

(43) International Publication Date
28 September 2017 (28.09.2017)

(51) International Patent Classification:

B60H 3/06 (2006.01) *B60H 1/00* (2006.01)
B01D 53/04 (2006.01)

(21) International Application Number:

PCT/EP2017/056956

(22) International Filing Date:

23 March 2017 (23.03.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1605052.8 24 March 2016 (24.03.2016) GB

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Warwickshire CV3 4LF (GB).(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN,
KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA,
MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG,
NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS,
RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY,
TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN,
ZA, ZM, ZW.(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: VEHICLE AIR TREATMENT SYSTEM WITH FILTER REGENERATION AND HEAT RECLAMATION

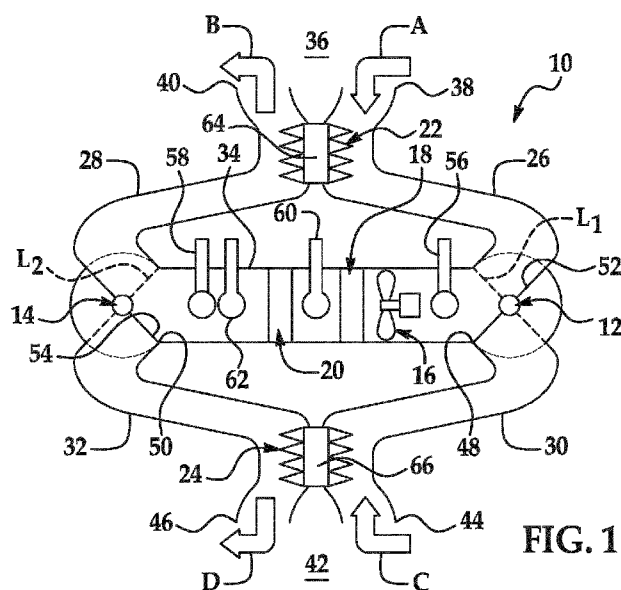


FIG. 1

(57) Abstract: A vehicle air treatment system (10)
with filter regeneration and heat reclamation. The
vehicle air treatment system (10) includes an inside
air inlet (38), an inside air outlet (40), an outside
air inlet (44), an outside air outlet (46), one or
more regenerable filters (20), one or more first heat
reclamation means (22), and one or more second
heat reclamation means (24). In an air treatment
mode of operation, heat yielded as air filters
through the regenerable filter(s) (20) is transferred
to air that enters the inside air inlet (38) via the
first heat reclamation means (22). And, in a filter
regeneration mode of operation, heat advancing to-
ward the outside air outlet (46) is transferred to air
that enters the outside air inlet (44) via the second
heat reclamation means (24).

VEHICLE AIR TREATMENT SYSTEM WITH FILTER REGENERATION AND HEAT RECLAMATION

TECHNICAL FIELD

5 The present disclosure relates generally to a vehicle air treatment system with filter regeneration and heat reclamation, and more particularly, but not exclusively, to a vehicle air treatment system that reclaims heat yielded when air is filtered and that reclaims heat remaining after a filter is regenerated. Aspects of the invention relate to a system, to a vehicle, and to a method.

BACKGROUND

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Vehicles such as automobiles are sometimes equipped with air treatment systems having regenerable filters. One type of regenerable filter includes an adsorbent material used to scrub carbon dioxide (CO₂) from air of an automobile's interior cabin that passes through the adsorbent material. Heat has to be introduced into the adsorbent material in order to release
15 the scrubbed CO₂ and regenerate and restore the adsorbent material for continued use. Producing that heat, however, can add cost to the air treatment system, both in terms of pecuniary costs and energy consumption costs. The pecuniary costs can be the result of added complexity in an air treatment system. The energy consumption costs are perhaps observed most acutely in an electric vehicle.

20 Accordingly, one aim of the invention is to address the issues identified above, as well as address other possible issues that may arise.

SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a vehicle air treatment system, a method of treating air in a vehicle, and a vehicle as claimed in the appended claims.

25 According to an aspect of the invention, there is provided a vehicle air treatment system with filter regeneration and heat reclamation. The vehicle air treatment system may comprise an inside air inlet arranged to receive air from an interior cabin of a vehicle; an inside air outlet arranged to deliver air to the interior cabin; an outside air inlet arranged to receive air from outside the interior cabin; an outside air outlet arranged to deliver air to outside of the interior
30 cabin; at least one regenerable filter; and at least one heat reclamation means. The inside air inlet may receive air from an interior cabin of a vehicle, and the inside air outlet may deliver air to the interior cabin. The outside air inlet may receive air from outside of the

interior cabin, and the outside air outlet may deliver air to outside of the interior cabin. The at least one regenerable filter may be located downstream of the inside air inlet and upstream of the inside air outlet, or may be located downstream of the outside air inlet and upstream of the outside air outlet, or may be located both downstream of the inside air inlet and upstream of the inside air outlet and downstream of the outside air inlet and upstream of the outside air outlet. The at least one heat reclamation means may be situated downstream of the inside air inlet and upstream of the at least one regenerable filter, and may be situated upstream of the inside air outlet and downstream of the at least one regenerable filter and/ or the at least one heat reclamation means may be situated downstream of the outside air inlet and upstream of the at least one regenerable filter, and may be situated upstream of said outside air outlet and downstream of the at least one regenerable filter. The vehicle air treatment system may be operable in an air treatment mode of operation and/or in a filter regeneration mode of operation. In the air treatment mode of operation, heat yielded as air filters through the at least one regenerable filter may be transferred to air that enters the inside air inlet via the at least one heat reclamation means. In the filter regeneration mode of operation, heat advancing toward the outside air outlet may be transferred to air that enters the outside air inlet via the at least one heat reclamation means.

In an embodiment of the invention the vehicle air treatment system may comprise a first and a second heat reclamation means, wherein the first heat reclamation means is situated downstream of the inside air inlet and upstream of said at least one regenerable filter, the first heat reclamation means being situated upstream of the inside air outlet and downstream of the at least one regenerable filter and the second heat reclamation means being situated downstream of the outside air inlet and upstream of the at least one regenerable filter, the second heat reclamation means situated upstream of the outside air outlet and downstream of the at least one regenerable filter.

The vehicle air treatment system, as described above, minimizes pecuniary costs and energy consumption costs by reclaiming heat yielded during the air treatment mode and by reclaiming heat remaining during the filter regeneration mode of operation. The heat reclaimed during the air treatment mode of operation may be employed to optimize the filtering effect, and the heat reclaimed during the filter regeneration mode of operation may be utilized to reduce the amount of heat introduced for regeneration by a supplemental component such as a heater.

The first and second heat reclamation means may take different forms, including a heat exchanger, a reversible heat pump, shared passage walls, and/or a thermal energy storage

means. The heat exchanger, if employed, may be a shell-and-tube type heat exchanger, a plate type heat exchanger, or may be another type of heat exchanger. The thermal energy storage means, if employed, may include a phase-change material, may involve heat-capturing battery technologies, may be a piece of metal block, and/or may involve other types of thermal energy storage capabilities. Further, the thermal energy storage means may additionally or alternatively include a suitable state-change material.

According to an embodiment in accordance with the invention, there may be provided a heater that is located upstream of the at least one regenerable filter. The heater heats air during the filter regeneration mode of operation, and supplements heat transferred to air entering the outside air inlet by way of the second heat reclamation means.

According to an embodiment in accordance with the invention, there may be provided an air mover that may be located upstream of the at least one regenerable filter. The air mover propels air through the at least one regenerable filter when the vehicle air treatment system is operated in the air treatment mode of operation, in the filter regeneration mode of operation, or in both the air treatment and filter regeneration modes of operation.

According to an embodiment in accordance with the invention, there may be provided a first valve and a second valve. The first valve may be located downstream of the inside air inlet and downstream of the outside air inlet and upstream of the at least one regenerable filter. The first valve regulates air flow during the air treatment and filter regeneration modes of operation. The second valve may be located downstream of the at least one regenerable filter and upstream of the inside air outlet and upstream of the outside air outlet. The second valve regulates air flow during the air treatment and filter regeneration modes of operation.

According to an embodiment in accordance with the invention, the at least one regenerable filter may include a carbon dioxide (CO₂) adsorbent material.

According to an embodiment in accordance with the invention, the first reclamation means may include a first heat exchanger, and the second reclamation means may include a second heat exchanger. The first heat exchanger may be situated at least partly in an inside air inlet passage and at least partly in an inside air outlet passage. The second heat exchanger may be situated at least partly in an outside air inlet passage and at least partly in an outside air outlet passage.

According to an embodiment in accordance with the invention, the first heat reclamation means may include a first heat exchanger and a second heat exchanger. The first heat

exchanger may be situated in an inside air inlet passage and the second heat exchanger may be situated in an inside air outlet passage.

According to an embodiment in accordance with the invention, there may be provided a reversible heat pump configured to pump heat between the first heat exchanger and the second heat exchanger.

According to an embodiment in accordance with the invention, there may be provided an outside air inlet passage and an outside air outlet passage. The outside air inlet passage and the outside air outlet passage may share at least one wall—the passages can be concentric, for instance. The at least one wall is configured to transfer heat via thermal conduction from air flowing through the outside air outlet passage to air flowing through the outside air inlet passage during the filter regeneration mode of operation.

According to an embodiment in accordance with the invention, the at least one regenerable filter may include a first regenerable filter and a second regenerable filter. The first regenerable filter may be located in a first passage and the second regenerable filter may be located in a second passage.

According to an embodiment in accordance with the invention, the first heat reclamation means may include a first heat exchanger and a second heat exchanger. The first heat exchanger may be situated in an inside air inlet passage, and the second heat exchanger may be situated in an inside air outlet passage. The second heat reclamation means may include a first heat exchanger and a second heat exchanger. The first heat exchanger of the second heat reclamation means may be situated in an outside air inlet passage, and the second heat exchanger of the second heat reclamation means may be situated in an outside air outlet passage. A reversible heat pump may be provided, and may be configured to pump heat between the first heat exchanger and the second heat exchanger of the first heat reclamation means. The reversible heat pump may also be configured to pump heat between the first heat exchanger and the second heat exchanger of the second heat reclamation means.

According to an embodiment in accordance with the invention, the air treatment mode of operation may comprise a first and second air treatment mode of operation, and the filter regeneration mode of operation may comprise a first and second filter regeneration mode of operation. When the vehicle air treatment system is operated in the first air treatment mode of operation and the first filter regeneration mode of operation, the first regenerable filter may receive air flow from the inside air inlet, and treated air flow may exit the first regenerable

filter to the inside air outlet. The second regenerable filter may be regenerated by air flow received from the outside air inlet, and air flow downstream of the second regenerable filter may exit the vehicle air treatment system through the outside air outlet. At least a part of the first air treatment and first filter regeneration modes of operation may be carried out concurrently (e.g., at the same time). In the second air treatment mode of operation and the second filter regeneration mode of operation, the second regenerable filter may receive air flow from the inside air inlet, and treated air flow may exit the second regenerable filter to the inside air outlet. The first regenerable filter may be regenerated by air flow received from the outside air inlet, and air flow downstream of the first regenerable filter may exit the vehicle air treatment system through the outside air outlet. At least a part of the second air treatment and second regeneration modes may be carried out concurrently (e.g. at the same time).

According to an embodiment in accordance with the invention, the first heat reclamation means may include a first heat exchanger and a second heat exchanger. The first heat exchanger may be situated in an inside air inlet passage, and the second heat exchanger may be situated in an inside air outlet passage. The second heat reclamation means may include a first heat exchanger and a second heat exchanger. The first heat exchanger of the second heat reclamation means may be situated in an outside air inlet passage, and the second heat exchanger of the second heat reclamation means may be situated in an outside air outlet passage. A reversible heat pump may be provided, and may be configured to pump heat between the first heat exchanger and the second heat exchanger of the first heat reclamation means. The reversible heat pump may also be configured to pump heat between the first heat exchanger and the second heat exchanger of the second heat reclamation means.

According to an embodiment in accordance with the invention, there may be provided a thermal energy storage means configured to store excess heat from the first heat exchanger when the vehicle air treatment system is operated in the air treatment mode of operation. The thermal energy storage means may be configured to supply the stored excess heat to air that enters the outside air inlet when the vehicle air treatment system is operated in the filter regeneration mode of operation.

The thermal energy storage means, if employed, may include any one or more of: a phase-change material, heat-capturing battery technology, a piece of metal block, and/or any other types of thermal energy storage technology. Further, the thermal energy storage means may additionally or alternatively include a suitable state-change material.

According to an aspect of the invention, there is provided a vehicle that includes the vehicle air treatment system described herein.

According to an aspect of the invention, there is provided a method of treating air in a vehicle with filter regeneration and heat reclamation. The method involves moving air through a
5 regenerable filter in order to filter the air. The air is received from an inside air inlet before it is moved through the regenerable filter. The air exits toward an inside air outlet after moving through the regenerable filter. The method involves moving air through the regenerable filter in order to regenerate the regenerable filter. The air is received from an outside air inlet before moving through the regenerable filter. The air exits toward an outside air outlet after
10 moving through the regenerable filter. The method involves at least one of reclaiming heat from air exiting toward the outside air outlet to air entering the outside air inlet and reclaiming heat from air exiting toward said outside air outlet to air entering said outside air inlet.

According to an embodiment in accordance with the invention, reclaiming heat may involve exchanging heat from exiting air to entering air via one or more heat exchangers.

15 According to an embodiment in accordance with the invention, the method may involve heating air moving through the regenerable filter via a heater.

According to an embodiment in accordance with the invention, the method may involve reducing the amount of heat provided by the heater by approximately the amount of heat reclaimed.

20 According to an embodiment in accordance with the invention, the method may involve pumping reclaimed heat between the inside air outlet and the inside air inlet.

According to an embodiment in accordance with the invention, the method may involve pumping reclaimed heat between the outside air outlet and the outside air inlet.

According to an embodiment in accordance with the invention, the method may involve
25 storing excess reclaimed heat from air exiting the inside air outlet to air entering the inside air inlet. The stored excess reclaimed heat may be supplied to air received from the outside air inlet before the air moves through the regenerable filter.

According to an embodiment in accordance with the invention, the method may involve pumping reclaimed heat between the inside air outlet and outside air inlet.

30 According to an embodiment in accordance with the invention, the method may involve pumping reclaimed heat between the outside air outlet and the inside air inlet.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples, and alternatives set out in the preceding paragraphs, in the claims, and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a schematic and diagrammatical view of an embodiment of a vehicle air treatment system;

FIG. 2 is a schematic and diagrammatical view of another embodiment of a vehicle air treatment system;

FIG. 3 is a schematic and diagrammatical view of a further embodiment of a vehicle air treatment system;

FIG. 4 is a schematic and diagrammatical view of still another embodiment of a vehicle air treatment system;

FIG. 5 is a flow chart representation of a method of treating air in a vehicle with filter regeneration and heat reclamation in accordance with an embodiment of the invention; and

FIG. 6 is a schematic illustration of a vehicle comprising a vehicle air treatment system in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

Referring to the drawings, several embodiments of a vehicle air treatment system and method (hereafter "air treatment system") 10, 110, 210, 310, 400 are depicted and will be detailed in this description. The air treatment system 10, 110, 210, 310 employs filter regeneration and heat reclamation, and minimizes pecuniary costs, component complexities, and energy consumption costs that might otherwise arise in vehicle air treatment systems. In

the embodiments presented by the figures, heat that is yielded when air is filtered in the air treatment system 10, 110, 210, 310 can be reclaimed, and heat that remains after filter regeneration in the air treatment system 10, 110, 210, 310 can also be reclaimed. The heat reclaimed during filtration can be used to optimize the filtering effect, and the heat reclaimed during filter regeneration can be used to reduce the amount of heat that might otherwise be introduced into the air treatment system 10, 110, 210, 310 by a supplemental system component such as a heater. The term "vehicle" is meant to encompass all-electric automobiles, hybrid automobiles, and perhaps the more common internal combustion engine automobiles—these types of automobiles include passenger cars, trucks, and sport utility vehicles (SUVs). Furthermore, the terms "downstream" and "upstream" are used herein with reference to the direction of air flow in the air treatment system 10, 110, 210, 310.

In general, the air treatment system 10, 110, 210, 310 is equipped in a vehicle 11 like the one depicted in FIG. 6. The air treatment system 10, 110, 210, 310 treats air by removing unwanted content out of air that passes through it. The air treatment system 10, 110, 210, 310 may be part of a larger vehicle air handling system that may condition the air in other ways. The air treatment system 10, 110, 210, 310 can be designed and constructed in different ways depending upon, among other potential influences, the particular vehicle application, the design and construction of surrounding vehicle components, packaging demands, and the design and construction of components equipped in the air treatment system 10, 110, 210, 310.

In the embodiment of FIG. 1, the air treatment system 10 has various air passages, a first valve 12, a second valve 14, an air mover 16, a heater 18, a regenerable filter 20, multiple sensors, a first heat reclamation means 22, and a second reclamation means 24. Still, and as with other embodiments depicted in the figures, the air treatment system 10 need not necessarily include all components shown in FIG. 1; for instance, the air treatment system 10 could lack the air mover, could lack the heater, and/or could lack one or more of the sensors. Yet still, and as with other embodiments depicted in the figures, the air treatment system 10 could include additional and/or different components than those shown here.

The various air passages route air through the air treatment system 10. The air passages can be established by a series of conduits that are communicable with one another. In the embodiment presented by FIG. 1, the air treatment system 10 includes an inside air inlet passage 26, an inside air outlet passage 28, an outside air inlet passage 30, an outside air outlet passage 32, and a working passage 34. The inside air inlet passage 26 receives inlet inside air **A** from an interior cabin 36 of the accompanying vehicle. Vehicle occupants sit or

otherwise reside in the vehicle's interior cabin 36. When enclosed, carbon dioxide (CO₂) can build-up in the interior cabin 36 and, in the embodiments detailed in this description, the air treatment system 10, 110, 210, 310 is operated to remove at least some of the built-up CO₂; in other embodiments, the air treatment system 10, 110, 210, 310 could be operated to remove other content from the interior cabin 36. The inside air inlet passage 26 has an inside air inlet 38 that serves as an entrance for incoming air into the air treatment system 10 for air leaving the interior cabin 36. After it is received, the inlet inside air **A** is guided downstream toward the working passage 34 by the inside air inlet passage 26. The inside air inlet passage 26 and working passage 34 selectively communicate with each other via the first valve 12. The inside air outlet passage 28, on the other hand, delivers outlet air **B** to the interior cabin 36. The outlet air **B** can be air that has been filtered by the regenerable filter 20. The inside air outlet passage 28 has an inside air outlet 40 that serves as an exit for outgoing air from the air treatment system 10 supplying the interior cabin 36. The inside air outlet passage 28 receives air downstream from the working passage 34, and selectively communicates with the working passage 34 via the second valve 14. The inlet inside air **A** and outlet air **B** can constitute re-circulated interior cabin air if desired by selective control of the first and second valves 12, 14, respectively.

The outside air inlet passage 30 receives inlet outside air **C** from an exterior environment 42 outside of the vehicle's interior cabin 36. The outside air inlet passage 30 has an outside air inlet 44 that serves as an entrance for outside air into the air treatment system 10. After it is received, the inlet outside air **C** is guided downstream toward the working passage 34 by the outside air inlet passage 30. The outside air inlet passage 30 and working passage 34 selectively communicate with each other via the first valve 12. The outside air outlet passage 32, on the other hand, delivers outlet air **D** from the air treatment system 10 to the exterior environment 42. The outside air outlet passage 32 has an outside air outlet 46 that serves as an exit out of the air treatment system 10 for outgoing air. The outside air outlet passage 32 receives air downstream from the working passage 34, and selectively communicates with the working passage 34 via the second valve 14. In the embodiment of FIG. 1, the air mover 16, heater 18, regenerable filter 20, and the sensors reside at least partly within the working passage 34. In the orientation of FIG. 1, air flows through the working passage 34 from right to left—i.e., from an inlet 48 adjacent the first valve 12 to an outlet 50 adjacent the second valve 14. The working passage 34 constitutes the common passage that fluidly connects the inside air inlet passage 26 and the inside air outlet passage 28, and that fluidly connects the outside air inlet passage 30 and the outside air outlet passage 32.

The first valve 12 regulates the flow of air through the air treatment system 10 during an air treatment mode of operation and during a filter regeneration mode of operation of the air treatment system 10. In the example shown in FIG. 1, the first valve 12 has a valve member 52 that revolves between a first position and a second position when commanded to do so by a controller such as a vehicle control unit. The valve member 52 can be a disc, a door, a register, or some other structure, depending in some cases on the first valve's location in the passages. The first valve 12 can include other components such as a motor or other type of actuator, as will be appreciated by one skilled in the art. The first position is shown in FIG. 1. In the first position, the inside air inlet passage 26 is open to the working passage 34 and air flow is hence permitted to travel from the inside air inlet passage 26 to the working passage 34. At the same time, the valve member 52 closes the outside air inlet passage 30 from the working passage 34 and air flow is hence prevented from traveling therebetween. The outside air inlet passage 30 is also closed from the inside air inlet passage 26 when the valve member 52 is in the first position. The valve member 52 is actuated to the first position when the air treatment system 10 is brought to the air treatment mode of operation. The second position, on the other hand, is shown by broken line L_1 in FIG. 1. In the second position, the outside air inlet passage 30 is open to the working passage 34 and air flow is hence permitted to travel from the outside air inlet passage 30 to the working passage 34. At the same time, the valve member 52 closes the inside air inlet passage 26 from the working passage 34 and air flow is hence prevented from traveling therebetween. The inside air inlet passage 26 is also closed from the outside air inlet passage 30 when the valve member 52 is in the second position. The valve member 52 is actuated to the second position when the air treatment system 10 is brought to the filter regeneration mode of operation.

Like the first valve 12, the second valve 14 regulates the flow of air through the air treatment system 10 during the air treatment mode of operation and during the filter regeneration mode of operation. In the example shown in FIG. 1, the second valve 14 has a valve member 54 that revolves between a first position and a second position when commanded to do so by the controller such as the vehicle control unit. The valve member 54 can be a disc, a door, a register, or some other structure, depending in some cases on the second valve's location in the passages. The second valve 14 can include other components such as a motor or other type of actuator, as will be appreciated by one skilled in the art. The first position is shown in FIG. 1. In the first position, the inside air outlet passage 28 is open to the working passage 34 and air flow is hence permitted to travel from the working passage 34 to the inside air outlet passage 28. At the same time, the valve member 54 closes the outside air outlet passage 32 from the working passage 34 and air flow is hence prevented from traveling therebetween. The outside air outlet passage 32 is also closed from the inside air outlet

passage 28 when the valve member 54 is in the first position. The valve member 54 is actuated to the first position when the air treatment system 10 is brought to the air treatment mode of operation. The second position, on the other hand, is shown by broken line L_2 in FIG. 1. In the second position, the outside air outlet passage 32 is open to the working passage 34 and air flow is hence permitted to travel from the working passage 34 to the outside air outlet passage 32. At the same time, the valve member 54 closes the inside air outlet passage 28 from the working passage 34 and air flow is hence prevented from traveling therebetween. The inside air outlet passage 28 is also closed from the outside air outlet passage 32 when the valve member 54 is in the second position. The valve member 54 is actuated to the second position when the air treatment system 10 is brought to the filter regeneration mode of operation.

The air mover 16 helps propel air passing through the air treatment system 10 and particularly through the heater 18 and through the regenerable filter 20. Still referring to FIG. 1, in this embodiment the air mover 16 is located downstream of the first valve 12, upstream of the heater 18, and upstream of the regenerable filter 20; still, the air mover 16 could have other locations in other embodiments. By its location in FIG. 1, the air mover 16 is able to force air through the heater 18 and through the regenerable filter 20. The air mover 16 can be a fan, or can be some other device that suitably propels air in the air treatment system 10.

The heater 18 supplies heat to, and raises the temperature of, air that passes through it when the heater 18 is activated during use of the air treatment system 10. In the embodiment of FIG. 1, the heater 18 is located downstream of the air mover 16 and upstream of the regenerable filter 20; still, the heater 18 could have other locations in other embodiments. By its location in FIG. 1, the heater 18 is able to heat air before the air passes through the regenerable filter 20. The heater 18 can be an electric heater, can have a heater core, or can be some other device that suitably raises the temperature of air that passes through it. During its use, the heater 18 can be activated to commence the air treatment and filter regeneration modes of operation since the air treatment system 10 could be initially at a cold temperature state, and then, as described below, the heater 18 may serve as a supplemental supplier of heat in the air treatment system 10.

The regenerable filter 20 removes unwanted content out of air that passes through the regenerable filter 20, and is capable of restoring and reconstituting its filtering effect for continued use in the air treatment system 10. In the embodiment of FIG. 1, the regenerable filter 20 is located downstream of the air mover 16, downstream of the heater 18, and

upstream of the second valve 14; still, the regenerable filter 20 could have other locations in other embodiments. The regenerable filter 20 can remove different types of content out of the air, and therefore the filter can be of different types itself. Here, the regenerable filter 20 is an adsorbent material that removes CO₂ out of the air that passes through the adsorbent material. In general, and as will be appreciated by one skilled in the art, the adsorbent material can reversibly adsorb CO₂ and then, when prompted, selectively release the adsorbed CO₂. During the air treatment mode of operation, CO₂ present in air that passes through the adsorbent material is adhered to surfaces of the adsorbent material. The CO₂ is hence filtered out of the air passing through the regenerable filter 20. Since the adsorption process in this embodiment is an exothermic process, energy in the form of heat is yielded and given off during the process. The heat advances downstream of the regenerable filter 20 and through the inside air outlet passage 28 and toward the inside air outlet 40. Examples of CO₂ adsorbent materials can include certain activated carbon and metal-oxide-based materials, as well as other suitable materials. During the filter regeneration mode of operation, the adsorbed and adhered CO₂ is released from the surfaces of the adsorbent material. In order to prompt release, energy in the form of heat is introduced into the adsorbent material. In one example, approximately one-hundred degrees Celsius (100°C) is introduced into the adsorbent material to release the adsorbed CO₂. The released CO₂ advances downstream of the regenerable filter 20, through the outside air outlet passage 32, and through the outside air outlet 46. And heat remaining post-release advances downstream of the regenerable filter 20, through the outside air outlet passage 32, and toward the outside air outlet 46.

The multiple sensors take measurements in order to ascertain certain information about air passing through the air treatment system 10. That information can then be transmitted as a signal to a controller, such as the vehicle control unit, for managing operation of the air treatment system 10. Managing operation can involve—among other actions—opening and closing inlets and outlets and passages of the air treatment system 10, actuating the first and second valves 12, 14, and activating and deactivating the air mover 16 and heater 18. In the embodiment of FIG. 1, the sensors include a first air quality sensor 56, a second air quality sensor 58, a first temperature sensor 60, and a second temperature sensor 62. The first air quality sensor 56 is located upstream of the heater 18 and upstream of the regenerable filter 20, and therefore can measure the quality of air before the air passes through the regenerable filter 20. The second air quality sensor 58 is located downstream of the regenerable filter 20, and therefore can measure the quality of air after the air has passed through the regenerable filter 20. One example air quality sensor is a CO₂ sensor that measures the amount of CO₂ in the air passing by the sensor. The first temperature sensor

60 is located downstream of the heater 18 and upstream of the regenerable filter 20, and therefore can measure the temperature of air after the air passes through the heater 18 and before the air passes through the regenerable filter 20. The second temperature sensor 62 is located downstream of the regenerable filter 20, and therefore can measure the temperature of air after the air has passed through the regenerable filter 20.

The first heat reclamation means 22 recovers heat yielded as air filters through the regenerable filter 20 during the air treatment mode of operation, and transfers the recovered heat to air that has not yet passed through the regenerable filter 20 but is intended to be filtered through the regenerable filter 20. The first heat reclamation means 22 can take different forms depending upon, among other potential influences, other components of the air treatment system 10 and the extent of heat recovery desired. In the embodiment of FIG. 1, the first heat reclamation means 22 is a heat exchanger 64. The heat exchanger 64 can be a shell-and-tube type heat exchanger, can be a plate type heat exchanger, or can be another type of heat exchanger. The heat exchanger 64 is situated, in part, in both the inside air inlet passage 26 and the inside air outlet passage 28. A portion of the heat exchanger 64 is exposed to air flow in the inside air inlet passage 26, and another portion of the heat exchanger 64 is exposed to air flow in the inside air outlet passage 28. The heat exchanger 64 resides downstream of the inside air inlet 38 and resides upstream of the inside air outlet 40. During its use, and in the air treatment mode of operation, the heat exchanger 64 is heated by the heat yielded during the adsorption process at the regenerable filter 20, and the heat exchanger 64 in turn heats the inlet inside air **A** received in the inside air inlet passage 26. Air led to the heater 18 is hence hotter than it would have been without the heat exchanger 64. And the heater 18 can therefore supply less heat to air that passes through it than the amount of heat the heater 18 would have supplied without the heat exchanger 64. Energy consumption via heater activation is minimized, and the optimal temperature for promoting adsorption is more readily maintained. Furthermore, the temperature of the outlet air **B** is lowered as the heat yielded during the adsorption process heats the heat exchanger 64. Hotter outlet air **B** is thus not delivered to the interior cabin 36, and a substantially noticeable difference in temperatures between the inlet inside air **A** and outlet air **B** can be avoided.

The second heat reclamation means 24 recovers heat remaining while the regenerable filter 20 is being restored and reconstituted during the filter regeneration mode of operation, and transfers the recovered heat to air that has not yet passed through the regenerable filter 20 but is intended for use in regenerating the regenerable filter 20. The second heat reclamation means 24 can take different forms depending upon, among other potential

influences, other components of the air treatment system 10 and the extent of heat recovery desired. In the embodiment of FIG. 1, the second heat reclamation means 24 is a heat exchanger 66. The heat exchanger 66 can be a shell-and-tube type heat exchanger, can be a plate type heat exchanger, or can be another type of heat exchanger. The heat exchanger 66 is situated, in part, in both the outside air inlet passage 30 and the outside air outlet passage 32. A portion of the heat exchanger 66 is exposed to air flow in the outside air inlet passage 30, and another portion of the heat exchanger 66 is exposed to air flow in the outside air outlet passage 32. The heat exchanger 66 resides downstream of the outside air inlet 44 and resides upstream of the outside air outlet 46. During its use, and in the filter regeneration mode of operation, the heat exchanger 66 is heated by the heat remaining post-release, and the heat exchanger 66 in turn heats the inlet outside air C received in the outside air inlet passage 30. Air led to the heater 18 is hence hotter than it would have been without the heat exchanger 66. And the heater 18 can therefore supply less heat to air that passes through it than the amount of heat the heater 18 would have supplied without the heat exchanger 66. Energy consumption via heater activation is minimized, and the heat needed to prompt release of adhered CO₂ from the regenerable filter 20 is more readily realized. In some cases, the heater 18—in a sense—merely supplies supplemental heat during the filter regeneration mode of operation, instead of being the sole supplier of heat.

In one example, the air treatment system 10 is brought to the air treatment mode of operation when the amount of CO₂ measured by an air quality sensor in the interior cabin 36 is above a predetermined CO₂ threshold level. This may serve as an indication that the amount of CO₂ present in the interior cabin 36 is at an undesirable level. The controller then commands actuation of the valve member 52 of the first valve 12 to its first position, and likewise commands actuation of the valve member 54 of the second valve 14 to its first position. Air flows from the inside air inlet passage 26, through the working passage 34, and through the inside air outlet passage 28. The regenerable filter 20 removes CO₂ out of the air that passes through it. The air treatment mode of operation can continue until the amount of CO₂ measured by the cabin air quality sensor or by the first air quality sensor 56 is below the predetermined CO₂ threshold level. During the air treatment mode of operation, the heat yielded by the adsorption process is recovered and transferred via the first heat reclamation means 22. The inlet inside air A is hence heated. The heater 18 may only be activated in the air treatment mode of operation when the temperature of air measured by the first temperature sensor 60 is below an optimal temperature threshold level for promoting the adsorption process, or may only be activated at mode commencement if the air treatment system 10 is initially cold, or may be activated in both of these situations. The optimal temperature threshold level is the temperature at which the regenerable filter 20 most

efficiently and effectively removes CO₂, and can be a range of temperature values. The optimal temperature threshold level may depend on the type and material of the regenerable filter 20.

In one example, the air treatment system 10 is brought to the filter regeneration mode of operation when the difference between the amount of CO₂ measured by the first air quality sensor 56 and the amount of CO₂ measured by the second air quality sensor 58 is below a threshold value. This may indicate that the regenerable filter 20 is no longer removing CO₂ because the regenerable filter 20 has reached its filtering capacity and is saturated. The controller then commands actuation of the valve member 52 of the first valve 12 to its second position, and likewise commands actuation of the valve member 54 of the second valve 14 to its second position. Air flows from the outside air inlet passage 30, through the working passage 34, and through the outside air outlet passage 32. Previously adsorbed CO₂ is released from the regenerable filter 20. The filter regeneration mode of operation can continue for a predetermined time period, or can continue until the amount of CO₂ measured by the second air quality sensor 58 is below a threshold level, indicating that the regenerable filter 20 is no longer releasing adsorbed CO₂. During the filter regeneration mode of operation, heat remaining downstream of the regenerable filter 20 is recovered and transferred via the second heat reclamation means 24. The inlet outside air C is hence heated. The heater 18 may only be activated in the filter regeneration mode of operation when the temperature of air measured by the first temperature sensor 60 is below a regeneration threshold level for prompting release of adhered CO₂, or may only be activated at mode commencement if the air treatment system 10 is initially cold, or may be activated in both of these situations. The regeneration threshold level is the temperature at which the regenerable filter 20 effectively releases CO₂, and can be a range of temperature values. The regeneration threshold level will depend on the type and material of the regenerable filter 20.

Another embodiment of an air treatment system 110 is presented in FIG. 2. This embodiment is similar in some ways to the embodiment of FIG. 1, and the similarities may not be repeated in this description of FIG. 2. Indeed, similar components in the embodiments of FIGS. 1 and 2 have similar reference numerals, with the reference numerals of FIG. 2 having the number 100 added to the reference numeral of the similar component in FIG. 1.

In the embodiment of FIG. 2, a first heat reclamation means 122 includes a first heat exchanger 168, a second heat exchanger 170, and a reversible heat pump 172. The first and second heat exchangers 168, 170 can be a shell-and-tube type heat exchanger, can be

a plate type heat exchanger, or can be another type of heat exchanger. The first heat exchanger 168 is situated in an inside air inlet passage 126, and the second heat exchanger 170 is situated in an inside air outlet passage 128. The first heat exchanger 168 resides downstream of an inside air inlet 138, and the second heat exchanger 170 resides upstream of an inside air outlet 140. The reversible heat pump 172 is functionally connected to both the first heat exchanger 168 and the second heat exchanger 170. As will be appreciated by one skilled in the art, the reversible heat pump 172 can be activated to transfer heat from the first heat exchanger 168 to the second heat exchanger 170, or conversely to transfer heat from the second heat exchanger 170 to the first heat exchanger 168. During their use, and in the air treatment mode of operation, the second heat exchanger 170 is heated by the heat yielded during the adsorption process at a regenerable filter 120. This heat can be drawn from the second heat exchanger 170 and transferred to the first heat exchanger 168 by the reversible heat pump 172. As before, the first heat exchanger 168 would then heat the inlet inside air **A** received in the inside air inlet passage 126. Conversely, heat can be drawn from the first heat exchanger 168 and transferred to the second heat exchanger 170 by the reversible heat pump 172. This would have the effect of cooling the inlet inside air **A** received in the inside air inlet passage 126. The inlet inside air **A** may be cooled in this way when the temperature of the inlet inside air **A** is initially above the optimal temperature threshold level for promoting the adsorption process. In this regard, in the embodiment of FIG. 2, additional temperature sensors can be located upstream of and/or downstream of the first heat exchanger 168. The first heat reclamation means 122 can recover and transfer heat by active control via activation of the reversible heat pump 172, as opposed to passive heat recovery and transfer like a second heat reclamation means 124 described below.

Furthermore, in the embodiment of FIG. 2, the second heat reclamation means 124 involves the use of one or more shared walls 174 between an outside air inlet passage 130 and an outside air outlet passage 132. The shared wall(s) 174 transfer heat via thermal conduction. The shared wall(s) 174 are heated by the heat remaining post-release. The heated shared wall(s) 174 then heat the inlet outside air **C** received in the outside air inlet passage 130. In the embodiment of FIG. 2, the outside air inlet passage 130 and the outside air outlet passage 132 have a concentric arrangement with the outside air inlet passage 130 positioned radially within the surrounding outside air outlet passage 132. Here, the outside air outlet passage 132 has a larger diameter than that of the outside air inlet passage 130, and the shared wall(s) 174 is the conduit defining the outside air inlet passage 130. In other embodiments, the outside air inlet passage 130 and outside air outlet passage 132 could be arranged side-by-side with a shared wall therebetween. Still, in other embodiments, the

shared wall(s) 174 could be designed and constructed with fins, spikes, or other structures or formations to increase the surface area available for thermal conduction heat transfer.

Another embodiment of an air treatment system 210 is presented in FIG. 3. This embodiment is similar in some ways to the embodiments of FIGS. 1 and 2, and the similarities may not be repeated in this description of FIG. 3. Indeed, similar components in the embodiments of FIGS. 1, 2, and 3 have similar reference numerals, with the reference numerals of FIG. 3 having the number 200 added to the reference numeral of the similar component in FIG. 1.

In the embodiment of FIG. 3, the air treatment system 210 includes a second working passage 235, a second air mover 217, a second heater 219, and a second regenerable filter 221. Furthermore, a second heat reclamation means 224 in this embodiment includes a first heat exchanger 276 and a second heat exchanger 278, and the air treatment system 210 includes a reversible heat pump 280. The second working passage 235 is similar to the working passage of previous embodiments. The second working passage 235 constitutes yet another common passage that fluidly connects an inside air inlet passage 226 and an inside air outlet passage 228, and that fluidly connects an outside air inlet passage 230 and an outside air outlet passage 232. Because of the second working passage 235 in this embodiment, first and second valves 212, 214 regulate air flow differently than previously described. The first positions of valve members 252, 254 of the first and second valves 212, 214 are shown in FIG. 3. In the first positions, air flow is permitted to travel from the inside air inlet passage 226, through a working passage 234, and to the inside air outlet passage 228. At the same time, air flow is permitted to travel from the outside air inlet passage 230, through the second working passage 235, and to the outside air outlet passage 232. The second positions of the valve members 252, 254 of the first and second valves 212, 214 are shown in FIG. 3 by broken lines L_1 , L_2 . In the second positions, air flow is permitted to travel from the inside air inlet passage 226, through the second working passage 235, and to the inside air outlet passage 228. At the same time, air flow is permitted to travel from the outside air inlet passage 230, through the working passage 234, and to the outside air outlet passage 232.

The second air mover 217 is similar to the air movers of previous embodiments. The second air mover 217 resides at least partly within the second working passage 235, and helps propel air through the second heater 219 and through the second regenerable filter 221. The second heater 219 is similar to the heaters of previous embodiments. The second heater 219 resides at least partly within the second working passage 235, and supplies heat to air

that passes through it when the second heater 219 is activated during use of the air treatment system 210. And the second regenerable filter 221 is similar to the regenerable filters of previous embodiments. The second regenerable filter 221 resides at least partly within the second working passage 235. The second regenerable filter 221 can be an
5 absorbent material that removes CO₂ out of the air that passes through the adsorbent material, as previously described. Furthermore, although not depicted in FIG. 3, the air treatment system 210 can include the multiple sensors of previous embodiments.

The first and second heat exchangers 276, 278 of the second heat reclamation means 224 are similar to the first and second heat exchangers 168, 170 as described in connection with
10 the embodiment of FIG. 2. In FIG. 3, the first heat exchanger 276 of the second heat reclamation means 224 is situated in the outside air inlet passage 230, and the second heat exchanger 278 of the second heat reclamation means 224 is situated in the outside air outlet passage 232. The first heat exchanger 276 resides downstream of an outside air inlet 244, and the second heat exchanger 278 resides upstream of an outside air outlet 246. In this
15 embodiment, the reversible heat pump 280 is functionally connected to all four of the first and second heat exchangers 268, 270, 276, 278. Heat can therefore be transferred via the reversible heat pump 280 among all four of the first and second heat exchangers 268, 270, 276, 278.

In the embodiment of FIG. 3, the air treatment system 210 can be operated in a first air
20 treatment mode of operation and first filter regeneration mode of operation, and in a second air treatment mode of operation and second filter regeneration mode of operation. In the first air treatment and filter regeneration modes of operation, the valve members 252, 254 of the first and second valves 212, 214 are actuated to their first positions. A regenerable filter 220
25 adsorbs CO₂ from air that passes through its adsorbent material, and, concurrently, the second regenerable filter 221 may release previously adsorbed CO₂. The second heat exchanger 270 of the first heat reclamation means 222 is heated by the heat yielded during the adsorption process at the regenerable filter 220. This heat can be drawn from the second heat exchanger 270 of the first heat reclamation means 222 and transferred to the first heat exchanger 268 of the first heat reclamation means 222 by the reversible heat pump 280,
30 transferred to the first heat exchanger 276 of the second heat reclamation means 224 by the reversible heat pump 280, or transferred to both of the first heat exchangers 268, 276 by the reversible heat pump 280. The inlet inside air **A**, inlet outside air **C**, or both, are then heated by the heat drawn from the second heat exchanger 270 of the first heat reclamation means 222. Concurrently, the second heat exchanger 278 of the second heat reclamation means
35 224 is heated by heat remaining post-release from the second regenerable filter 221. This

heat can be drawn from the second heat exchanger 278 and transferred to the first heat exchanger 276 by the reversible heat pump 280. The inlet outside air **C** is then heated by the heat drawn from the second heat exchanger 278 of the second heat reclamation means 224. The heat can also be drawn from the second heat exchanger 278 of the second heat reclamation means 224 and transferred to the first heat exchanger 268 of the first heat reclamation means 222 by the reversible heat pump 280. As before, the inlet inside air **A** is then heated by the heat drawn from the second heat exchanger 278 of the second heat reclamation means 224. As described, in the embodiment of FIG. 3, as the regenerable filter 220 is filtering during the first air treatment mode of operation, the second regenerable filter 221 is regenerating during the first filter regeneration mode of operation. The first air treatment and filter regeneration modes of operation need not necessarily begin and cease at the same times, nor do the modes of operation have to be carried out in overlapping time periods.

In the second air treatment and filter regeneration modes of operation, the valve members 252, 254 of the first and second valves 212, 214 are actuated to their second positions. The regenerable filter 220 releases previously adsorbed CO₂, and, concurrently, the second regenerable filter 221 may adsorb CO₂ from air that passes through its adsorbent material. The second heat exchanger 270 of the first heat reclamation means 222 is heated by the heat yielded during the adsorption process at the second regenerable filter 221. This heat can be drawn from the second heat exchanger 270 of the first heat reclamation means 222 and transferred to the first heat exchanger 268 of the first heat reclamation means 222 by the reversible heat pump 280, transferred to the first heat exchanger 276 of the second heat reclamation means 224 by the reversible heat pump 280, or transferred to both of the first heat exchangers 268, 276 by the reversible heat pump 280. The inlet inside air **A**, inlet outside air **C**, or both, are then heated by heat drawn from the second heat exchanger 270 of the first heat reclamation means 222. Concurrently, the second heat exchanger 278 of the second heat reclamation means 224 is heated by heat remaining post-release at the regenerable filter 220. This heat can be drawn from the second heat exchanger 278 of the second heat reclamation means 224 and transferred to the first heat exchanger 276 of the second heat reclamation means 224 by the reversible heat pump 280. The inlet outside air **C** is then heated by the heat drawn from the second heat exchanger 278 of the second heat reclamation means 224. The heat can also be drawn from the second heat exchanger 278 of the second heat reclamation means 224 and transferred to the first heat exchanger 268 of the first heat reclamation means 222 by the reversible heat pump 280. As before, the inlet inside air **A** is then heated by the heat drawn from the second heat exchanger 278 of the second heat reclamation means 224. As described, in the embodiment of FIG. 3, as the

second regenerable filter 221 is filtering during the second air treatment mode of operation, the regenerable filter 220 is regenerating during the second filter regeneration mode of operation. The second air treatment and filter regeneration modes of operation need not necessarily begin and cease at the same times, nor do the modes of operation have to be carried out in overlapping time periods.

Yet another embodiment of an air treatment system 310 is presented in FIG. 4. This embodiment is similar in some ways to the embodiments of FIGS. 1, 2, and 3, and the similarities may not be repeated in this description of FIG. 4. Indeed, similar components in the embodiments of FIGS. 1, 2, 3, and 4 have similar reference numerals, with the reference numerals of FIG. 4 having the number 300 added to the reference numeral of the similar component in FIG. 1.

In the embodiment of FIG. 4, the air treatment system 310 includes a thermal energy storage means 382. The thermal energy storage means 382 stores excess heat from heat yielded during the adsorption process. The stored heat can then be employed to heat air intended for use in regenerating a regenerable filter 320. The thermal energy storage means 382 can take different forms depending upon, among other potential influences, other components of the air treatment system 310 and the extent of heat storage desired. In different examples, the thermal energy storage means 382 may include a phase-change material, may involve heat-capturing battery technologies, may be a piece of metal block, or may involve other types of thermal energy storage capabilities. The thermal energy storage means 382 may additionally or alternatively include a suitable state-change material. Furthermore, although not depicted in FIG. 4, the air treatment system 310 may include the multiple sensors of previous embodiments.

In the air treatment mode of operation in the embodiment of FIG. 4, a second heat exchanger 370 of a first heat reclamation means 322 is heated by the heat yielded during the adsorption process at the regenerable filter 320. This heat can be drawn from the second heat exchanger 370 of the first heat reclamation means 322 and transferred to a first heat exchanger 368 of the first heat reclamation means 322 by a reversible heat pump 380. Surplus heat—i.e., heat in excess of the optimal temperature threshold level for promoting the adsorption process—can be stored by the thermal energy storage means 382 instead of being transferred to the first heat exchanger 368 of the first heat reclamation means 322. The surplus heat can be transferred to the thermal energy storage means 382 by the reversible heat pump 380, as indicated by the arrowed lines in FIG. 4. Subsequently, in the filter regeneration mode of operation in this embodiment, the stored heat in the thermal

energy storage means 382 can be set free and transferred to a first heat exchanger 376 of a second heat reclamation means 324 by the reversible heat pump 380. In addition to the stored heat, heat remaining post-release and recovered by a second heat exchanger 378 of the second heat reclamation means 324 is also transferred to the first heat exchanger 376 of the second heat reclamation means 324 by the reversible heat pump 380. Both of these heat sources may therefore be used in the filter regeneration mode of operation in this embodiment.

FIG. 5 is a flow chart representation of an embodiment of a method 400 of treating air in the vehicle 11 with filter regeneration and heat reclamation. The method 400 may involve moving air through a regenerable filter—like the regenerable filters 20, 120, 220, 221, 320 described with reference to previous embodiments—in order to filter the air (numeral 402 in FIG. 5). The air may be received from the inside air inlet 38, 138, 238, 338 prior to moving through the regenerable filter 20, 120, 220, 221, 320. And the air may exit toward the inside air outlet 40, 140, 240, 340 after moving through the regenerable filter 20, 120, 220, 221, 320. The method may also involve reclaiming heat from air exiting toward the inside air outlet 40, 140, 240, 340 to air entering the inside air inlet 38, 138, 238, 338 (numeral 404 in FIG. 5). Further, the method may involve moving air through the regenerable filter 20, 120, 220, 221, 320 in order to regenerate the regenerable filter (numeral 406 in FIG. 5). The air may be received from the outside air inlet 44, 144, 244, 344 prior to moving through the regenerable filter 20, 120, 220, 221, 320. And the air may exit toward the outside air outlet 46, 146, 246, 346 after moving through the regenerable filter 20, 120, 220, 221, 320. Furthermore, the method may involve reclaiming heat from air exiting toward the outside air outlet 46, 146, 246, 346 to air entering the outside air inlet 44, 144, 244, 344 (numeral 408 in FIG. 5). Still, other embodiments of the method 400 may involve more, less, and/or different steps than those described with reference to FIG. 5.

Figure 6 is a schematic perspective illustration of a vehicle 11 comprising the above described vehicle air treatment system. The precise configuration of the air treatment system within the vehicle is immaterial provided that the inside air inlet and outlet are configured in fluid communication with the vehicle cabin, and the outside air inlet and outlet are configured in fluid communication with an exterior of the vehicle cabin, such that air may be inlet and outlet from a surrounding environment of the vehicle.

Designs, constructions, and components presented by the embodiments of FIGS. 1–6 could be combined and interchanged with one another in different embodiments. For instance, the

shared wall(s) 174 of FIG. 2 could be used as the first heat reclamation means 22 in the embodiment of FIG. 1.

It will be understood that the embodiments described above are given by way of example only and are not intended to limit the invention, the scope of which is defined in the appended claims. The invention is not limited to the particular embodiment(s) disclosed herein, but rather is defined solely by the claims below. Furthermore, the statements contained in the foregoing description relate to particular embodiments and are not to be construed as limitations on the scope of the invention or on the definition of terms used in the claims, except where a term or phrase is expressly defined above. Various other embodiments and various changes and modifications to the disclosed embodiment(s) will become apparent to those skilled in the art. All such other embodiments, changes, and modifications are intended to come within the scope of the appended claims.

As used in this specification and claims, the terms "for example," "e.g.," "for instance," "such as," and "like," and the verbs "comprising," "having," "including," and their other verb forms, when used in conjunction with a listing of one or more components or other items, are each to be construed as open-ended, meaning that that the listing is not to be considered as excluding other, additional components or items. Other terms are to be construed using their broadest reasonable meaning unless they are used in a context that requires a different interpretation.

CLAIMS

1. A vehicle air treatment system with filter regeneration and heat reclamation, the vehicle air treatment system comprising:

an inside air inlet arranged to receive air from an interior cabin of a vehicle, and an

inside air outlet arranged to deliver air to the interior cabin;

an outside air inlet arranged to receive air from outside of the interior cabin and an outside air outlet arranged to deliver air to outside of the interior cabin;

at least one regenerable filter located downstream of said inside air inlet and upstream of said inside air outlet, or located downstream of said outside air inlet and upstream of said outside air outlet, or located both downstream of said inside air inlet and downstream of said inside air outlet and downstream of said outside air inlet and upstream of said outside air outlet;

at least one heat reclamation means, the at least one heat reclamation means being at least one of:

- situated downstream of said inside air inlet and upstream of said at least one regenerable filter, and situated upstream of said inside air outlet and downstream of said at least one regenerable filter; and

- situated downstream of said outside air inlet and upstream of said at least one regenerable filter, and situated upstream of said outside air outlet and downstream of said at least one regenerable filter; and

wherein the vehicle air treatment system is operable in an air treatment mode of operation and/or in a filter regeneration mode of operation, and:

- in the air treatment mode of operation, heat yielded as air filters through said at least one regenerable filter is transferred to air that enters said inside air inlet via said at least one heat reclamation means, and/ or

- in the filter regeneration mode of operation, heat advancing toward said outside air outlet is transferred to air that enters said outside air inlet via said at least one heat reclamation means.

2. The vehicle air treatment system of claim 1, comprising a first and a second heat reclamation means, wherein;

the first heat reclamation means being situated downstream of said inside air inlet and upstream of said at least one regenerable filter, said first heat reclamation means being situated upstream of said inside air outlet and downstream of said at least one regenerable filter; and

the second heat reclamation means being situated downstream of said outside air inlet and upstream of said at least one regenerable filter, said second heat reclamation means situated upstream of said outside air outlet and downstream of said at least one regenerable filter.

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3. The vehicle air treatment system of claim 2, wherein in the air treatment mode of operation, heat yielded as air filters through said at least one regenerable filter is transferred to air that enters said inside air inlet via said first heat reclamation means, and, in the filter regeneration mode of operation, heat advancing toward said outside air outlet is transferred to air that enters said outside air inlet via said second heat reclamation means.

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4. The vehicle air treatment system of claim 2 or claim 3, comprising a heater located upstream of said at least one regenerable filter, said heater arranged to heat air during the filter regeneration mode of operation, said heater being arranged to supplement heat transferred to air entering said outside air inlet via said second heat reclamation means.

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5. The vehicle air treatment system of any one of the preceding claims, comprising an air mover located upstream of said at least one regenerable filter, said air mover being configured to propel air through said at least one regenerable filter during the air treatment mode of operation, or during the filter regeneration mode of operation, or during both the air treatment and filter regeneration modes of operation.

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6. The vehicle air treatment system of any one of the preceding claims, comprising:
a first valve located downstream of said inside air inlet and downstream of said outside air inlet and upstream of said at least one regenerable filter, said first valve being arranged to regulate air flow during the air treatment and filter regeneration modes of operation; and

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a second valve located downstream of said at least one regenerable filter and upstream of said inside air outlet and upstream of said outside air outlet, said second valve being arranged to regulate air flow during the air treatment and filter regeneration modes of operation.

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7. The vehicle air treatment system of one of the preceding claims, wherein said at least one regenerable filter comprises a first regenerable filter located in a first passage and a second regenerable filter located in a second passage.

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8. The vehicle air treatment system of any one of the preceding claims, wherein said at least one regenerable filter comprises a carbon dioxide (CO₂) adsorbent material.

9. The vehicle air treatment system of any one of claims 2 to 8, wherein said first heat reclamation means comprises a first heat exchanger situated at least partly in an inside air inlet passage and situated at least partly in an inside air outlet passage, and said second heat reclamation means comprises a second heat exchanger situated at least partly in an outside air inlet passage and situated at least partly in an outside air outlet passage.

10. The vehicle air treatment system of any one of claims 2 to 9, wherein said first heat reclamation means comprises a first heat exchanger situated in an inside air inlet passage and a second heat exchanger situated in an inside air outlet passage.

11. The vehicle air treatment system of claim 10, comprising a reversible heat pump configured to pump heat between said first heat exchanger and said second heat exchanger.

12. The vehicle air treatment system of claim 11, comprising an outside air inlet passage and an outside air outlet passage, said outside air inlet passage and said outside air outlet passage sharing at least one wall, said at least one wall being configured to transfer heat from air flowing through said outside air outlet passage to air flowing through said outside air inlet passage during the filter regeneration mode of operation.

13. The vehicle air treatment system of any of claims 2 to 8, wherein said first heat reclamation means comprises a first heat exchanger situated in an inside air inlet passage and a second heat exchanger situated in an inside air outlet passage, said second heat reclamation means comprises a first heat exchanger situated in an outside air inlet passage and a second heat exchanger situated in an outside air outlet passage, the vehicle air treatment system comprising a reversible heat pump configured to pump heat between said first and second heat exchangers of said first heat reclamation means and between said first and second heat exchangers of said second heat reclamation means.

14. The vehicle air treatment system of claim 13, wherein the air treatment mode of operation comprises a first and second air treatment mode of operation, the filter regeneration mode of operation comprises a first and second filter regeneration mode of operation, and when the vehicle air treatment system is operated in the first air treatment mode of operation and in the first filter regeneration mode of operation, said first regenerable

filter is arranged to receive air flow from said inside air inlet and treated air flow exits said first regenerable filter to said inside air outlet, and said second regenerable filter is arranged to be regenerated by air flow received from said outside air inlet and air flow downstream of said second regenerable filter is arranged to exit the vehicle air treatment system through said outside air outlet, at least part of the first air treatment and first filter regeneration modes of operation being arranged to be carried out concurrently, and wherein, in the second air treatment mode of operation and the second filter regeneration mode of operation, said second regenerable filter is arranged to receive air flow from said inside air inlet and treated air flow is arranged to exit said second regenerable filter to said inside air outlet, and said first regenerable filter is arranged to be regenerated by air flow received from said outside air inlet and air flow downstream of said first regenerable filter is arranged to exit the vehicle air treatment system through said outside air outlet, at least part of the second air treatment and second filter regeneration modes of operation being arranged to be carried out concurrently.

15. The vehicle air treatment system of any one of claims 2 to 8, wherein said first heat reclamation means comprises a first heat exchanger situated in an inside air inlet passage and a second heat exchanger situated in an inside air outlet passage, said second heat reclamation means comprises a first heat exchanger situated in an outside air inlet passage and a second heat exchanger situated in an outside air outlet passage, the vehicle air treatment system comprising a reversible heat pump configured to pump heat between said first and second heat exchangers of said first heat reclamation means and between said first and second heat exchangers of said second heat reclamation means.

16. The vehicle air treatment system of claim 15, comprising a thermal energy storage means configured to store excess heat from said first heat exchanger when the vehicle air treatment system is operated in the air treatment mode of operation, the thermal energy storage means being configured to supply the stored excess heat to air that enters said outside air inlet when the vehicle air treatment system is operated in the filter regeneration mode of operation.

17. The vehicle air treatment system of claim 16, wherein said thermal energy storage means comprises a phase-change material.

18. A vehicle comprising the vehicle air treatment system of any one of the preceding claims.

19. A method of treating air in a vehicle with filter regeneration and heat reclamation, the method comprising:

moving air through a regenerable filter to filter the air, the air received from an inside air inlet before moving through said regenerable filter, the air exiting toward an inside air outlet after moving through said regenerable filter; and

moving air through said regenerable filter to regenerate said regenerable filter, the air received from an outside air inlet before moving through said regenerable filter, the air exiting toward an outside air outlet after moving through said regenerable filter; and

wherein the method comprises at least one of:

reclaiming heat from air exiting toward said inside air outlet to air entering said inside air inlet; and

reclaiming heat from air exiting toward said outside air outlet to air entering said outside air inlet.

20. The method of treating air in a vehicle of claim 19, wherein reclaiming heat involves exchanging heat from exiting air to entering air via at least one heat exchanger.

21. The method of treating air in a vehicle of claim 19 or 20, comprising heating air moving through said regenerable filter via a heater.

22. The method of treating air in a vehicle of claim 21, comprising reducing the amount of heat provided by said heater by approximately the amount of heat reclaimed.

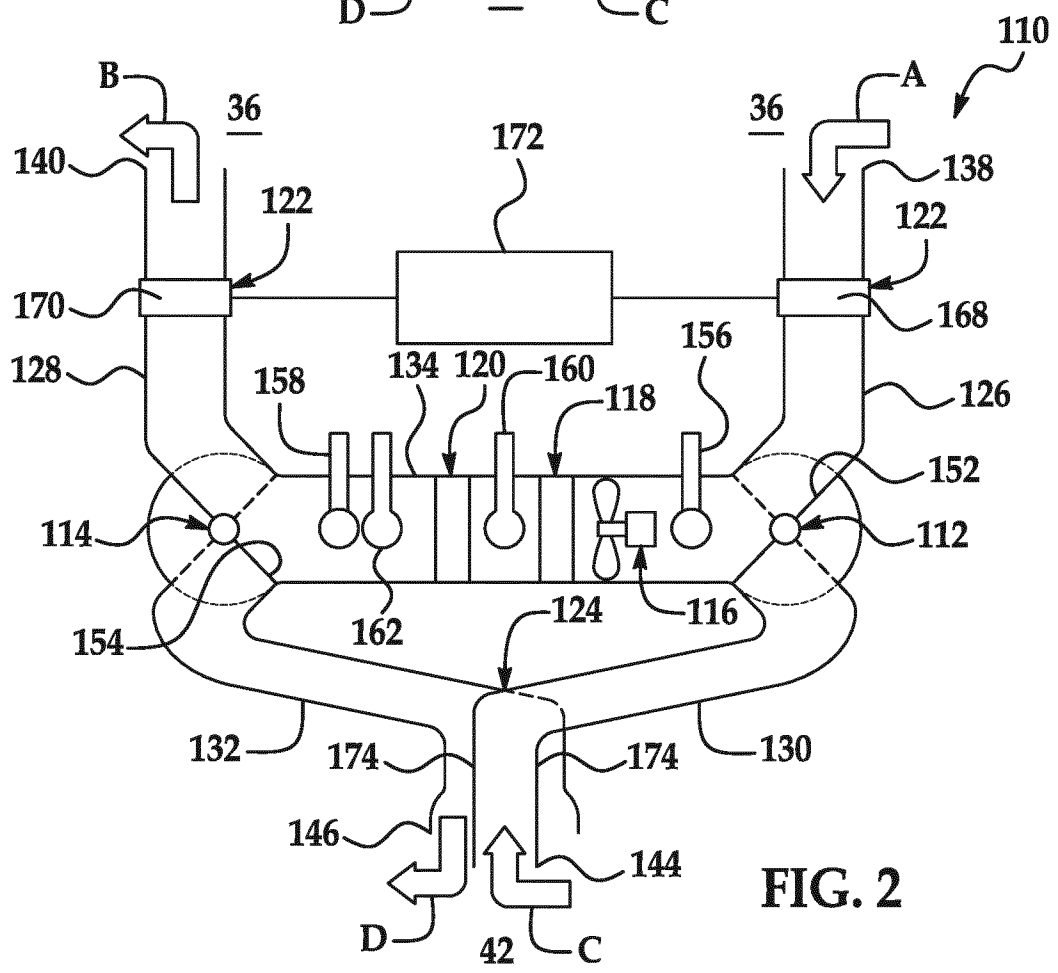
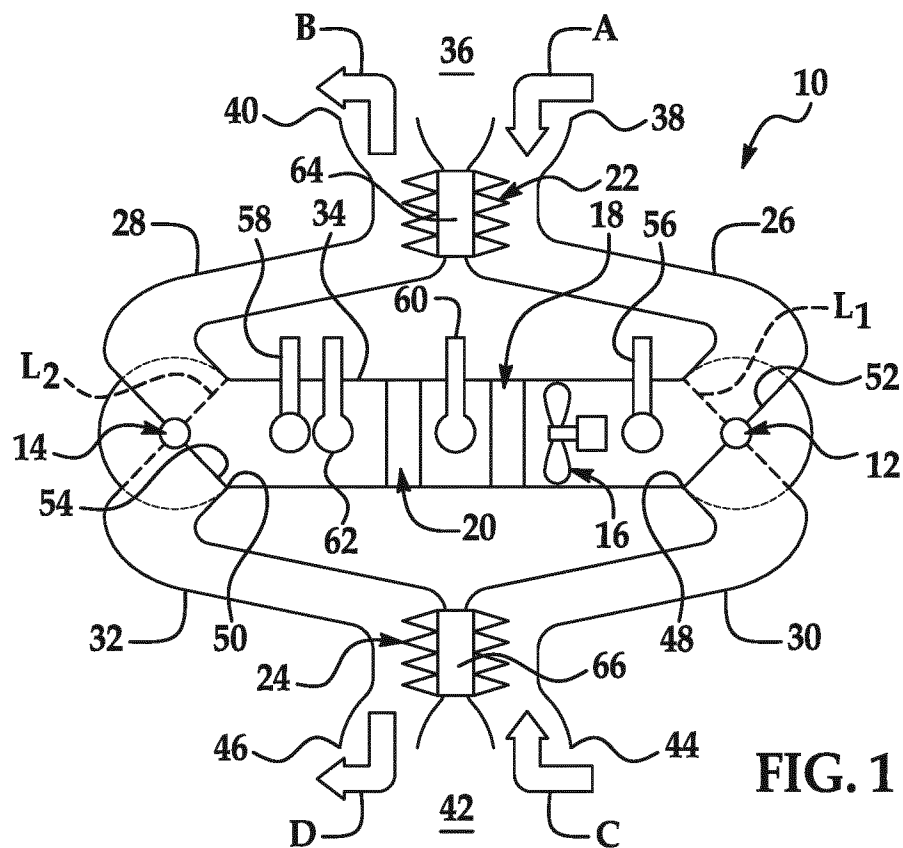
23. The method of treating air in a vehicle of any one of claims 19 to 22, comprising pumping reclaimed heat between said inside air outlet and said inside air inlet.

24. The method of treating air in a vehicle of any one of claims 19 to 23, comprising pumping reclaimed heat between said outside air outlet and said outside air inlet.

25. The method of treating air in a vehicle of any one of claims 19 to 24, comprising storing excess reclaimed heat from air exiting said inside air outlet to air entering said inside air inlet, and supplying the stored excess reclaimed heat to air received from said outside air inlet before the air moves through said regenerable filter.

26. The method of treating air in a vehicle of any one of claims 19 to 25, comprising pumping reclaimed heat between said inside air outlet and said outside air inlet.

27. The method of treating air in a vehicle of any one of claims 19 to 26, comprising pumping reclaimed heat between said outside air outlet and said inside air inlet.



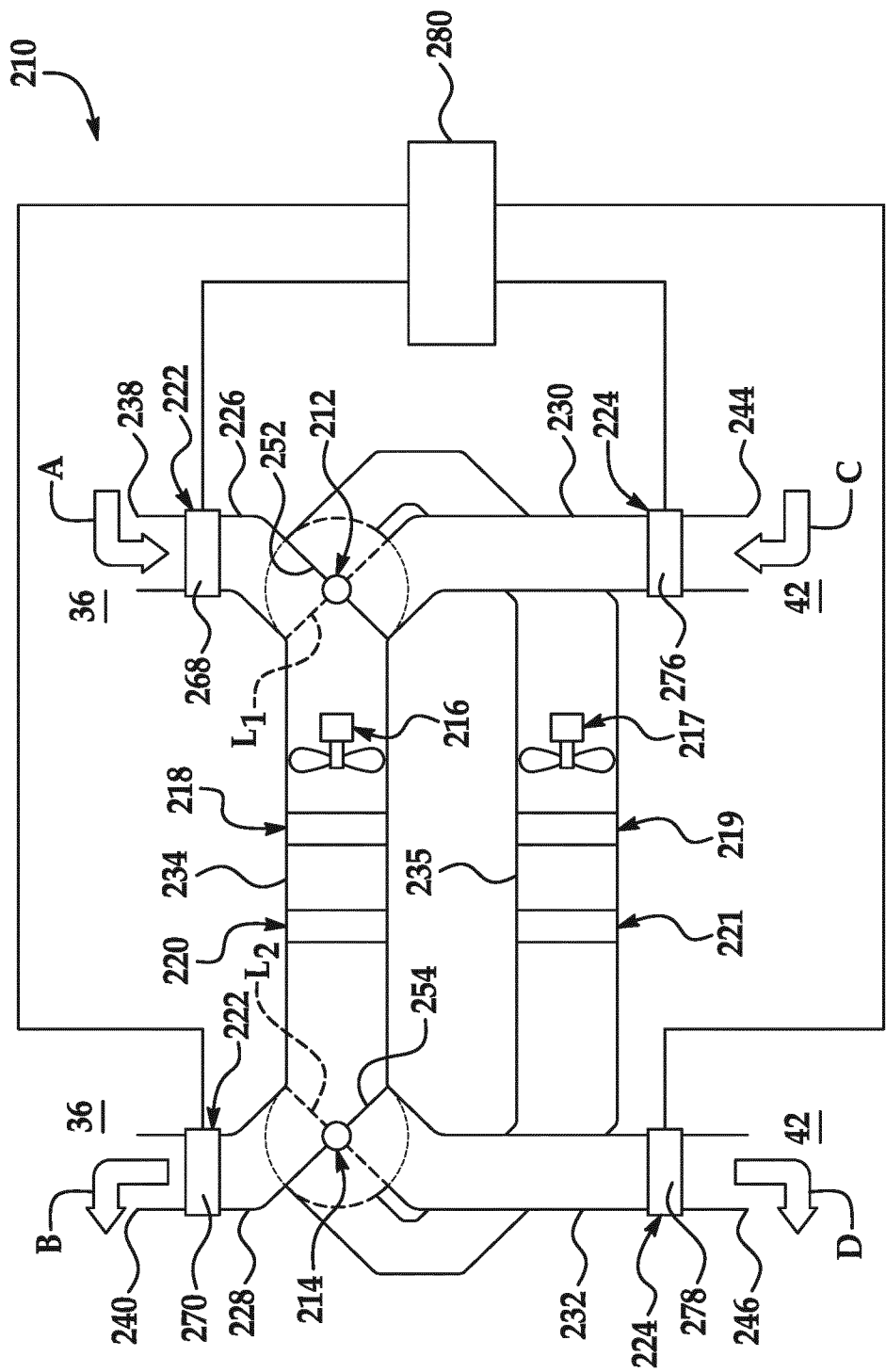


FIG. 3

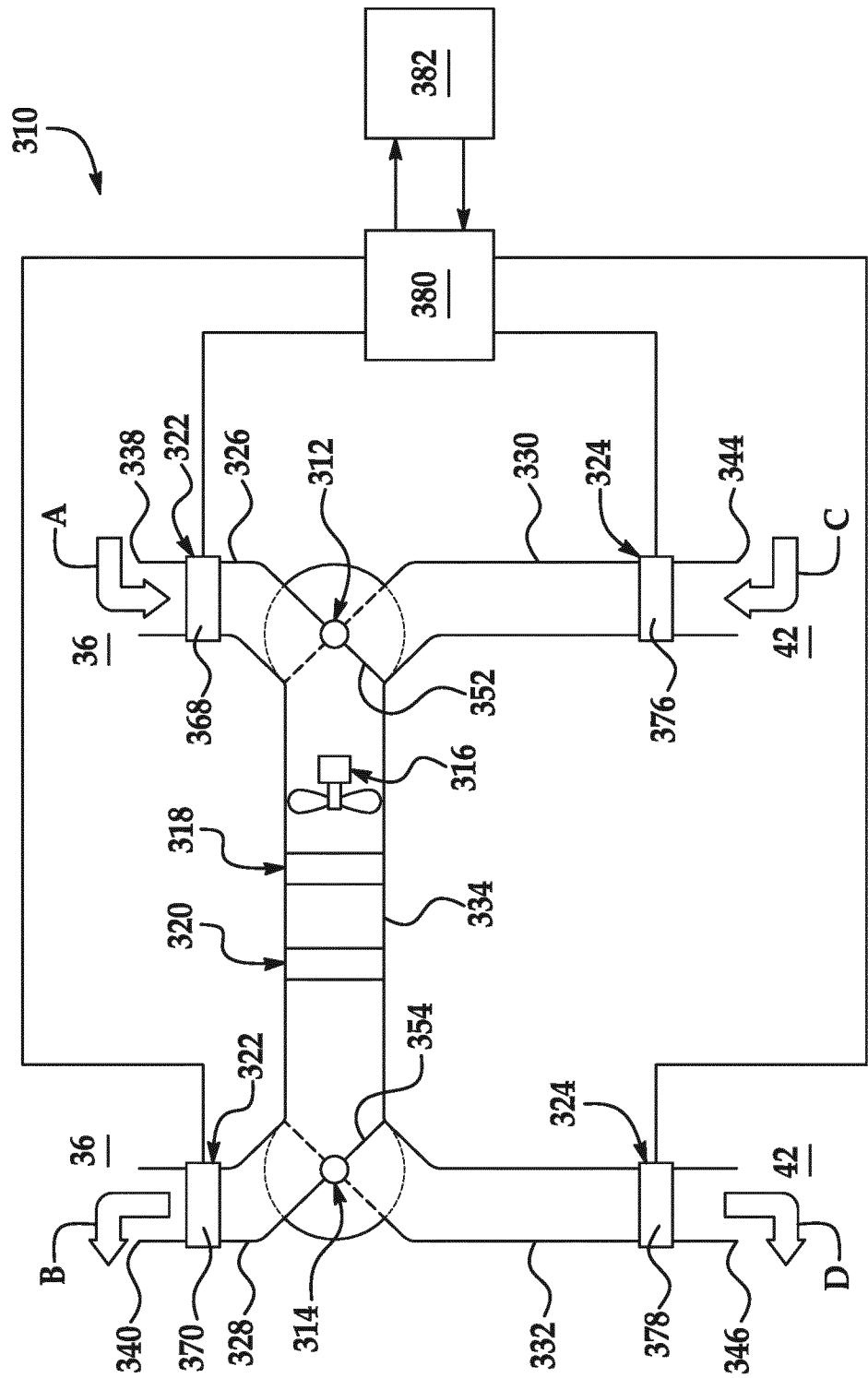
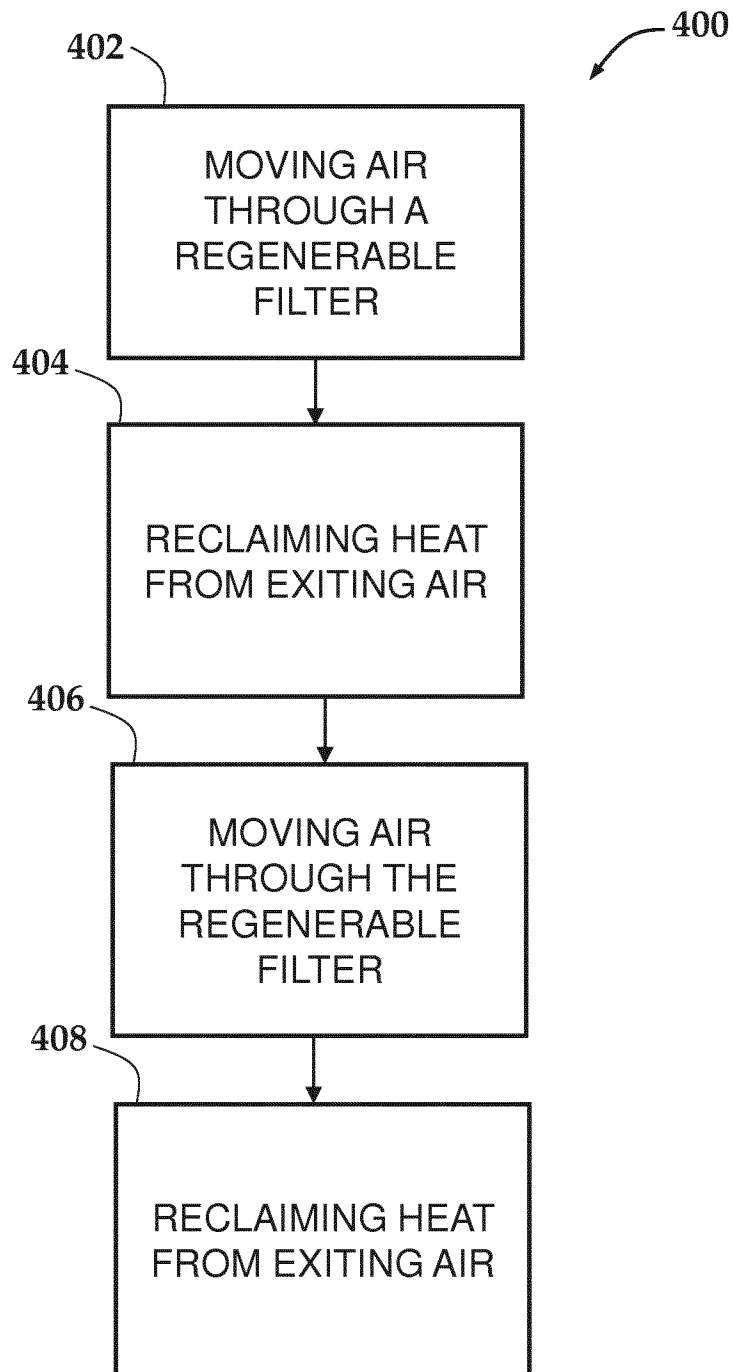


FIG. 4

**FIG. 5**

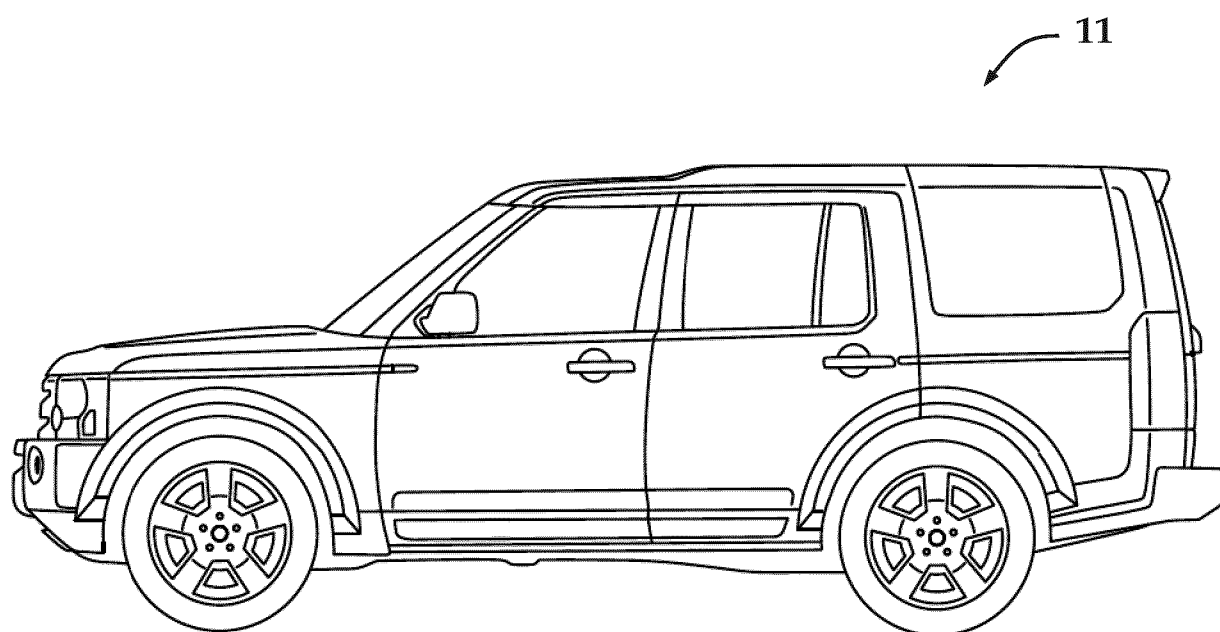


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/056956

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60H3/06 B01D53/04 B60H1/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60H B01D F24F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/042150 A1 (ENVERID SYSTEMS INC [US]) 26 March 2015 (2015-03-26) paragraphs [0009], [0026] - [0064]; figures 1a-1c -----	1,5,6,8, 18-22
A	GB 2 521 450 A (JAGUAR LAND ROVER [GB]) 24 June 2015 (2015-06-24) sentence 13, paragraph 7 - sentence 16, paragraph 20; figures -----	1-27
A	DE 197 30 291 A1 (DAIMLER BENZ AG [DE]) 21 January 1999 (1999-01-21) column 2, line 67 - column 4, line 5; figures -----	1-27
A	CN 201 618 493 U (MINTECH TIANJIN MINERALS CO LTD) 3 November 2010 (2010-11-03) abstract; figures -----	1-27
	-/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

13 June 2017

Date of mailing of the international search report

28/06/2017

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Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/056956

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	WO 2016/183237 A1 (ENVERID SYSTEMS INC [US]) 17 November 2016 (2016-11-17) paragraph [0133] - paragraph [0136]; figure 14 -----	1-27

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/056956

Patent document cited in search report		Publication date		Patent family member(s)		Publication date
WO 2015042150	A1	26-03-2015	CN	105745004 A		06-07-2016
			US	2016228809 A1		11-08-2016
			WO	2015042150 A1		26-03-2015

GB 2521450	A	24-06-2015	NONE			

DE 19730291	A1	21-01-1999	DE	19730291 A1		21-01-1999
			WO	9903693 A1		28-01-1999

CN 201618493	U	03-11-2010	NONE			

WO 2016183237	A1	17-11-2016	NONE			
