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(54) HVAC SYSTEM, METHOD FOR OPERATING AN HVAC SYSTEM AND RAIL VEHICLE

(57) HVAC system, particularly for a rail vehicle, comprising the components:
- a condenser
- an expansion valve,
- an evaporator,
- a compressor,
- wherein the components are connected by cooling circuit tubes and arranged in this sequence in a closed cooling fluid loop,
- a flammable refrigerant is circulating in the closed cooling fluid loop and
- a fire extinguishing system comprising a fire extinguishing circuit with a fire extinguishing fluid, wherein the fire extinguishing circuit runs along the closed cooling fluid loop.

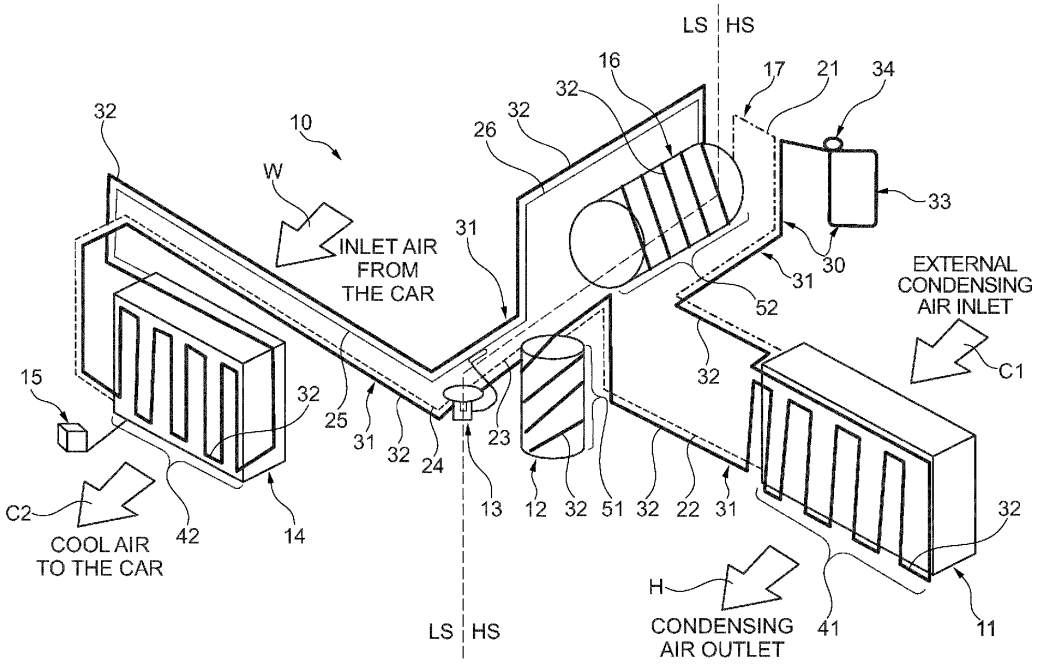

Fig. 1

EP 3 974 032 A1

Description

[0001] The present invention relates to an HVAC system, a method for operating an HVAC system and a rail vehicle with an HVAC system.

[0002] The railway field is very sensible to smoke and fire issues due to historical reasons.

[0003] All regions are subject to dedicated standards such as the EN45545 in Europe the ASTM E662-09 in the U.S. or the GOST 12.1.004-91 in Russia. All substances must be certified as not flammable with a low index of smoke, and if it is flammable the admissible quantities are very limited. When there is a possible source of fire it must be protected with a high-level security device, an example is represented by heaters protected by two independent protection devices. On the other hand, the global warming is pushing the air-conditioning and refrigeration world versus a reduction of Global Warming Potential (GWP) refrigerants. Following this direction in the past years Hydrofluoroolefin (HFO) and natural gas were increasingly considered. But sometimes this evolution introduces additional issues related to new technologies, additional weight, cost, or risk related to flammability. The gas regulation is imposing a progressing reduction of Hydrofluorocarbon (HFC) introduced in the market starting from Europe to the U.S./Australia and Asia.

[0004] Today, existing Heating, Ventilation Air Conditioning (HVAC) systems in the market are charged by HFC such as R407C and R134a but, to reduce the impact in term of overhaul, some drop-in refrigerants as R513a and R450a are used. For the future, the alternatives are natural gas and HFO but with some inconveniences. The CO2 cycle is used in a trans critical way and works with high pressures. The CO2 cycle is disadvantageous in direct cycle with high external conditions and has an unfavourable weight/cost impact. The alternative is represented by HFO such as 1234yf that is classified A2L and Propane classified A3 for flammability. The advantage of HFO for the railway market is that it is possible to fill it in an HVAC system instead of R134a with small modifications on the cooling circuit and with a good alignment in terms of cooling capacity. The advantage of Propane is that it is a natural gas and it is very efficient for high external temperatures as well as for low temperatures in a heat pump mode. This aspect is very important considering that the HVAC system is in second place in terms of energy consumption onboard a train. Moreover, smoke produced by burnt gas is not toxic. The problem now is how an HVAC system can be used with HFO or Propane without any risk for the passengers.

[0005] Usually, a cooling circuit of an HVAC is welded even if some demountable parts are present such as pressure sensors or Rotalock demountable compressors. In any case the cooling circuit is sealed and tested with nitrogen under high pressure and the leakages are treated with corrective maintenance. A cooling circuit charged with propane will be dangerous if in presence of leakage the fluid gets in contact with a temperature of 455°C. In normal conditions, only heaters present in the HVAC can pass a temperature of 300°C but the temperature will not pass 400°C. A similar condition is known for 1234YF having a burning point at 405°C

[0006] In the field of railways, nozzles are used to spray water in a passenger saloon and a driver's cab from the ceiling. However, this solution is not applicable inside an HVAC because the fire can start from different directions. Water cannot be used because there are electrical devices inside the HVAC. In addition, due to the toxicity of the smoke produced by burning HFO it is needed to stop the burning quickly.

[0007] Document JP2015156947A discloses an electrical cabinet of a rail vehicle, where a fuse tube is used. The fuse tube includes a fire extinguishing fluid compatible with the presence of electricity. The fuse tube is connected to a reservoir charged with the fire extinguishing fluid such as Nitrogen. The fuse tube is flame sensitive to permit extinguishing the fire in a zone where the fire originated. The fuse tube can be combined with a switch permitting to send signals when the device is activated by a decreasing pressure.

[0008] The technical problem underlying the present invention consisted in developing an HVAC system, a method for operating an HVAC system and a rail vehicle with an HVAC system, wherein the HVAC system has a flammable refrigerant and a fire extinguishing system.

[0009] The technical problem outlined above is solved by the HVAC system according to claim 1, the method for operating an HVAC system defined in claim 8 and the rail vehicle with an HVAC system defined in claim 15. The dependent claims define further developments of the invention.

[0010] An inventive HVAC system, particularly for a rail vehicle, comprises the components:

- a condenser
- an expansion valve,
- an evaporator,
- a compressor,
- wherein the components are connected by cooling circuit tubes and arranged in this sequence in a closed cooling fluid loop,
- a flammable refrigerant is circulating in the closed cooling fluid loop and
- a fire extinguishing system comprising a fire extinguishing circuit with a fire extinguishing fluid, wherein the fire extinguishing circuit runs along the closed cooling fluid loop.

[0011] The advantage of the inventive solution is that

a flammable refrigerant with a low global warming potential (GWP), e.g. Propane (R290) or HFO (e.g.1234YF), can be used in a railway HVAC protected by a fire extinguishing system. Only in the presence of fire the fire extinguishing system is activated at a location where the fire started. The fire extinguishing fluid is then expelled from the fire extinguishing circuit and stops the fire.

[0012] According to the present invention

- the fire extinguishing circuit can be wound in a helix around the outside of the compressor and/or a receiver drier of the HVAC system and/or
- the fire extinguishing circuit can run along the cooling circuit tubes, particularly along upper parts of the cooling circuit tubes.

[0013] The use of such a special geometry and accommodation of the fire extinguishing circuit permits to cover a part of the surface of the compressor and/or the receiver drier and/or the cooling circuit tubes, respectively. The airflow direction and the characteristics of the closed cooling fluid loop are considered. Thus, the fire extinguishing circuit protects the outer surfaces of the compressor and/or the receiver drier and/or the cooling circuit tubes.

[0014] Advantageously,

- the fire extinguishing circuit forms serpentines parallel to the cooling circuit tubes of the evaporator and/or the condenser and/or
- the fire extinguishing circuit forms a grid parallel to the cooling circuit tubes of the evaporator and/or the condenser.

[0015] The use of such a special geometry and accommodation of the fire extinguishing circuit permits to cover the cooling circuit tubes of the evaporator and/or the condenser. The airflow direction and the characteristics of the closed cooling fluid loop are considered. The serpentines and/or the grid ensure that the evaporator and/or the condenser is/are protected by the fire extinguishing circuit.

[0016] Preferably,

- the fire extinguishing circuit comprises a fuse tube that runs along the closed cooling fluid loop,
- the fuse tube has a melting point at a predetermined temperature,
- the fuse tube is connected to a fire extinguisher fluid tank, both filled and pressurized with the fire extinguishing fluid.

[0017] Such a fuse tube along the closed cooling fluid loop provides efficient fire protection of the components of the HVAC system.

[0018] The extinguisher fluid tank can have a pressure sensor and/or the extinguisher fluid tank can be installed in a region between the compressor and the condenser. The pressure sensor of the extinguisher fluid tank is for communication with an HVAC controller. The fire extinguisher fluid tank is charged with the fire extinguishing fluid can be installed between the compressor and the condenser because often there is available space.

[0019] The HVAC system may have a gas sensor and/or a smoke sensor for a fire alarm.

[0020] The HVAC system preferably has a manual button for discharging the fire extinguishing fluid, particularly for separately sprinkling each component of the HVAC and/or specific locations of the cooling circuit tubes, especially with foam. If the fuse tube does not react on a fire at the HVAC system, it can be replaced by sprinkling foam. If the fuse tube does not react fast enough or not efficient enough it can be supported by sprinkling foam.

[0021] An inventive method for operating an HVAC system, wherein the method is activated in case of a fire and comprises

- stopping the fire by a fire extinguishing fluid streaming out of the fire extinguishing means,
- stopping ventilation and
- opening a fresh air flap of the HVAC system.

[0022] This method efficiently stops or avoids an increase of a fire by using the fire extinguishing means, the ventilation and the fresh air flap of an HVAC. The fresh air flap is opened such that smoke can exit from the HVAC system.

[0023] The method can be activated by a pressure switch and/or by the pressure sensor when the fire extinguishing fluid is streaming out of the fire extinguishing circuit. The pressure sensor will send a message to an HVAC controller to indicate a possible problem before the pressure switch application. Only if the tube is fused, the pressure switch will be activated.

[0024] Furthermore, the fire extinguishing fluid streams out of the fire extinguishing circuit at a location where the fire started. This allows for targeted stopping of the fire.

[0025] Preferably, a recycled air flap of the HVAC system is closed to prevent smoke from entering a passenger or driver's area.

[0026] The fresh air flap and/or the recycled air flap may each be driven by a spring servomotor and in case of missing voltage and/or a missing signal from an HVAC controller the fresh air flap is opened and/or the recycled air flap is closed. Usually the servomotors are controlled by an HVAC controller. In case of missing voltage, e.g. because of a broken cable, or in case of a missing signal, e.g. if the HVAC controller is defect, the flap position will be set open for the fresh air and closed for the recycled

air. The method can thus be activated by the cabling to avoid fire oxygenation. The method will be performed at wiring level with reversed logic to permit to have a good Security Integrity Level (SIL). This results in a security by wiring, not by software.

[0027] Advantageously, the pressure sensor is connected to an HVAC controller of the HVAC system and sends a message to the HVAC controller of the HVAC system to indicate a fire and activate the method. The pressure sensor can be easily installed and indicates a pressure decrease in the fuse tube.

[0028] Moreover, the HVAC system can comprise electrical heaters which are excluded from the cooling circuit tubes and the fire extinguishing circuit such that the method is not activated by a heat of the electrical heaters. Thus, the method is adaptable to a present electrical device.

[0029] An inventive rail vehicle comprises an HVAC system, wherein the HVAC controller is particularly connected to a Train Control Management System (TCMS). In this case the signal from the HVAC controller can be sent to the TCMS. The HVAC controller is used to signal the presence of fire in the HVAC via TCMS. The pressure sensor is present close to a receiver and sends a message to the HVAC controller to indicate a possible problem before the pressure switch application.

[0030] Further features, characteristics and advantages of the invention will become clear from the following description of one specific embodiment of the invention represented in the accompanying drawing.

Fig. 1 shows a diagrammatic perspective view of an inventive HVAC system according to one embodiment, and

Fig. 2 shows a flow diagram for a signal transmission of an inventive HVAC system.

[0031] Figure 1 shows an inventive HVAC system 10 with a fire extinguishing system 30.

[0032] The HVAC system comprises a condenser 11, an optional receiver drier 12, an expansion valve 13, an evaporator 14, a thermostat 15, and a compressor 16 as components of the HVAC system. There can be more than one of each component in the HVAC system. The HVAC system has a high side HS and a low side LS. The receiver drier 12 can be omitted. If the receiver drier 12 is present, there is large volume of a refrigerant inside the receiver drier 12. Thus, the receiver drier 12 is especially at risk in terms of flammability.

[0033] The HVAC system has a closed cooling fluid loop 17, where an HVAC fluid circulates. The closed cooling fluid loop 17 starts at the compressor 16 which is connected to the condenser 11 by a first cooling circuit tube 21. The condenser 11 is connected to the receiver drier 12 by a second cooling circuit tube 22. The receiver drier 12 is connected to the evaporator 14 by a third cooling circuit tube 23 and a fourth cooling circuit tube 24. The evaporator 14 is connected to the compressor 16 by a fifth cooling circuit tube 25 and a sixth cooling circuit tube 26. The expansion valve 13 is located between the third cooling circuit tube 23 and the fourth HVAC 24 tube. The expansion valve 13 is also located between the fifth cooling circuit tube 25 and the sixth cooling circuit tube 26.

[0034] The first cooling circuit tube 21, the condenser 11, the second cooling circuit tube 22, the receiver drier 12, and the third cooling circuit tube 23 are located on the high side HS of the HVAC system 10. The fourth cooling circuit tube 24, the evaporator 14, the fifth cooling circuit tube 25, the sixth cooling circuit tube 26, and the compressor 16 are located on the low side LS of the HVAC system.

[0035] The fire extinguishing system 30 comprises a fire extinguishing circuit 31 and a fire extinguisher fluid tank 33 with a pressure sensor 34. The fire extinguishing circuit 31 has fuse tubes 32 which run along the closed cooling fluid loop 17 of the HVAC system 10. The fire extinguishing circuit 31 comprises a first serpentine 41 of fuse tubes 32 at the condenser 11 and a second serpentine 42 of fuse tubes 32 at the evaporator 14. A fuse tube 32 is wound around the receiver drier 12 in a first helix 51. Another fuse tube 32 is wound around the compressor 16 in a second helix 52. The fuse tube 32 has a material with a predefined melting temperature.

[0036] Air from an external condensing air inlet C1 is heated in the condenser 11. The heated air from the condenser 11 flows through a condensing air outlet H. Inlet air W, e.g. from a car or passenger area, respectively (not shown) of a rail vehicle (not shown) is cooled in the evaporator 14 and exits from the evaporator 14 as cool air C2 to the car or passenger area, respectively.

[0037] Fig. 2 shows a flow diagram for a signal transmission. A pressure sensor and a pressure switch are connected to an HVAC controller. The HVAC controller can be connected to a TCMS of a rail vehicle (not shown).

[0038] In operation, the fire extinguisher fluid in the fuse tube 32 and the fire extinguisher fluid tank 33 are pressurised. The fire extinguisher fluid can be e.g. Nitrogen. The fuse tube 32 is flame sensitive. In case of a fire in the HVAC system 10 the fuse tube 32 melts in a zone where the fire started.

[0039] If the pressure in the fire extinguisher fluid tank decreases the pressure sensor sends a signal to the HVAC controller. If the HVAC system is part of a TCMS of a rail vehicle (not shown) the HVAC controller sends a signal to the TCMS.

[0040] In addition, ventilation can be stopped by opening a fresh air flap (not shown) of the HVAC system 10. The fresh air flap is activated by the pressure switch. Furthermore, a recycled air flap (not shown) of the HVAC system 10 can be closed by the pressure switch. The recycled air flap is in communication with e.g. the passenger area of the rail vehicle so in case of fire this will limit an introduction of smoke in the passenger area.

[0041] The fresh air flap and the recycled air flap are

each driven by a spring servomotor (not shown). If a voltage for the servomotor is missing, e.g. because a cable (not shown) is broken, the fresh air flap is opened and/or the recycled air flap is closed. If a signal is missing, e.g. because the HVAC controller is broken, the fresh air flap is opened and/or the recycled air flap is closed as well.

[0042] If the HVAC system 10 comprises an electrical heater (not shown) there will be no fuse tube 32 in a region of the electric heater.

[0043] Existing HVAC systems can be retrofitted with the fire extinguishing system 30.

Reference List

[0044]

10	HVAC system
11	Condenser
12	Receiver drier
13	Expansion valve
14	Evaporator
15	Thermostat
16	Compressor
17	Closed cooling fluid loop
21	First cooling circuit tube
22	Second cooling circuit tube
23	Third cooling circuit tube
24	Fourth cooling circuit tube
25	Fifth cooling circuit tube
26	Sixth cooling circuit tube
30	Fire extinguishing system
31	Fire extinguishing circuit
32	Fuse tube
33	Fire extinguisher fluid tank
34	Pressure sensor
41	First serpentine
42	Second serpentine
51	First helix
52	Second helix
C1	External condensing air inlet
H	Condensing air outlet
W	Inlet air
C2	Cool air
HS	High side
LS	Low side

Claims

1. HVAC system (10), particularly for a rail vehicle, comprising the components:

   - a condenser (11)
   - an expansion valve (13),
   - an evaporator (14),
   - a compressor (16),
   - wherein the components are connected by cooling circuit tubes (21, 22, 23, 24, 25,26) and arranged in this sequence in a closed cooling fluid loop (17),
   - a flammable refrigerant is circulating in the closed cooling fluid loop (17) and
   - a fire extinguishing system (30) comprising a fire extinguishing circuit (31) with a fire extinguishing fluid, wherein the fire extinguishing circuit (31) runs along the closed cooling fluid loop (17).

2. HVAC system (10) according to claim 1, wherein

   - the fire extinguishing circuit (31) is wound in a helix (51, 52) around the outside of the compressor (16) and/or a receiver drier (12) of the HVAC system and/or
   - the fire extinguishing circuit (31) runs along the cooling circuit tubes (21, 22, 23, 24, 25,26), particularly along upper parts of the cooling circuit tubes (21, 22,23, 24, 25, 26).

3. HVAC system (10) according to claim 1 or 2, wherein

   - the fire extinguishing circuit (31) forms serpentines (41, 42) parallel to the cooling circuit tubes (21, 22, 23, 24, 25,26) of the evaporator (14) and/or the condenser (11) and/or
   - the fire extinguishing circuit (31) forms a grid parallel to the cooling circuit tubes (21, 22, 23, 24, 25,26) of the evaporator (14) and/or the condenser (11).

4. HVAC system (10) according to any of the preceding claims, wherein

   - the fire extinguishing circuit (31) comprises a fuse tube (32) that runs along the closed cooling fluid loop (17),
   - the fuse tube (32) has a melting point at a predetermined temperature,
   - the fuse tube (32) is connected to a fire extinguisher fluid tank (33), both filled and pressurized with the fire extinguishing fluid.

5. HVAC system (10) according to claim 4, wherein the extinguisher fluid tank (33) has a pressure sensor (34) and/or the extinguisher fluid tank (33) is installed in a region between the compressor (16) and the condenser (11) .

6. HVAC system (10) according to any of the preceding claims, wherein the HVAC system (10) has a gas sensor and/or a smoke sensor.

7. HVAC system (10) according to any of the preceding claims, wherein the HVAC system (10) has a manual button for discharging the fire extinguishing fluid, particularly for separately sprinkling each component of

the HVAC and/or specific locations of the cooling circuit tubes (21, 22, 23, 24, 25,26), especially with foam.

8. Method for operating an HVAC system (10) according to claims 1 to 7, wherein the method is activated in case of a fire and comprises

- stopping the fire by a fire extinguishing fluid streaming out of the fire extinguishing system (30),
- stopping ventilation and
- opening a fresh air flap of the HVAC system (10).

9. Method according to claim 8, wherein the method is activated by a pressure switch and/or by the pressure sensor (34) when the fire extinguishing fluid is streaming out of the fire extinguishing circuit (31).

10. Method according to claim 8 or 9, wherein the fire extinguishing fluid streams out of the fire extinguishing circuit (31) at a location where the fire started.

11. Method according to any of claims 8 to 10, wherein a recycled air flap of the HVAC system (10) is closed.

12. Method according to any of claims 8 to 11, wherein the fresh air flap and/or the recycled air flap are each driven by a spring servomotor and in case of missing voltage and/or a missing signal from an HVAC controller the fresh air flap is opened and/or the recycled air flap is closed.

13. Method according to any of claims 8 to 12, wherein the pressure sensor (34) is connected to an HVAC controller of the HVAC system (10) and sends a message to the HVAC controller of the HVAC system (10) to indicate a fire and activate the method.

14. Method according to any of claims 8 to 13, wherein the HVAC system (10) comprises electrical heaters which are excluded from the cooling circuit tubes (21, 22, 23, 24, 25, 26) and the fire extinguishing circuit (31) such that the method is not activated by a heat of the electrical heaters.

15. Rail vehicle with an HVAC system (10) according to any of claims 1 to 7, wherein the HVAC controller is particularly connected to a Train Control Management System (TCMS).

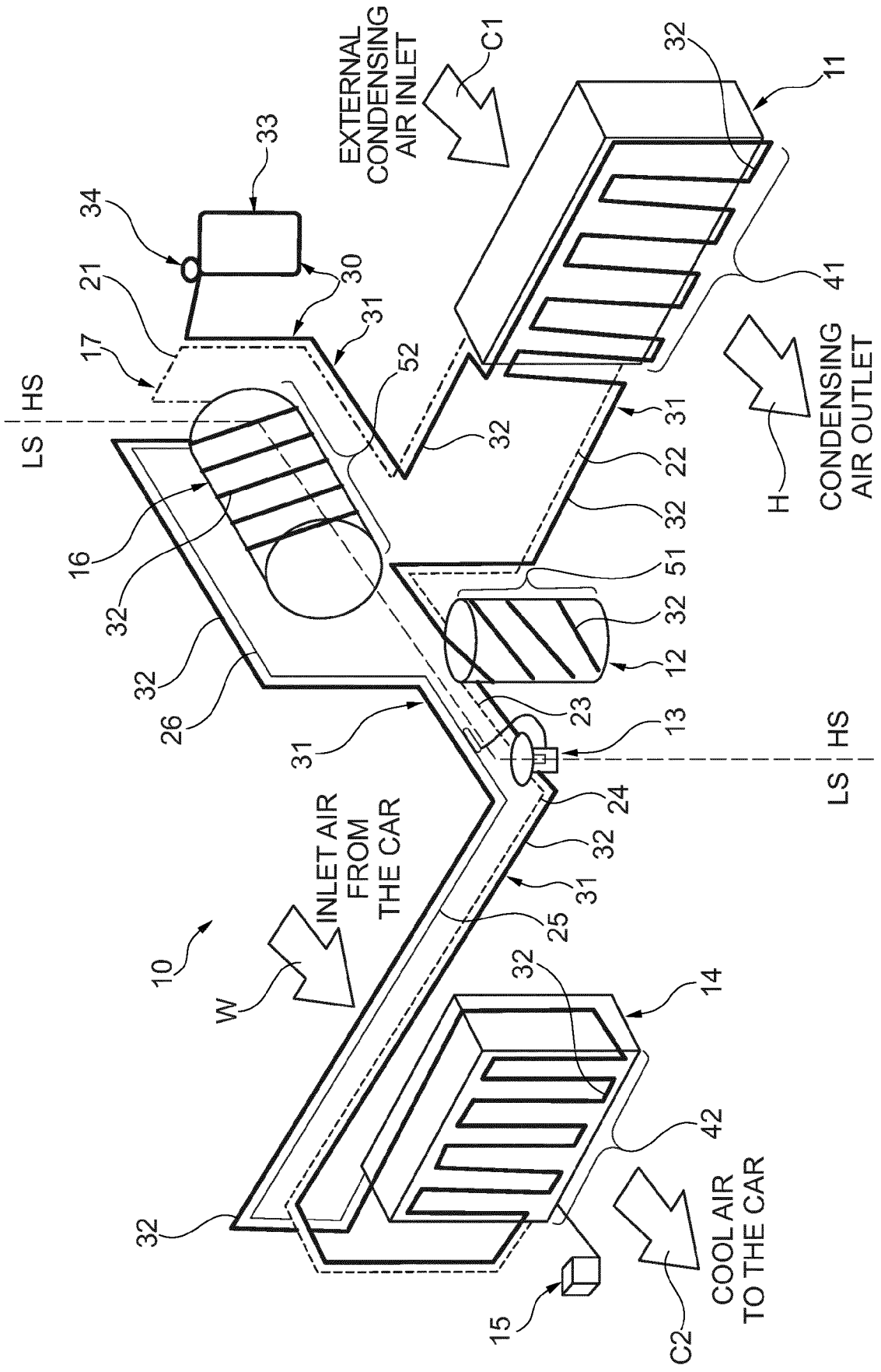
EXTERNAL CONDENSING AIR INLET
C1
11
32
33
34
21
17
30
31
52
LS
HS
41
CONDENSING AIR OUTLET
H
22
51
16
12
23
13
26
24
INLET AIR FROM THE CAR
W
10
25
14
42
COOL AIR TO THE CAR
C2
15

Fig. 1

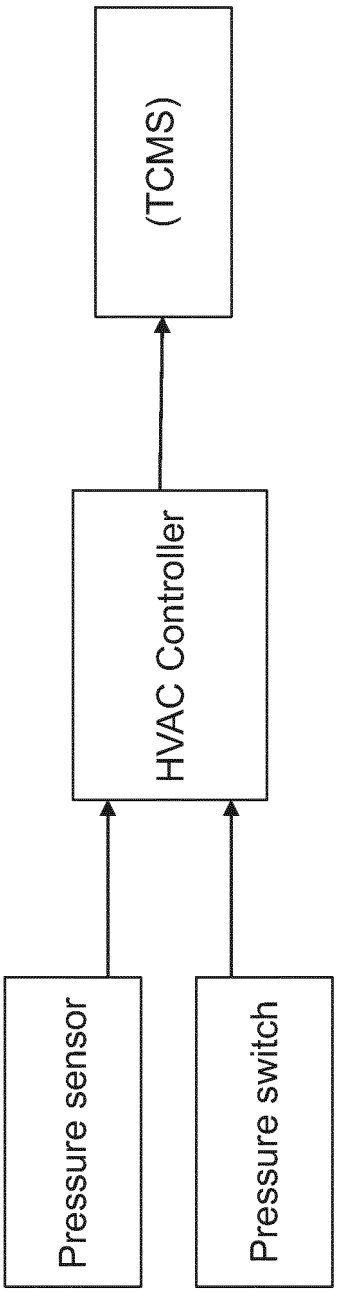

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 20 19 8160

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2020/129796 A1 (BOGART JAMES E [US] ET AL) 30 April 2020 (2020-04-30)	1-3,6-14	INV.
			A62C3/06
A	* figures 1,2 *	4,5	A62C3/07
	* paragraph [0025] - paragraph [0030] *		A62C35/60
	* paragraph [0040] - paragraph [0045] *		A62C37/12

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TECHNICAL FIELDS SEARCHED (IPC)

A62C
B61D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	23 March 2021	Cardin, Aurélie

CATEGORY OF CITED DOCUMENTS

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23-03-2021

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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