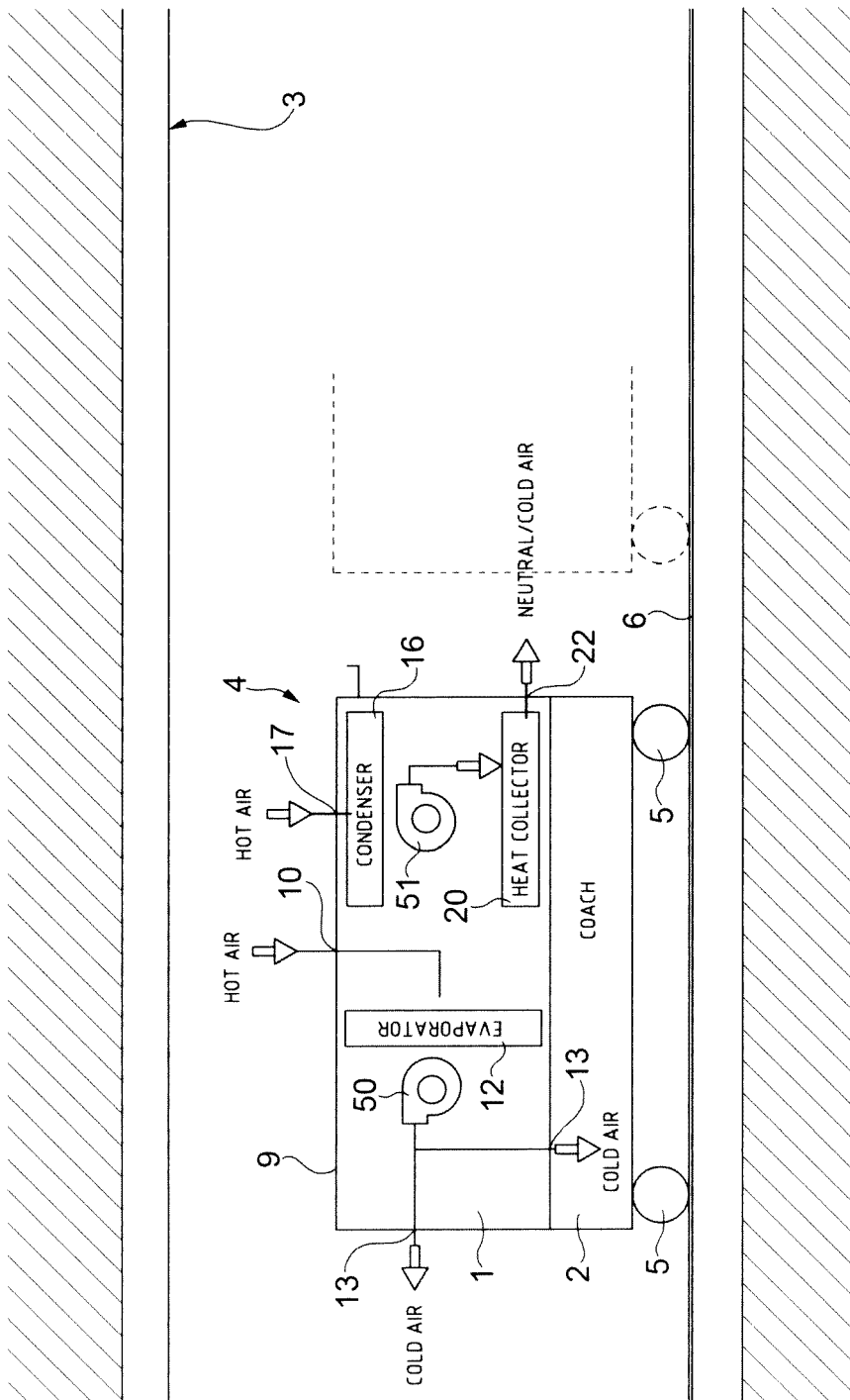


FIG. 1

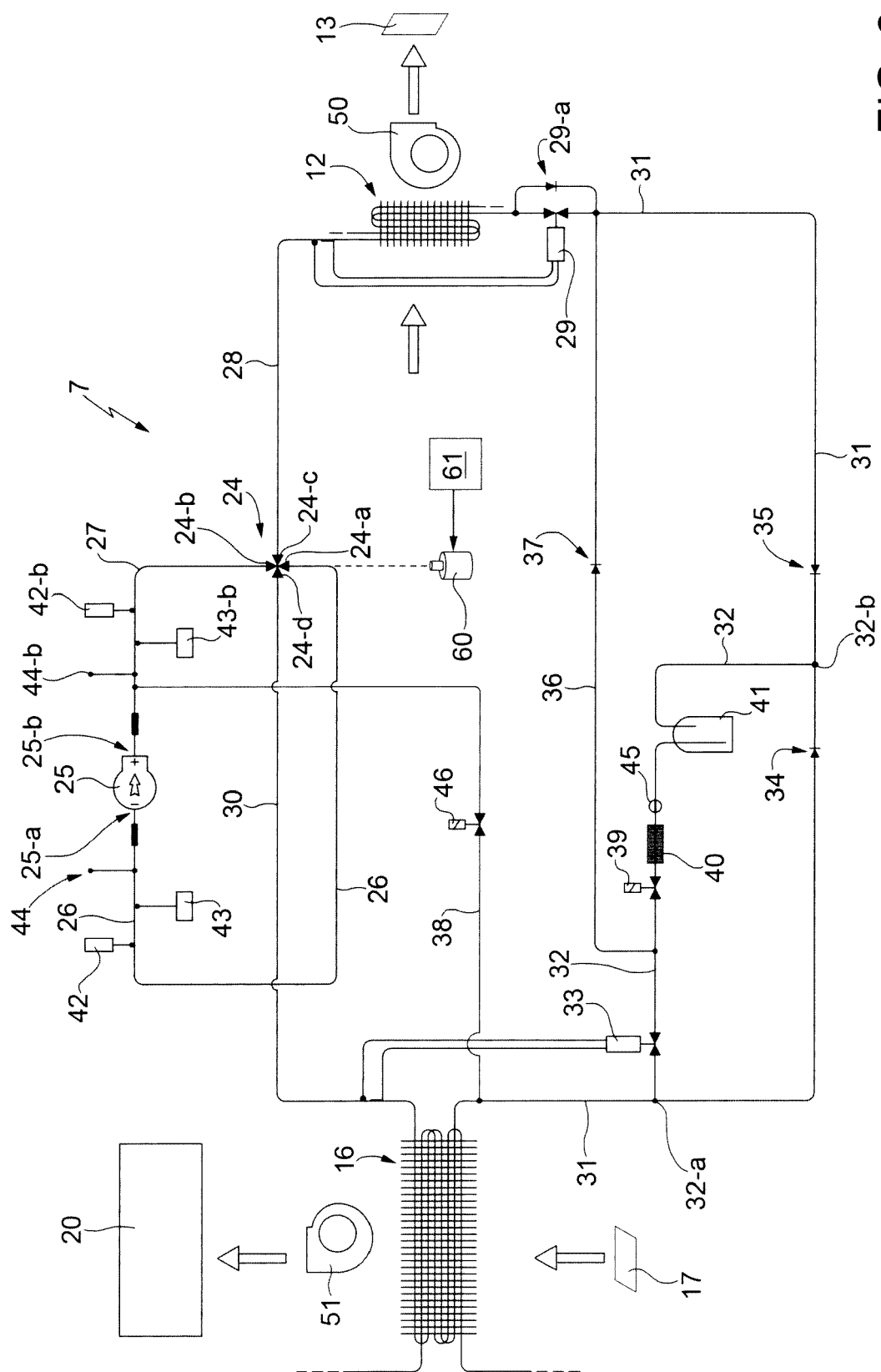


FIG. 2

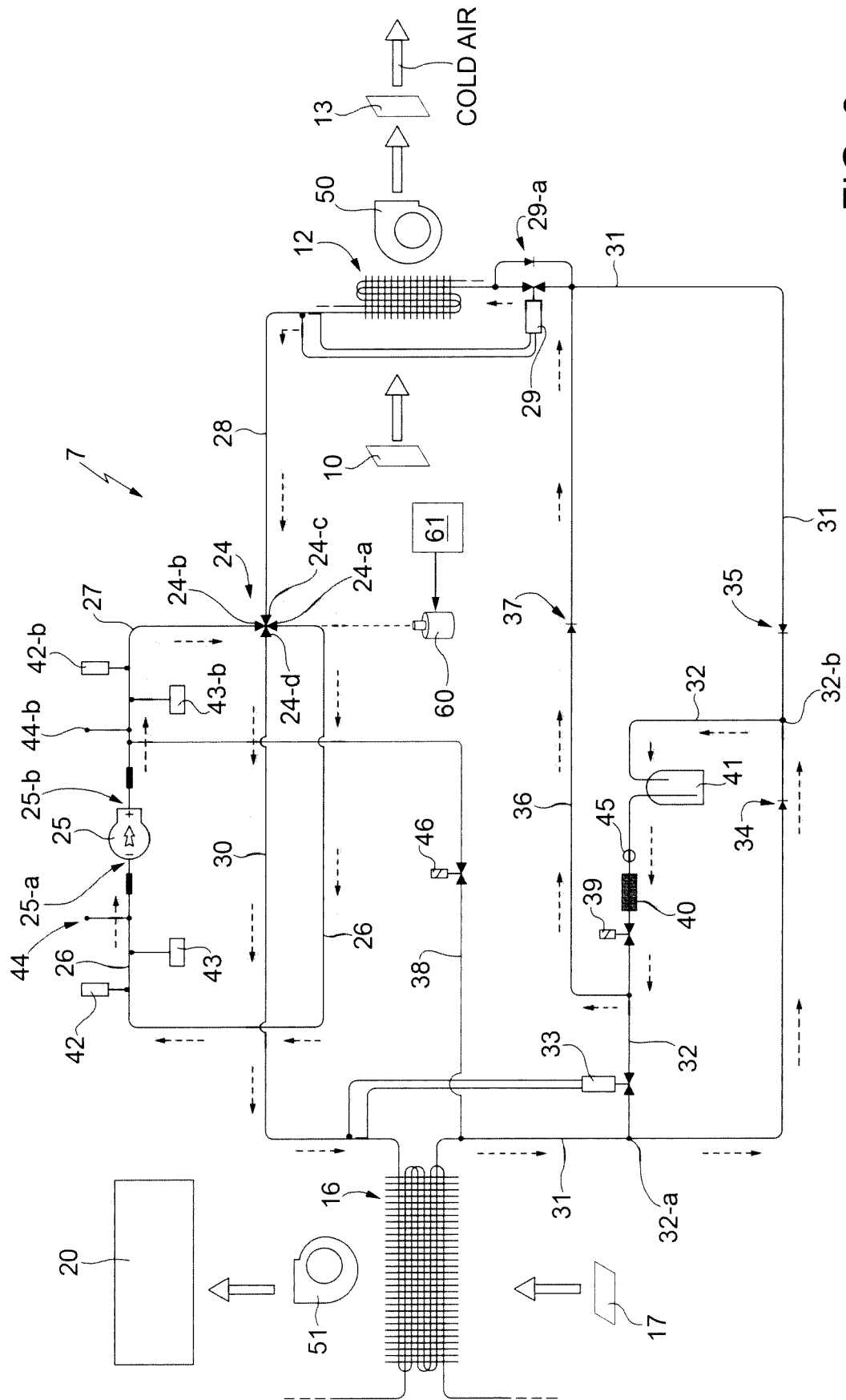


FIG. 3

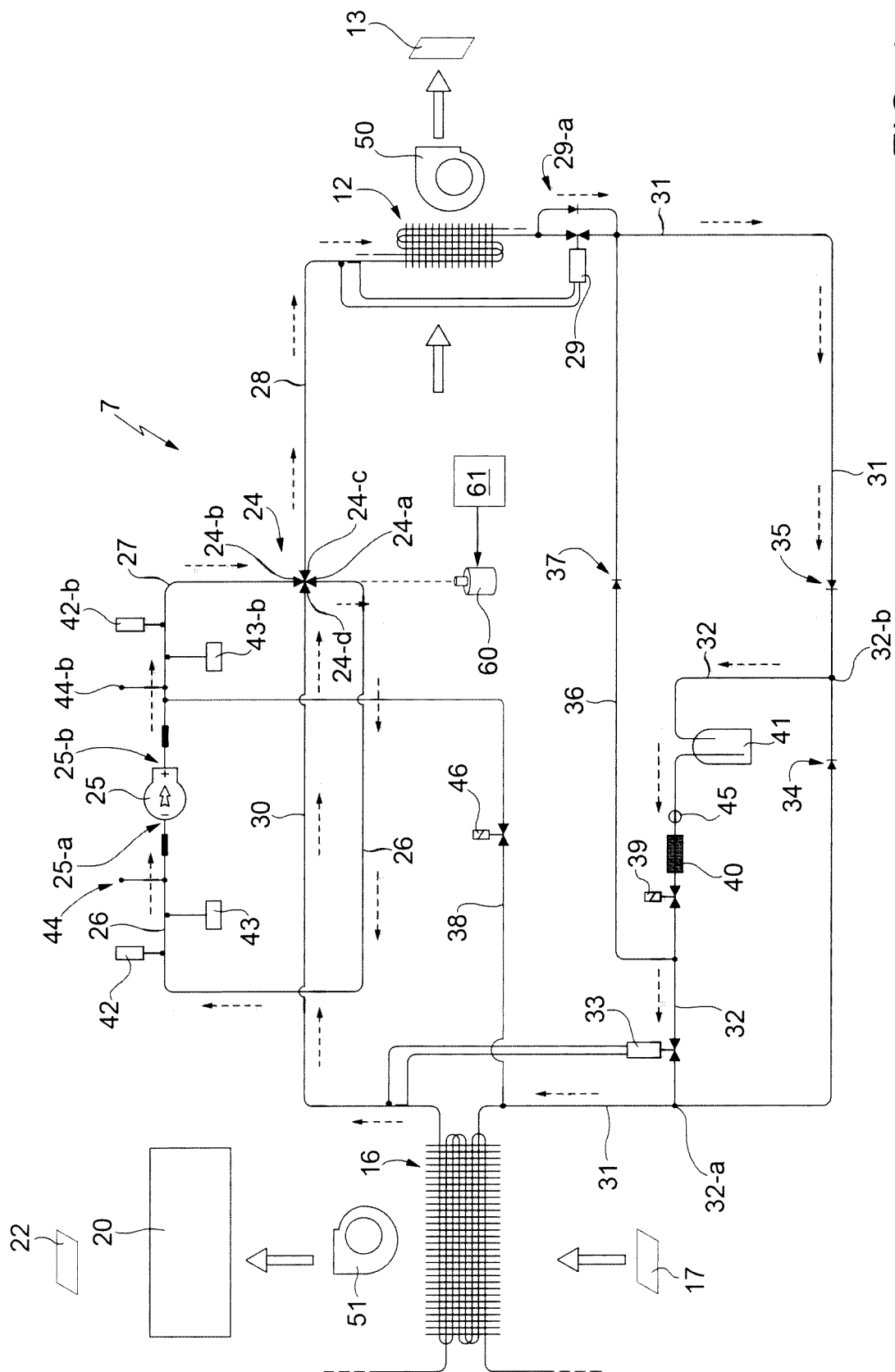


FIG. 4

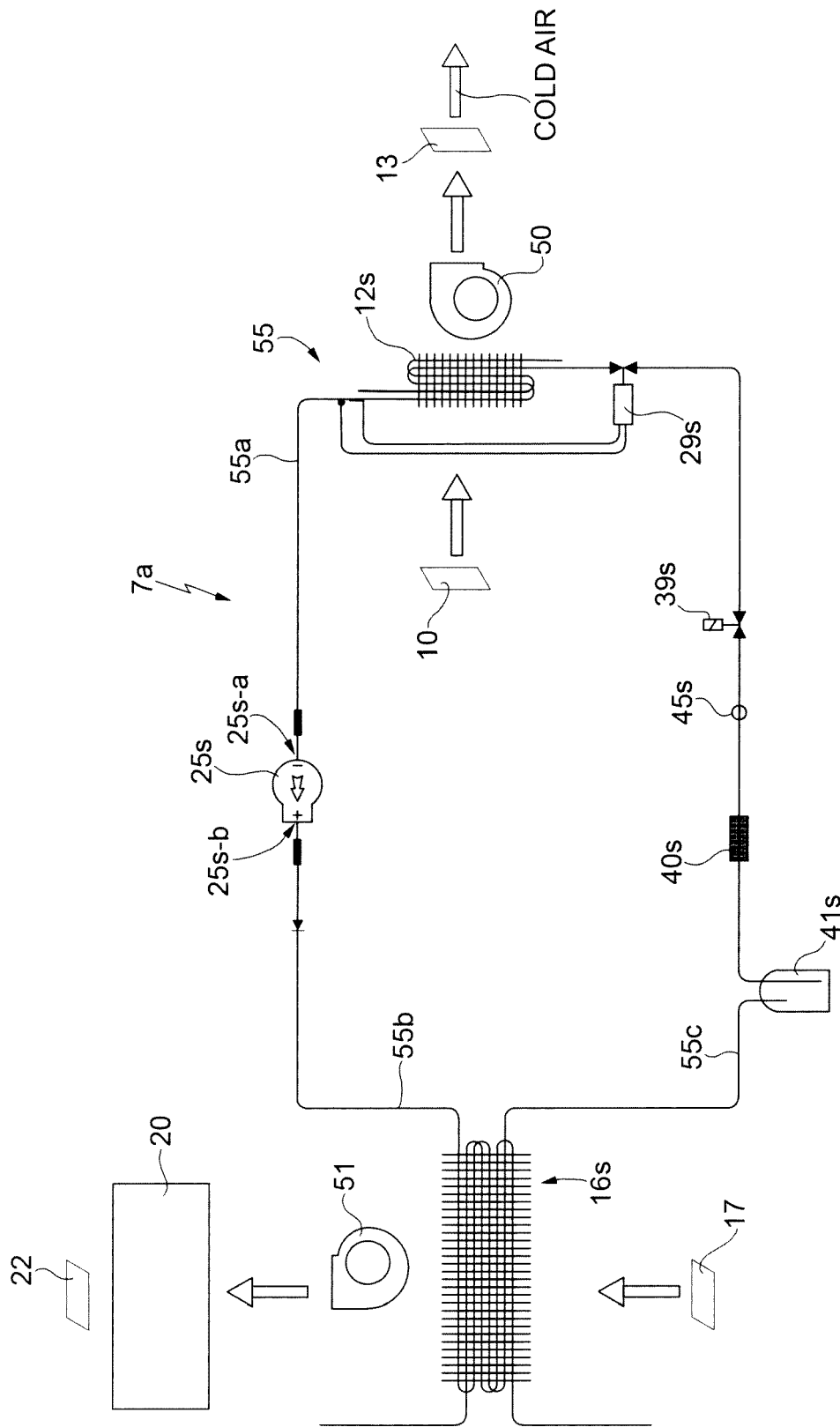


FIG. 5



EUROPEAN SEARCH REPORT

Application Number
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