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(54) SINGLE EXCHANGER HVAC UNIT AND POWER MACHINES USING THE SAME

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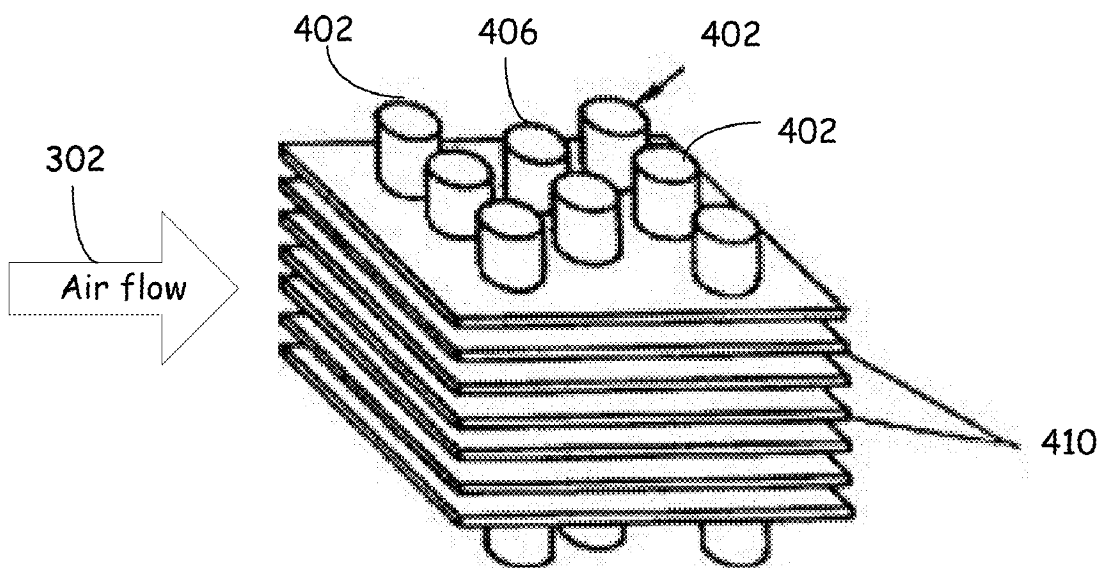
(57) **ABSTRACT**

Disclosed embodiments include HVAC systems, and power machines incorporating the same, which utilize an improved exchanger configuration in which the two separate heating and cooling exchangers of conventional systems are replaced with one composite exchanger. The composite heating and cooling exchanger includes nested heating and cooling tubes. The configuration of the tubes can be used to improve conductive efficiency in transferring heat energy to conductive fins, as well as to improve convective efficiency by increasing dwell time of air passing through the exchanger. The disclosed composite exchanger allows for a reduction in the overall exchanger package size package used in an HVAC unit.



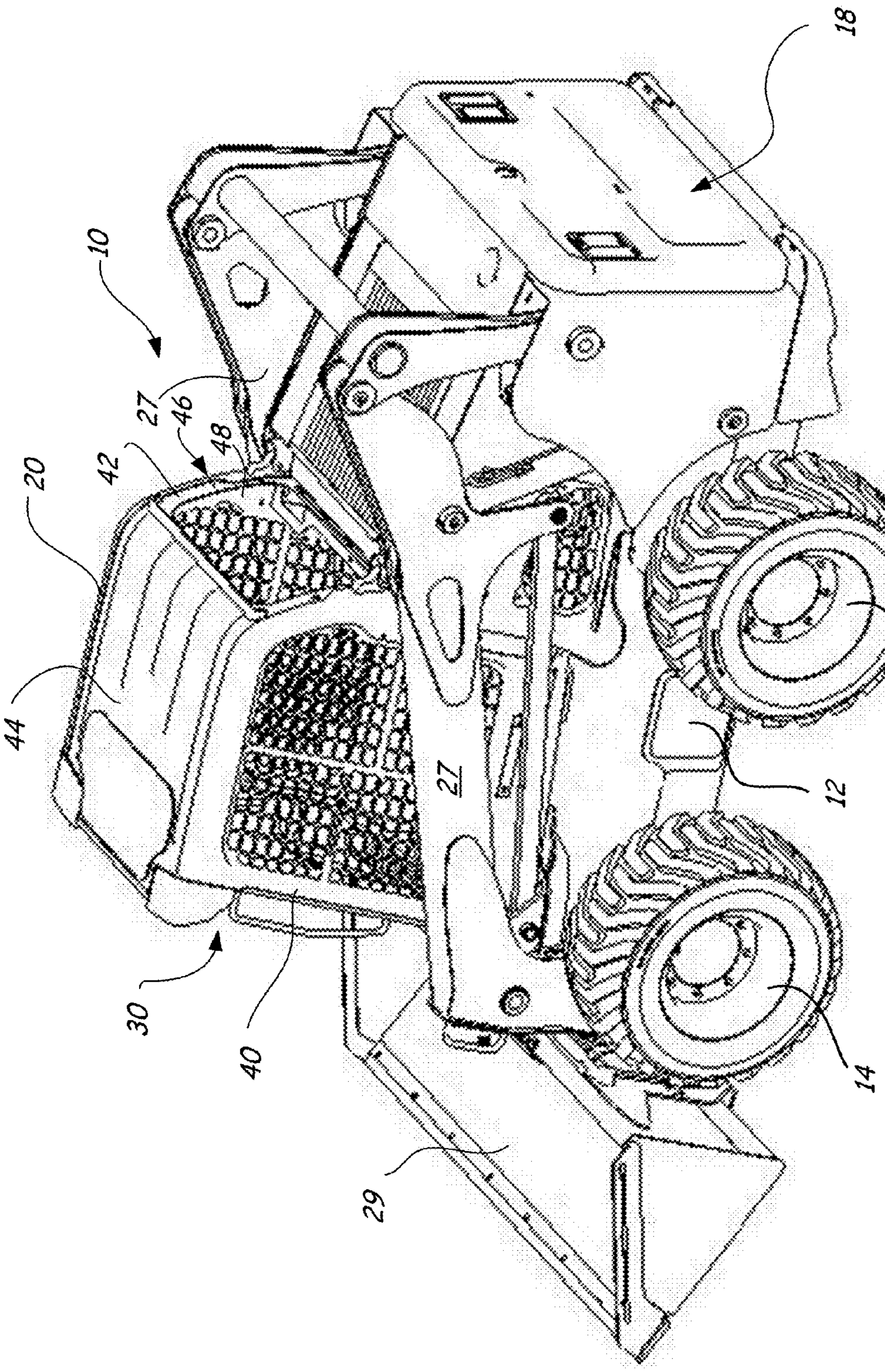


FIG. 1

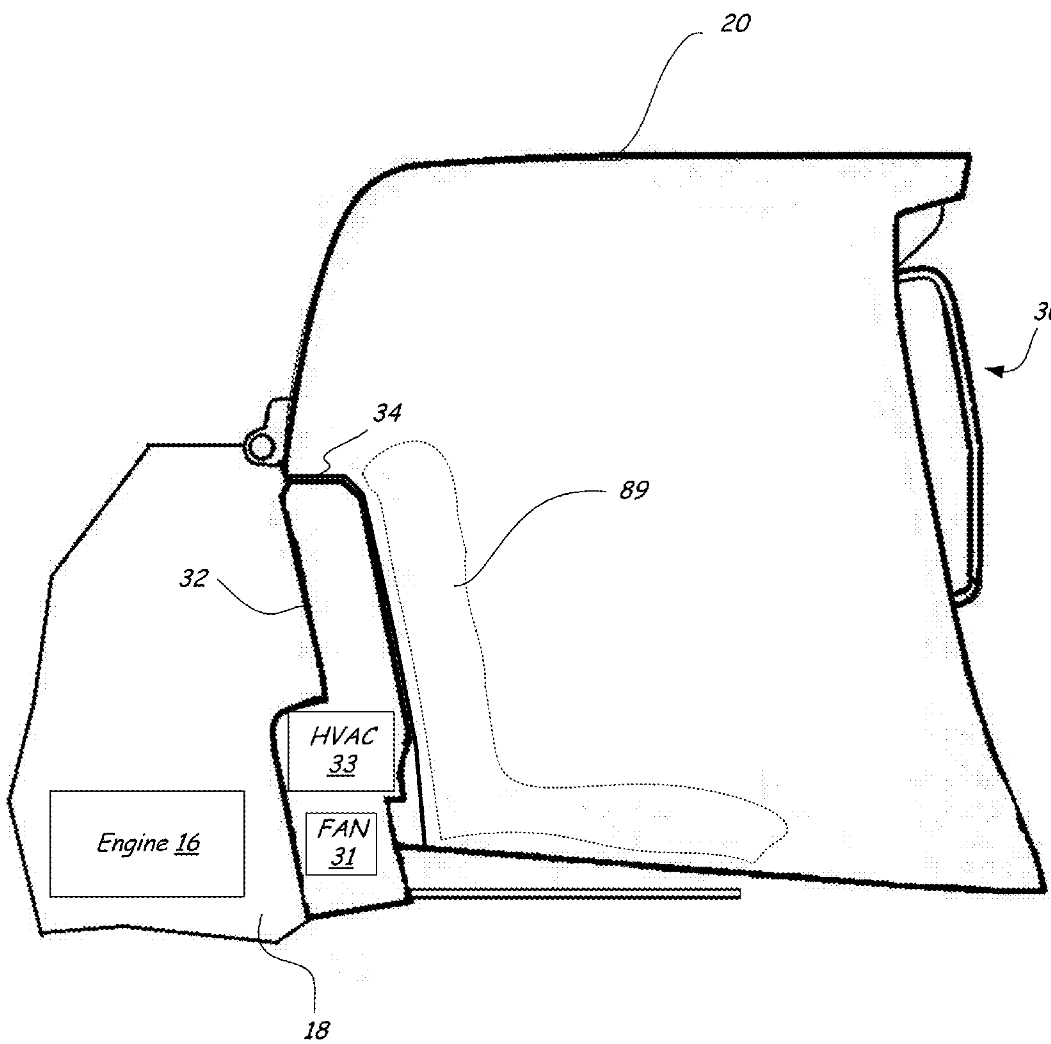


FIG. 2

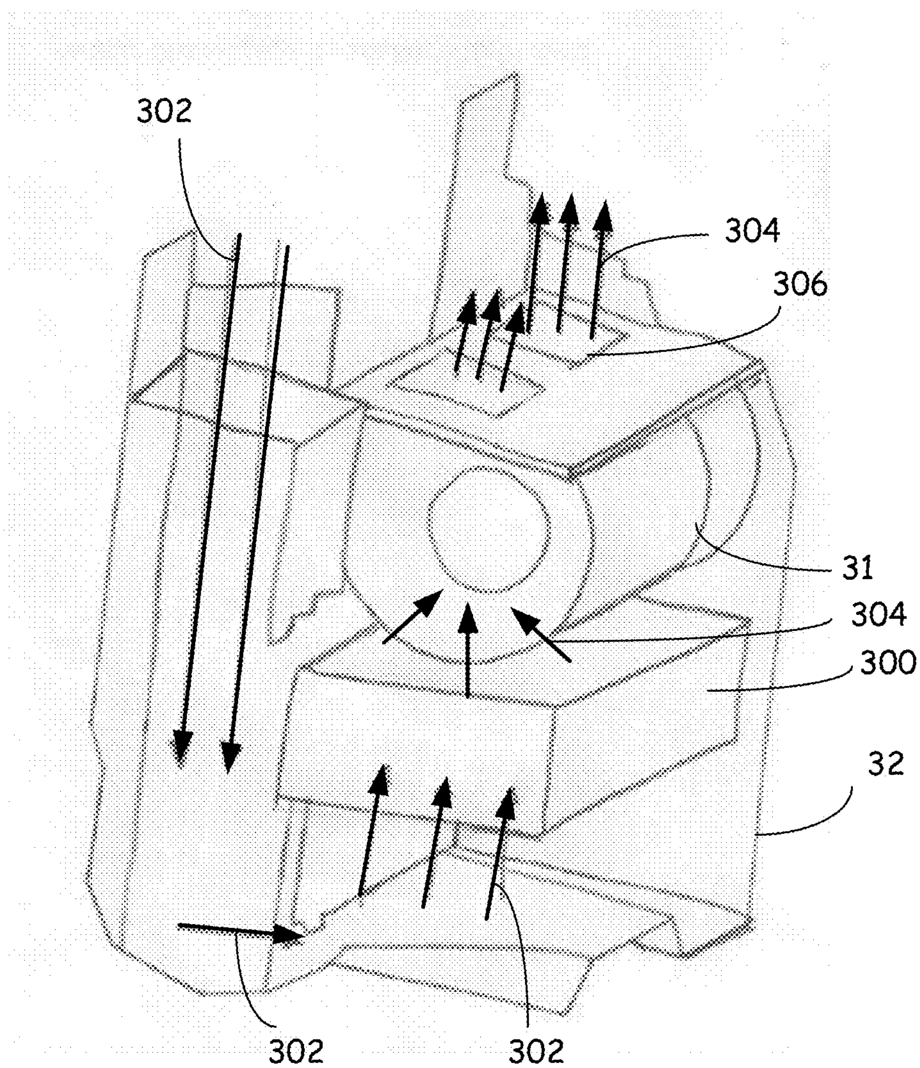


Fig. 3

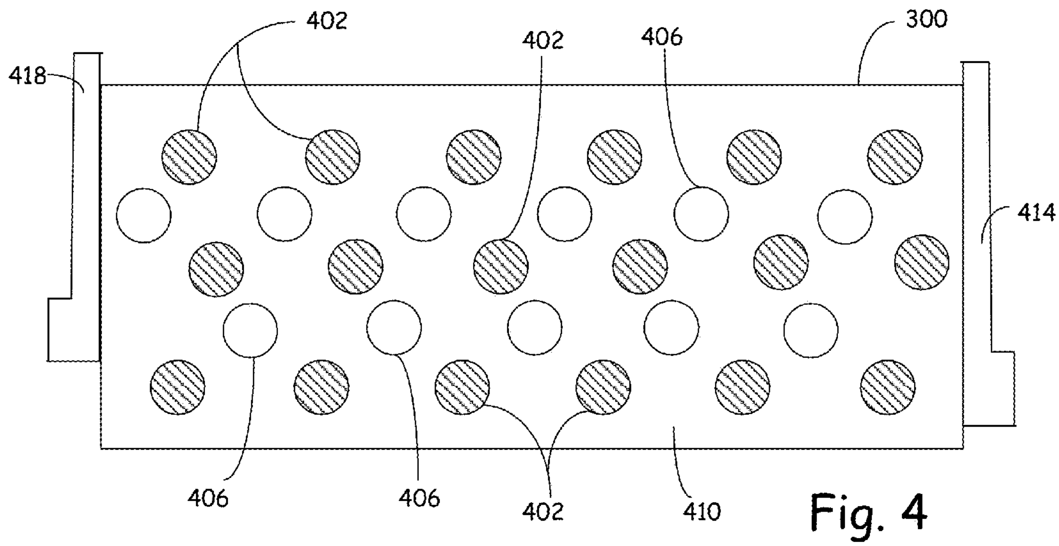

402
402
406
300
418
414
406
406
402
410

Fig. 4

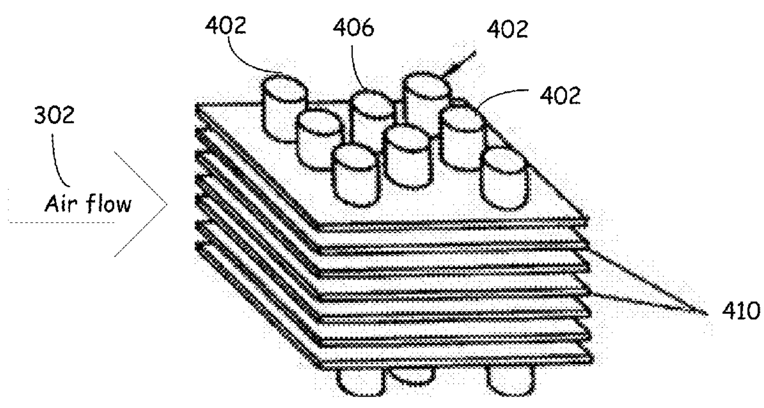

402
406
402
402
302
Air flow
410

Fig. 5

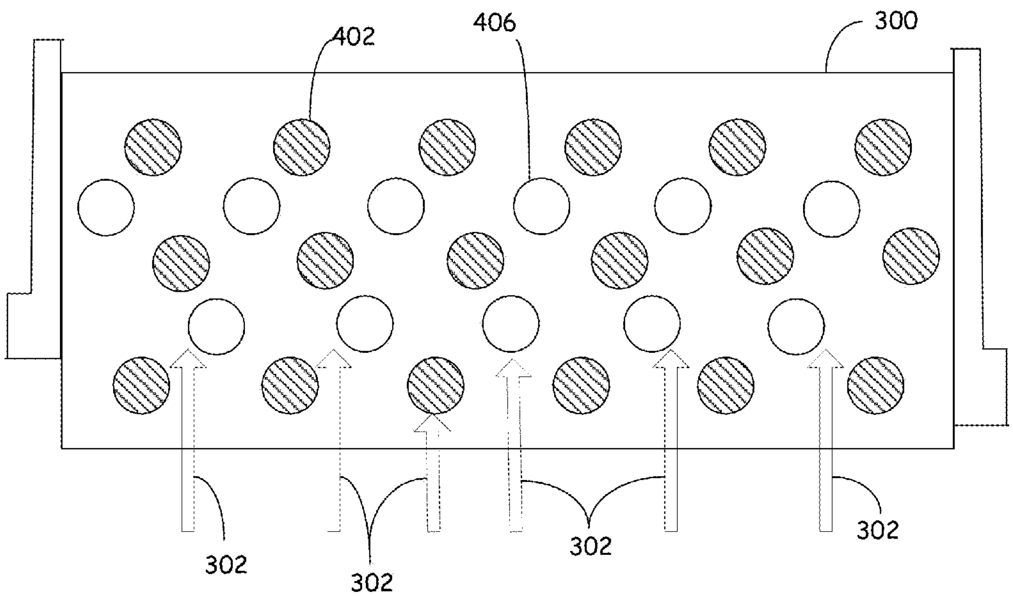


Fig. 6

SINGLE EXCHANGER HVAC UNIT AND POWER MACHINES USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application is based on and claims the benefit of U.S. provisional patent application Ser. No. 61/793,579, filed Mar. 15, 2013, the content of which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] The present disclosure relates to heating, ventilating, and air conditioning systems (HVAC) for power machines, particularly compact construction equipment.

[0003] Power machines include various work vehicles such as skid steer loaders, tracked loaders, excavators, telehandlers, and utility vehicles. Various power machines include cabs that protect the operator of the power machine and define, at least in part, an operator compartment in which an operator is positioned while operating the power machine. Enclosed operating compartments provide the option for providing the operator a climate controlled working environment with heating, ventilating, and air conditioning (HVAC) systems.

[0004] HVAC systems that provide both heating and cooling of the power machine cab utilize a heat exchanger and a cooling exchanger each capable of treating air that subsequently enters the operator's environment. A warm fluid (e.g., typically engine coolant) travels inside tubes in the heat exchanger when heated air is required to heat the cab, and an expanded gas (e.g., a refrigerant) travels inside tubes of the cooling exchanger when the cab environment is cooled. The respective fluids transfer their heat potential to their respective exchanger tubes via conduction. In typical HVAC systems, this heat is conducted to air treatment fins. The HVAC system then forces air over the tubes and fins to treat the air via convection.

[0005] While HVAC systems provide desirable operating environments in compact construction equipment, the compact nature of such power machines leaves little space for HVAC systems, meaning that smaller HVAC exchanges are preferable. One way to reduce the physical size of HVAC packages is to decrease the overall volume of the exchangers while increasing the number of air treatment fins in communication with each exchanger. However, this is typically accomplished by reducing the spacing between the fins and inherently leads to plugging of the fins due to debris in the air stream. Another way to reduce the physical size of HVAC packages is to increase the airflow across the heating and cooling exchangers. However, since the air needs sufficient dwell-time crossing the exchangers to become effectively treated, this method has limited effectiveness. In addition, forcing additional air past exchanges can generate noise as well as require more power draw from the blowing fan.

[0006] The discussion above is merely provided for general background information and is not intended to be used as an aid in determining the scope of the claimed subject matter.

SUMMARY

[0007] Disclosed embodiments include HVAC systems, and power machines incorporating the same, which utilize an improved exchanger configuration in which the two separate heating and cooling exchangers of conventional systems are replaced with one composite exchanger. The configuration of the tubes can be used to improve conductive efficiency in transferring heat energy to conductive fins, as well as to improve convective efficiency by increasing dwell time of air passing through the exchanger. The composite exchanger allows for a reduction in the overall exchanger package size package used in an HVAC unit.

[0008] In one embodiment, a composite exchanger has a plurality of cooling tubes configured to be coupled to a source of a cooling material and to selectively allow the cooling material to travel in an interior of each of the plurality of cooling tubes. The composite exchanger also has a plurality of heating tubes configured to be coupled to a source of heating material and to selectively allow the heating material to travel in an interior of each of the plurality of heating tubes. A plurality of conductive fins are in contact with the plurality of cooling tubes and the plurality of heating tubes to conductively transfer heat energy between the plurality of cooling tubes and the plurality of heating tubes. The plurality of cooling tubes and the plurality of heating tubes are positioned in a nested arrangement and staggered within each other.

[0009] In another embodiment, an HVAC system is disclosed. The HVAC system has sources of cooling material and heating material, a fan, and a composite exchanger. The composite exchanger has a plurality of tubes including a first group of tubes coupled to the source of cooling material for selectively receiving cooling material therein and a second group of tubes coupled to the source of heating material for selectively receiving heating material therein. A plurality of conductive fins are in contact with the plurality of tubes to conductively transfer heat energy between the first group and the second group of tubes. The first group of tubes and the second group of tubes are positioned within the composite exchanger in a nested arrangement. The fan is configured to force air into the composite exchanger across the fins.

[0010] In yet another embodiment, a power machine is disclosed. The power machine has an operator compartment and an HVAC system for providing conditioned air to the operator compartment. The HVAC system includes sources of cooling material and heating material, an operable input device for selecting a heating mode and a cooling mode, a fan, and a composite exchanger. The composite exchanger has tubes arranged in a plurality of rows with each tube coupled to one of the source of cooling material and the source of the heating material. Conductive fins are in contact with the plurality of tubes to conductively transfer heat energy between the plurality of tubes coupled to the cooling material and the plurality of tubes coupled to the heating material.

[0011] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1** is a schematic perspective view of one example embodiment of a power machine having an HVAC system in accordance with disclosed embodiments.

[0013] FIG. **2** is a diagrammatic side sectional view of portions of the power machine shown in FIG. **1**.

[0014] FIG. **3** is a diagrammatic illustration of portions of an HVAC system and housing including a composite heating and cooling exchanger in accordance with disclosed embodiments.

[0015] FIG. **4** is a diagrammatic end view illustration of the composite heating and cooling exchanger shown in FIG. **3**.

[0016] FIG. **5** is an illustration of a portion of the exchanger shown in FIGS. **3** and **4** and showing the orientation of nested and staggered heating and cooling tubes relative to conductive fins.

[0017] FIG. **6** is a diagrammatic end view illustration similar to FIG. **4**, and illustrating features which increase air tumbling.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0018] The concepts disclosed herein are not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. Rather, the disclosed concepts are capable of being practiced or carried out in various embodiments other than the exemplary embodiments discussed below. The terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," or "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings.

[0019] In power machines, especially compact construction equipment, space is limited for placement of HVAC heating and cooling exchangers for treating or conditioning air. The disclosed embodiments discussed below provide for reduced exchanger package size used in an HVAC unit by replacing two separate heating and cooling exchangers with a single composite exchanger. The innovative composite exchanger eliminates different manufacturing configurations, as all heating and/or cooling packages can use the same single exchanger. The composite exchanger provides space and cost savings.

[0020] FIG. **1** illustrates a power machine **10**, in the form of a skid steer loader as an example of a power machine on which an HVAC system composite exchanger of the present disclosure is advantageously employed. However, the disclosed embodiments are not limited to use in a skid steer loader, but rather, disclosed embodiments include use of the exchanger in the HVAC system of any power machine. For example, the disclosed exchanger can be used in power machines such as tracked loaders, excavators, telehandlers, utility vehicles, and other power machines.

[0021] Power machine **10** includes a frame **12**, supported by tractive elements in the form of wheels **14** that are driven through a suitable power train (not shown). The power train can include hydraulic motors that are driven in turn by a hydraulic power supply. Other power machines can employ other tractive elements such as tracks. A power supply in the form of an engine mounted in an engine compartment **18** (the location of which is generally shown in FIG. **1**) that is located within the frame **12** and is generally rearward of a cab or operator enclosure **20**, which is supported on the frame **12** that defines, at least part, of an operator compartment **30**. The loader has pivoting arms **27** that can be raised and lowered under power. A bucket implement **29** is supported by the arms **27** although other implements can be attached to the arms **27**.

[0022] The operator compartment **30** is capable of being generally enclosed including by cab **20**, which has a pair of opposing side walls **40** and **42**, a roof **44**, and a rear portion **46**, including a rear window **48** and a back wall **34** (shown in FIG. **2**). On a front side of the power machine, the cab **20** has an aperture (not shown in FIG. **1**, which allows for entry into and exit from the operator compartment **30**, which is generally defined as a space enclosed by the side walls **40** and **42**, roof **44**, rear portion **46**, and back wall **34**. In addition, the operator compartment **30** may extend beneath the cab **20** and within a portion of the frame **12** of the power machine. In some embodiments, a door (not shown in FIG. **1** is rotatably attached to the cab so that when rotated into a closed position, the entry and exit aperture is covered or substantially covered.

[0023] The side walls **40** and **42** of the cab **20** are shown as being made of side plates (preferably steel) with a plurality of apertures formed therethrough. In addition, transparent windows can be attached to the side plates. Alternatively still, the side walls **40** and **42** may not have the pattern of apertures shown in FIG. **1**, but instead can have a large aperture which is covered by a transparent window. When the cab **20** is equipped with a door and windows are attached to the side walls **40** and **42**, the operator compartment is generally enclosed. An operator seat **89** is positioned in the operator compartment **30** and is shown outlined in dotted lines in FIG. **2**.

[0024] FIG. **2** provides a cut away of cab **20**, showing a portion of operator compartment **30** and an HVAC housing **32** mounted behind the cab **20**. HVAC system housing **32** houses an HVAC system **33** which includes the composite exchanger in accordance with disclosed embodiments. A primary HVAC system fan **31** is included to force conditioned air through one or more ducts into the operator compartment. With the exception of the use of the disclosed composite exchanger, HVAC system **33** can, in exemplary embodiments, be configured in accordance with the HVAC system disclosed in U.S. Pat. No. 6,223,807, issued to Asche et al. on May 1, 2001. However, disclosed embodiments are not limited to the particular HVAC system housing and/or engine compartment configurations illustrated. Instead, these illustrations are provided as a non-limiting example. For instance, it is not necessary that the HVAC system **33**, fan **31** and system housing **32** be located behind cab **20** in all types of power machines or in the particular location shown in FIG. **2**.

[0025] FIG. **3** illustrates a diagrammatic cutaway of HVAC housing **32** as shown in FIG. **2** containing HVAC system **33** and fan **31**. Also shown is a composite exchanger **300** of HVAC system **33** in accordance with one exemplary embodiment. As described below in greater detail, the composite exchanger **300** includes both heating tubes and cooling tubes nested together described below and illustrated in FIG. **4**. Because of the design of composite exchanger **300**, the HVAC system and housing **32** can be smaller allowing other systems or components to utilize space, which would otherwise not be available using conventional two exchanger configurations. As shown in FIG. **3**, air flow **302** is drawn in by fan **31** (or other fan), then travels up through composite exchanger **300** where it is treated. The resulting treated air **304** is pulled into the fan assembly **31** and then exits the HVAC system through openings **306** as shown.

[0026] FIG. **4** illustrates a diagrammatic cross-sectional view of the nested configuration of heating and cooling tubes in composite exchanger **300**. The term nested refers to the arrangement where cooling tubes **402** and heating tubes **406** are intermingled as opposed to being grouped together in two otherwise segregated groups. As shown in FIG. **4**, the cooling tubes **402** and the heating tubes **406** are nested in that they are arranged in alternating rows. In alternate embodiments, the heating and cooling tubes can be arranged so that they are otherwise intermingled such as by having both heating and cooling tubes in the same row. The rows of tubes are staggered with respect to each other, meaning at least some tubes do not align into columns but are laterally offset with respect to tubes in the contiguous rows. In some embodiments, some or all of the tubes are not aligned in rows contrary to the arrangement shown in FIG. **5**. Various embodiments can have some or all of the rows staggered with respect to any of the other rows in the composite exchanger. Showing one exemplary embodiment, for illustrative purposes cooling tubes **402** are represented using cross-hatching, while heating tubes **406** are represented without cross-hatching. Cooling material is selectively provided to cooling tubes **402** via source (not shown) in communication with cooling tubes **402** at coupling hose or connection **414**. A source of heating fluid, such as an engine coolant selectively provides heating fluid to tubes **406** via a coupling hose or connection **418**. With the heating and cooling exchangers combined into composite exchanger **300** having the heating **406** and cooling **402** tubes in a staggered arrangement, rows of tubes can be positioned closer together, resulting in a smaller standard exchanger that can be provided for all HVAC configurations of a particular model of power machine. In addition, tubes **402** and **406** are each in contact with conductive metal fins **410**. Fins **410** are oriented perpendicularly with respect to tubes **402** and **406** as is illustrated in FIG. **5**. Fins **410** are preferably made of a material that is highly thermally conductive such as aluminum or other similar materials. Air flow **302** passes by fins **410** and tumbles around tubes **402** and **406** to provide improved convective heat transfer to treat the air for use in conditioning the interior of cab **20**.

[0027] In exemplary embodiments, at most only one set of the nested tubes, i.e. either the cooling tubes **402** or the heating tubes **406**, supplied with heating or cooling material at any one time. The corresponding tubes will then conduct heat energy to the fins **410** as well as the other set of tubes **406** or **402** that are not being supplied with heating or cooling material, which will then tend to reach the same or similar heating or cooling potential as the tubes being supplied with heating or cooling material as the case may be, therein providing additional surface area to treat flowing air **302** that is forced across the exchanger **300**. All of these tubes will then similarly transfer their respective potential to the heating/cooling fins **410** also via conduction. This greatly enhances the conductive transfer of heat energy. Finally, the flowing air **302** across the exchanger **300** becomes treated normally via convection.

[0028] The disclosed staggered configuration of composite exchanger **300** does not lend itself to plugging, nor does it require any additional air flow or fan power to be effective, because the staggered design also increases the degree of air tumbling while passing through the exchanger, thus allowing more "raw" or untreated air to become treated, as well as allows for a much smaller overall package size. Many heating or cooling exchangers are inefficient because air can travel through the exchanger core in a relatively straight line without intersecting a cross-tube. This diminishes the amount of air that actually touches the exchanger tubes. Thus, due to skin-effect, the air that touches the fins is also reduced.

[0029] In contrast to conventional separate heating or cooling exchangers in which significant portions of the air flow can travel through the exchangers without intersecting a cross-tube, FIG. **6** illustratively shows the advantages of the configuration of exchanger **300**. In exchanger **300** in which cooling tubes **402** and heating tubes **406** are nested in alternating rows, and staggered along the width of the exchanger, very little if any of air flow **302** can travel in a straight line through the exchanger without a tube blocking the flow path and diverting the air causing it to tumble through the exchanger. The additional cross-tubes placed in the air stream to augment the air tumbling also provide a slightly larger dwell-time in the exchanger for the air to become more fully treated.

[0030] In some embodiments, the resulting improvements in convective heat energy transfer caused by the increased air tumbling combine with the improvements in conductive heat energy transfer discussed above to allow for less heating or cooling tubes to be used, without sacrificing cooling or heating potential. This can allow the size of the composite exchanger to be reduced even more as compared to the combined sizes of separate heat and cooling exchangers. For example, in one exemplary embodiment, it was found that the volume of the composite exchanger **300** package as compared to the combined sizes of separate heat and cooling exchangers could be reduced from 405 cubic inches to 246 cubic inches.

[0031] The embodiments described above provide important advantages by employing a single exchanger for both the heating and cooling functions. Considerable improvements in exchanger efficiency can be achieved, thereby allowing the size of exchange **300** to be less than the combined sizes of separate heating and cooling exchangers. This efficiency increase is partially due to the large discrepancy in heat transfer effectiveness between conduction and convection. For example, the coefficient of heat transfer "k" for aluminum is 117 Btu/ft^2-° F. The same coefficient "k" for air is only 0.014 Btu/ft^2-° F. This means that aluminum transfers heat about 8,357 times more readily as compared to air (117/0.014). By nesting the tubes **402** and **406** of exchanger **300**, more energy is transferred via conduction between the tubes **402** and **406** and fins **410**, thus improving efficiency.

[0032] Although concepts of the present disclosure have been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the disclosure.

What is claimed is:

1. A composite exchanger for a heating, ventilating and air conditioning (HVAC) system in a power machine, the composite exchanger comprising:

a plurality of cooling tubes configured to be coupled to a source of a cooling material and to selectively allow the cooling material to travel in an interior of each of the plurality of cooling tubes;

a plurality of heating tubes configured to be coupled to a source of heating material and to selectively allow the heating material to travel in an interior of each of the plurality of heating tubes; and

a plurality of conductive fins in contact with the plurality of cooling tubes and the plurality of heating tubes to conductively transfer heat energy between the plurality of cooling tubes and the plurality of heating tubes;

wherein the plurality of cooling tubes and the plurality of heating tubes are positioned in a nested arrangement.

2. The composite exchanger of claim **1**, wherein the cooling tubes and the heating tubes are nested such that the composite exchanger has alternating rows of cooling tubes and heating tubes.

3. The composite exchanger of claim **2**, wherein tubes of a first row of cooling tubes are arranged laterally between a first end and a second end, and wherein at least one tube of a first row of heating tubes is staggered laterally relative to cooling tubes in the first row of cooling tubes.

4. The composite exchanger of claim **1**, wherein the plurality of heating tubes and the plurality of cooling tubes are arranged into a first row having a first set of tubes selected from the plurality of heating tubes and the plurality of cooling tubes and a second row having a second set of tubes selected from the plurality of heating tubes and the plurality of cooling tubes, wherein tubes in the first row are arranged laterally between a first end and a second end of the composite exchanger, and wherein at least one of the tubes in the second row is staggered laterally relative to the tubes in the first row.

5. The composite exchanger of claim **1**, wherein the plurality of conductive fins are oriented perpendicularly with respect to the plurality of cooling tubes and the plurality of heating tubes.

6. The composite exchanger of claim **1**, wherein the plurality of cooling tubes and the plurality of heating tubes are arranged into a plurality of rows each having sets of tubes selected from the plurality of heating tubes and the plurality of cooling tubes, wherein tubes in multiple of the plurality of rows are arranged laterally between a first end and a second end of the composite exchanger, and wherein the tubes in multiple of the plurality of rows are staggered laterally relative to tubes in others of the plurality of rows.

7. A heating, ventilating and air conditioning (HVAC) system in a power machine, the HVAC system comprising:

a source of cooling material;

a source of heating material;

a fan; and

a composite exchanger, comprising:

a plurality of tubes including a first group of tubes coupled to the source of cooling material for selectively receiving cooling material therein and a second group of tubes coupled to the source of heating material for selectively receiving heating material therein;

a plurality of conductive fins in contact with the plurality of tubes to conductively transfer heat energy between the first group and the second group of tubes; and

wherein the first group of tubes and the second group of tubes are positioned within the composite exchanger in a nested arrangement; and

wherein the fan is configured to force air into the composite exchanger across the fins.

8. The HVAC system of claim **7**, wherein the plurality of tubes are arranged into rows including a first row of tubes having tubes from one of the first group and the second group of tubes and second and third rows of tubes having tubes from the other of the first group and second group of tubes, wherein the first row is adjacent to the second row and the third row.

9. The HVAC system of claim **8**, wherein at least one of the tubes in the second row of tubes is staggered laterally with respect to the first row.

10. The HVAC system of claim **9**, wherein at least one of the tubes in the second row of tubes is staggered laterally with respect to the third row.

11. The HVAC system of claim **9**, wherein the plurality of conductive fins are oriented perpendicular to the plurality of cooling tubes and the plurality of heating tubes.

12. A power machine comprising:

an operator compartment; and

a heating, ventilating and air conditioning (HVAC) system configured to provide conditioned air to the operator compartment, the HVAC system comprising:

a source of cooling material;

a source of heating material;

at least one operable input device manipulable to select a heating mode and a cooling mode;

a fan; and

a composite exchanger having a plurality of tubes arranged in a plurality of rows with each tube coupled to one of the source of cooling material and the source of the heating material and such that one of a plurality of conductive fins is in contact with the plurality of tubes to conductively transfer heat energy between the plurality of tubes coupled to the cooling material and the plurality of tubes coupled to the heating material.

13. The power machine of claim **12**, wherein the plurality of conductive fins are oriented perpendicularly with respect to the plurality of tubes.

14. The power machine of claim **12**, wherein at least one of the rows in the composite exchanger is laterally staggered with respect to another row.

15. The power machine of claim **12**, wherein the plurality of rows are arranged into at least one row of tubes that are each coupled to the source cooling material and at least one row of tubes that are each coupled to the source heating material.

16. The power machine of claim **15**, wherein the rows are nested such that the composite exchanger has alternating rows of tubes coupled to the cooling material and tubes coupled to the heating material.

17. The power machine of claim **12**, wherein multiple of the plurality of conductive fins of the composite exchanger are in contact with the plurality of tubes to conductively transfer heat energy between the plurality of tubes coupled to the cooling material and the plurality of tubes coupled to the heating material.

* * * * *