MULTI-STAGE STAGGERED RADIATOR FOR HIGH PERFORMANCE LIQUID COOLING APPLICATIONS

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Abstract

A fluid-based cooling system including a multistage staggered radiator is configured to distribute a parallel airflow to each radiator in the multistage radiator. Each radiator is staggered so as to expose a total frontal area of the radiators to the parallel airflow in a minimized vertical space. Air ducts are configured to provide isolated air pathways into and, in some cases, out of each radiator in the multistage radiator.
Fig. 6
Fig. 7
MULTI-STAGE STAGGERED RADATOR FOR HIGH PERFORMANCE LIQUID COOLING APPLICATIONS

RELATED APPLICATIONS


FIELD OF THE INVENTION

[0002] The invention relates to an apparatus for cooling a heat producing device in general, and specifically, to a multi-stage staggered radiator used in liquid cooling applications.

BACKGROUND OF THE INVENTION

[0003] Cooling of high performance integrated circuits with high heat dissipation is presenting significant challenge in the electronics cooling arena. Conventional cooling with heat pipes and fan mounted heat sinks are not adequate for cooling chips with ever increasing wattage requirements.

[0004] A particular problem with cooling integrated circuits within personal computers is that more numerous and powerful integrated circuits are configured within the same size or smaller personal computer chassis. As more powerful integrated circuits are developed, each with an increasing density of heat generating transistors, the heat generated by each individual integrated circuit continues to increase. Further, more and more integrated circuits, such as graphics processing units, microprocessors, and multiple-chip sets, are being added to personal computers. Still further, the more powerful and more plentiful integrated circuits are being added to the same, or smaller size personal computer chassis, thereby increasing the per unit heat generated for these devices. In such configurations, conventional personal computer chassis’ provide limited dimensions within which to provide an adequate cooling solution. Conventionally, the integrated circuits within a personal computer are cooled using a heat sink and a large fin that blows air over the heat sink, or simply by blowing air directly over the circuit boards containing the integrated circuits. However, considering the limited free space within the personal computer chassis, the amount of air available for cooling the integrated circuits and the space available for conventional cooling equipment, such as heat sinks and fans, is limited.

[0005] Closed loop liquid cooling presents alternative methodologies for conventional cooling solutions. Closed loop liquid cooling solutions more efficiently reject heat to the ambient than air cooling solutions. A closed loop cooling system includes a cold plate to receive heat from a heat source, a radiator with fan cooling for heat rejection, and a pump to drive liquid through the closed loop. The design of each component is often complex and requires detailed analysis and optimization for specific applications. A conventional micro-tube radiator is designed with two header tanks and a set of parallel liquid channels through which heated liquid flows. The liquid channels have internal fins for enhanced heat transfer, and folded fins brazed on the outside for air cooling. The performance of the radiator depends on an air flow rate over the external radiator fins, a liquid flow rate through the liquid channels, a surface area of the internal fins and the external fins on the air side, and the difference in temperature between the air and the liquid. In general, the radiator performance is limited by the size of the radiator, the space constraints within which the radiator is installed, the ability of the fan to move air, and the resistance of the radiator to airflow.

SUMMARY OF THE INVENTION

[0006] What is needed is a more efficient cooling methodology for cooling integrated circuits within a personal computer. What is also needed is a cooling methodology that increases cooling performance within a given space constraint.

[0007] A fluid-based cooling system including a multi-stage staggered radiator is configured to distribute a parallel airflow to each radiator in the multistage radiator. Each radiator is staggered so as to expose a total frontal area of the radiators to the parallel airflow in a minimized vertical space. Air ducts are configured to provide isolated air pathways into and, in some cases, out of each radiator in the multistage radiator. By staggering the stages, more frontal area for cooling is obtained with the same total airflow.

[0008] In one aspect, a cooling system for cooling one or more heat generating devices is disclosed. The cooling system includes a multistage fluid-to-air heat exchanger including a plurality of individual fluid-to-air heat exchangers and a plurality of independent air ducts, a specific air duct coupled to each individual fluid-to-air heat exchanger, wherein each air duct is configured to provide a portion of an input airflow received by the multistage fluid-to-air heat exchanger to a corresponding fluid-to-air heat exchanger, further wherein the plurality of fluid-to-air heat exchangers are positioned in a staggered configuration such that a frontal area of the multistage fluid-to-air heat exchanger is less than a sum of a frontal area of each fluid-to-air heat exchanger within the multistage fluid-to-air heat exchanger, and a fluid based cooling loop coupled to the multistage fluid-to-air heat exchanger, wherein the cooling loop is configured to provide heated fluid to each of the multistage fluid-to-air heat exchangers. The multistage fluid-to-air heat exchanger can be a multistage radiator, and each individual fluid-to-air heat exchanger within the multistage radiator can be a radiator. The cooling system can also include one or more air movers configured to provide the input airflow to the multistage fluid-to-air heat exchanger. In this case, each air mover can be a fan. Each cooling loop can also include one or more heat exchangers and a pump. The cooling loop can be configured to fluidically couple the plurality of individual fluid-to-air heat exchangers in series. Alternatively, the cooling loop can be configured to fluidically couple the plurality of fluid-to-air heat exchangers in parallel such that each individual fluid-to-air heat exchanger receives a portion of the heated fluid provided to the multistage radiator. In some embodiments, each independent air duct includes an output air duct dedicated to the corresponding fluid-to-air heat exchanger. In these embodiments, each independent air duct can be configured to form an isolated
air pathway through the multistage fluid-to-air heat exchanger via one of the individual fluid-to-air heat exchangers. In some embodiments, each independent air duct is configured to form an isolated air pathway to the corresponding individual fluid-to-air heat exchanger.

In another aspect, a multistage fluid-to-air heat exchanger includes a plurality of individual fluid-to-air heat exchangers positioned in a staggered configuration such that a frontal area of the multistage fluid-to-air heat exchanger is less than a sum of a frontal area of each individual fluid-to-air heat exchanger within the multistage fluid-to-air heat exchanger, a plurality of air ducts, an independent air duct coupled to each individual fluid-to-air heat exchanger, wherein each air duct is configured to provide a portion of an input airflow received by the multistage fluid-to-air heat exchanger to a corresponding individual fluid-to-air heat exchanger, and a plurality of fluid lines coupled to each of the plurality of individual fluid-to-air heat exchangers and configured to distribute fluid to each of the plurality of individual fluid-to-air heat exchangers, wherein the plurality of fluid lines includes an input fluid line to receive heated fluid and an output fluid line to output cooled fluid from the multistage radiator. The multistage fluid-to-air heat exchanger can be a multistage radiator, and each individual fluid-to-air heat exchanger within the multistage radiator can be a radiator. The plurality of individual fluid-to-air heat exchangers can be fluidically coupled in series. Alternatively, the plurality of fluid-to-air heat exchangers can be fluidically coupled in parallel such that each individual fluid-to-air heat exchanger receives a portion of the heated fluid provided to the multistage radiator. Each independent air duct can include an output air duct dedicated to the corresponding fluid-to-air heat exchanger. In some embodiments, each independent air duct is configured to form an isolated air pathway through the multistage fluid-to-air heat exchanger via one of the individual fluid-to-air heat exchangers. In some embodiments, each independent air duct is configured to form an isolated air pathway to the corresponding individual fluid-to-air heat exchanger.

Other features and advantages of the present invention will become apparent after reviewing the detailed description of the embodiments set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a cut out side view of an exemplary configuration of a multistage radiator.

FIG. 2A illustrates a relationship between the frontal area A of each individual radiator and a frontal area A' for the multistage radiator configuration.

FIG. 2B illustrates a relationship between the frontal area A of each individual radiator and the frontal area A' for a stacked radiator configuration.

FIG. 3 illustrates a perspective view of an exemplary configuration of the multistage radiator coupled to a cooling loop.

FIG. 4 illustrates a cut out side view of an alternative configuration of a multistage radiator.

FIG. 5 illustrates a first exemplary configuration of the four radiator multistage radiator.

FIG. 6 illustrates a second exemplary configuration of the four radiator multistage radiator.

FIG. 7 illustrates a third exemplary configuration of the four radiator multistage radiator.

The present invention is described relative to the several views of the drawings. Where appropriate and only where identical elements are disclosed and shown in more than one drawing, the same reference numeral will be used to represent such identical elements.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

Embodiments of the present invention are directed to a cooling system including a multistage liquid-to-air heat exchanger, where the cooling system removes heat generated by one or more heat generating devices within a personal computer. The heat generating devices include, but are not limited to, one or more central processing units (CPUs), a chipset used to manage the input/output of one or more CPUs, one or more graphics processing units (GPUs), and/or one or more physics processing units (PPUs), mounted on a motherboard, a daughter card, and/or a PC expansion card. The cooling system can also be used to cool power electronics, such as mosfets, switches, and other high-power electronics requiring cooling. In general, the cooling system described herein can be applied to any electronics sub-system that includes a heat generating device to be cooled. For simplicity, any sub-system installed within the personal computer that includes one or more heat generating devices to be cooled is referred to as a PC card.

The cooling system is preferably configured within a personal computer chassis. Alternatively, the cooling system is configured as part of any electronics system that includes heat generating devices to be cooled. The cooling system includes one or more air movers and a fluid-based cooling loop. As described herein, reference is made to a single air mover, although more than one air mover can be used. Each air mover is preferably a fan.

The cooling loop includes the multistage liquid-to-air heat exchanger, a pump, and at least one other heat exchanger. The components in the cooling loop are coupled via flexible fluid lines. In some embodiments, the multistage fluid-to-air heat exchanger is a radiator. As described herein, reference to a multistage radiator and a radiator are used. It is understood that reference to a radiator is representative of any type of fluid-to-air heat exchanger system unless specific characteristics of the radiator are explicitly referenced.

Each of the other heat exchangers in the cooling loop are coupled to either another heat exchanger, which is part of a different cooling loop or device, or to a heat generating device. As described herein, reference is made to a single heat exchanger within the cooling loop, although the cooling loop can include multiple heat exchangers.

The multistage radiator includes a plurality of individual radiators. As described herein, reference is made to a multistage radiator that includes two radiators, although the multistage radiator can include more than two radiators. Each radiator is configured in a staggered series such that each radiator receives a portion of a parallel airflow. On an input side of each radiator, an air duct is configured to
provide an isolated air pathway to each radiator. In some embodiments, an air duct is configured on an output side of each radiator. Each radiator is also coupled in series such that a cooling fluid flows from one radiator to another in series. The radiators are coupled in series via the fluid lines.

[0025] Heat generated from a heat generating device is received by the heat exchanger. The heat exchanger is configured with fluid channels through which fluid in the cooling loop passes. As the fluid passes through the heat exchanger, heat is passed to the fluid, and heated fluid is output from the heat exchanger and directed to the multistage radiator. The heated fluid is input to a first radiator in the multistage radiator. Airflow provided by the air mover is directed over and through the first radiator to cool the fluid. Cooled fluid is output from the first radiator and directed to a second radiator in the multistage radiator. Airflow directed over and through the second radiator cools the fluid. As the airflow directed to the second radiator is part of the same parallel airflow directed to the first radiator, the airflow directed to the second radiator is substantially equal in temperature to the airflow directed to the first radiator. However, since the fluid directed to the second radiator has already been cooled within the first radiator, the temperature of the fluid entering the second radiator is lower than the temperature of the fluid entering the first radiator. As such, the temperature difference, referred to as ΔT, between the fluid entering the first radiator and the airflow directed to the first radiator is greater than the temperature difference ΔT between the fluid entering the second radiator and the airflow directed to the second radiator.

[0026] FIG. 1 illustrates a cut out side view of an exemplary configuration of a multistage radiator. The multistage radiator includes a radiator 10 and a radiator 20 within an outer housing 18. The radiator 10 and the radiator 20 can be of the same or different types. The housing 18 includes an inlet opening 8 and an outlet opening 12 to allow airflow to pass through the housing 18. Internal ducting material 14, 16, 22 and the housing 18 are configured so as to provide isolated air pathways for each of the radiators 10, 20. In reference to FIG. 1, a first air pathway includes the radiator 10 and a second air pathway includes the radiator 20. Although not shown in FIG. 1, the housing 18, or additional internal ducting, is configured around the each radiator 10, 20 to direct the airflow from the front of the radiator to the back, substantially eliminating air from flowing out the sides of the radiator.

[0027] Each air pathway is defined by a corresponding air resistance through the air pathway. In some embodiments, the total air resistance of each air pathway is defined as the sum of the air resistance through the radiator, referred to as the radiator air resistance, and the air resistance within the air pathway, referred to as the ducting air resistance. In the staggered radiator configuration shown in FIG. 1, the air duct in the first air pathway is constructed nearest the radiator 20, indicated as cross-sectional area B, and the air duct in the second air pathway is constructed nearest the radiator 10, indicated as cross-sectional area A. Cross-sectional area A corresponds approximately to the inlet of the second air pathway, and cross-sectional area B corresponds approximately to the outlet of the first air pathway.

[0028] In some embodiments, the multistage radiator is configured to provide equal air flow to each radiator. Equal airflow corresponds to equal air resistance in each air pathway. As the total air resistance in each air pathway is measured as the sum of the radiator air resistance and the ducting air resistance, the desired total air resistance in a given air pathway is achieved by specifically configuring both the radiator and the duct of the given air pathway. Air pathways with equal total air resistance can each include radiators with the same air resistance, in which case the ducting air resistance for each air pathway is also the same, or each radiator can be configured with a different air resistance, in which case the correspond ducting air resistance for each air pathway is also different. In other embodiments, the multistage radiator is configured to provide different air flows to each radiator. In general, the total air resistance for a given air pathway is adjusted by changing the characteristics of the radiator, changing the cross-sectional area and/or the length of the duct, and/or adding/removing an impediment within the air duct, such as adding fluid lines and a pump of a cooling loop as in FIG. 3. By adjusting the total air resistance of the given air pathway, the amount of air distributed to the radiator in the given air pathway is adjusted.

[0029] The cooling effectiveness of a radiator is measured in part by the area of the front side of the radiator facing the on-coming airflow. The area of the front side is referred to as the frontal area of the radiator. In general, the larger the frontal area, the better the thermal performance of the radiator.

[0030] FIG. 2A illustrates a relationship between the frontal area A for each individual radiator and a frontal area A1 for the multistage radiator configuration. FIG. 2B illustrates a relationship between the frontal area A for each individual radiator and the frontal area A1 for a stacked radiator configuration. Stacking the radiators 10, 20 obtains a total frontal area, frontal area A11 plus frontal area A12, that is equal to the frontal area A1 of the entire stacked radiator configuration. By staggering the radiators 10, 20 as in the multistage configuration of FIG. 2A, the same total frontal area associated with the radiators 10, 20 is obtained in a smaller frontal area A1 of the multistage radiator. Such a configuration is particularly useful in space-constraint applications.

[0031] Individually, the thermal performance of each radiator is determined by its dimensions, such as the frontal area. However, as part of the cooling system, the thermal performance of one radiator compared to another radiator is dependent on the type of radiator use, the dimensions of the radiator, the temperature difference ΔT of the fluid to air provided to the radiator, and the amount of airflow through the radiator as measured by the total air resistance of the corresponding air pathway. Each of these parameters can be adjusted to meet specific performance requirements.

[0032] FIG. 3 illustrates a perspective view of an exemplary configuration of the multistage radiator coupled to a cooling loop. The cooling loop includes a heat exchanger 28, a pump 26, the radiator 10, and the radiator 20 coupled together via fluid lines 30, 32, 34, 36. A portion of the housing 18 (FIG. 1) is shown in FIG. 3, including the forward facing sides of the radiators 10, 20, the bottom support surface 24, and the forward and backward facing sides on opposing sides of the pump 26. The remaining portion of the outer housing 18 (FIG. 1) is not shown for
ease of illustration. Additional internal ducting material 18 is added at the output of the radiator 10. It is understood that alternative internal ducting configurations can be used to configure the first air pathway for the radiator 10 and the second air pathway for the radiator 20. The surface 24 includes access openings through which the fluid lines 30, 32 pass. In alternative embodiments, the pump 26 is positioned external to the multistage housing 18, thereby removing an impediment from the second air pathway.

[0033] In some embodiments, the cooling loop is configured to provide heated fluid from the heat exchanger 28 to the radiator 10, fluid from the radiator 10 to the radiator 20, and cooled fluid from the radiator 20 to the heat exchanger 28. In other embodiments, the fluid flow direction is reversed such that fluid flows from the heat exchanger 28 to the radiator 20, from the radiator 20 to the radiator 10, and from the radiator 10 to the heat exchanger 28. It is understood that the relative position of the pump 26 within the cooling loop can be different than the configuration shown in FIG. 3.

[0034] Although the multistage radiator of FIGS. 1-3 is configured with the radiator 10 in the front position and the radiator 20 in the back position relative to the direction of the air flow, the multistage radiator can alternatively be configured with the radiator positions reversed. FIG. 4 illustrates a cut out side view of an alternative configuration of a multistage radiator. The multistage radiator includes a radiator 110 and a radiator 120 within an outer housing 118. The multistage radiator of FIG. 4 is configured similarly and functions similarly to the multistage radiator of FIG. 1, except that the front radiator is included within a lower air pathway, and a back radiator is included within an upper air pathway. The terms “upper” and “lower” are relative terms only, and are used in reference to the relative positions within the FIG. 4. The housing 16 includes an inlet opening 108 and an outlet opening 112 similar to the inlet opening 8 and the outlet opening 12, respectively, of the multistage radiator of FIG. 1. Internal ducting material 114, 116, 122 and the housing 118 are configured so as to provide isolated air pathways for each of the radiators 110, 120. In reference to FIG. 4, a first air pathway includes the radiator 120 and a second air pathway includes the radiator 110.

[0035] The multistage radiator can also be extended to include more than two staggered radiators. The number of radiators included in the multistage radiator is limited to the available space into which the multistage radiator is positioned and the applicable size of each radiator. FIGS. 5-6 illustrate three exemplary configurations of a multistage radiator that includes four radiators. Each radiator in the series is coupled to the previous radiator by a fluid line, such as the fluid line 36 in FIG. 3. FIG. 5 illustrates a first exemplary configuration of the four radiator multistage radiator in which there are independent air ducts to direct airflow to each of the radiators 110, 120, 130, 140, however, there are no independent air ducts at the output of each radiator. For example, a first input air pathway to the radiator 140 is formed from the internal ducting material 136, 134, and a top and sides of a housing 146. A second input air pathway to the radiator 130 is formed from the internal ducting material 136, 126, 124, and sides of the housing 146. A third input air pathway to the radiator 120 is formed from the internal ducting material 126, 116, 114, and sides of the housing 146. A fourth input air pathway to the radiator 110 is formed from the internal ducting material 116, and a bottom and sides of the housing 146. Air flow output from each of the radiators 110, 120, 130, 140 is directed through a common area and output from the housing 146 via output opening 150.

[0036] FIG. 6 illustrates a second exemplary configuration of the four radiator multistage radiator in which partial independent ducts are added to the output of each radiator in the multistage radiator. In particular, the multistage radiator of FIG. 6 includes the multistage radiator of FIG. 5 plus partial independent ducts added to the output of each radiator 110, 120, 130, 140. The partial independent output ducts are formed from ducting material 128, 138, 148, and portions of the housing 146. The ducting material 128, 138, 148 does not extend completely to the output opening 150.

[0037] FIG. 7 illustrates a third exemplary configuration of the four radiator multistage radiator in which complete independent ducts are added to the output of each radiator in the multistage radiator. In particular, the multistage radiator of FIG. 7 includes the multistage radiator of FIG. 5 plus complete independent ducts added to the output of each radiator 110, 120, 130, 140. The complete independent output ducts are formed from ducting material 122, 132, 142, and portions of the housing 146. The ducting material 122, 132, 142 extends completely to the output opening 150. The multistage radiator of FIG. 7 is four-radiator version of the multistage radiator of FIG. 4.

[0038] The cooling system is described above as including a cooling loop that serially delivers fluid to each radiator. In other embodiments, the cooling loop is configured to split the heated fluid output from the heat exchanger and to provide heated fluid to each radiator in parallel via independent fluid lines. Output fluid lines form each radiator are recombined into a single fluid line that is provided as input to the heat exchanger. In this configuration, substantially same temperature fluid is provided to each radiator in parallel. As such, the temperature difference AT between the fluid entering the radiator and the airflow directed to the radiator is substantially the same for each radiator.

[0039] It is apparent to one skilled in the art that the present cooling system is not limited to the components shown in FIG. 3 and alternatively includes other components and devices. For example, although not shown in FIG. 3, the first cooling loop can also include a fluid reservoir. The fluid reservoir accounts for fluid loss over time due to permeation. The cooling system can also include one or more air movers, such as fans, to direct airflow to the multistage radiator.

[0040] The present invention has been described in terms of specific embodiments incorporating details to facilitate the understanding of the principles of construction and operation of the invention. Such reference herein to specific embodiments and details thereof is not intended to limit the scope of the claims appended hereto. It will be apparent to those skilled in the art that modifications may be made in the embodiment chosen for illustration without departing from the spirit and scope of the invention.

What is claimed is:

1. A cooling system for cooling one or more heat generating devices, the cooling system comprising:
a. a multistage fluid-to-air heat exchanger including a plurality of individual fluid-to-air heat exchangers and a plurality of independent air ducts, a specific air duct coupled to each individual fluid-to-air heat exchanger, wherein each air duct is configured to provide a portion of an input airflow received by the multistage fluid-to-air heat exchanger to a corresponding fluid-to-air heat exchanger, further wherein the plurality of fluid-to-air heat exchangers are positioned in a staggered configuration such that a frontal area of the multistage fluid-to-air heat exchanger is less than a sum of a frontal area of each fluid-to-air heat exchanger within the multistage fluid-to-air heat exchanger; and

b. a fluid-based cooling loop coupled to the multistage fluid-to-air heat exchanger, wherein the cooling loop is configured to provide heated fluid to each of the multistage fluid-to-air heat exchangers.

2. The cooling system of claim 1 wherein the multistage fluid-to-air heat exchanger is a multistage radiator, and each individual fluid-to-air heat exchanger within the multistage radiator is a radiator.

3. The cooling system of claim 1 further comprising one or more air movers configured to provide the input airflow to the multistage fluid-to-air heat exchanger.

4. The cooling system of claim 3 wherein each air mover comprises a fan.

5. The cooling system of claim 1 wherein each cooling loop further comprises one or more heat exchangers and a pump.

6. The cooling system of claim 1 wherein the cooling loop is configured to fluidically couple the plurality of individual fluid-to-air heat exchangers in series.

7. The cooling system of claim 1 wherein the cooling loop is configured to fluidically couple the plurality of fluid-to-air heat exchangers in parallel such that each individual fluid-to-air heat exchanger receives a portion of the heated fluid provided to the multistage radiator.

8. The cooling system of claim 1 wherein each independent air duct includes an output air duct dedicated to the corresponding fluid-to-air heat exchanger.

9. The cooling system of claim 8 wherein each independent air duct is configured to form an isolated air pathway through the multistage fluid-to-air heat exchanger via one of the individual fluid-to-air heat exchangers.

10. The cooling system of claim 1 wherein each independent air duct is configured to form an isolated air pathway to the corresponding individual fluid-to-air heat exchanger.

11. A multistage fluid-to-air heat exchanger comprising:

a. a plurality of individual fluid-to-air heat exchangers positioned in a staggered configuration such that the frontal area of the multistage fluid-to-air heat exchanger is less than a sum of a frontal area of each individual fluid-to-air heat exchanger within the multistage fluid-to-air heat exchanger;

b. a plurality of air ducts, an independent air duct coupled to each individual fluid-to-air heat exchanger, wherein each air duct is configured to provide a portion of an input airflow received by the multistage fluid-to-air heat exchanger to a corresponding individual fluid-to-air heat exchanger;

c. a plurality of fluid lines coupled to each of the plurality of individual fluid-to-air heat exchangers and configured to distribute fluid to each of the plurality of individual fluid-to-air heat exchangers, wherein the plurality of fluid lines includes an input fluid line to receive heated fluid and an output fluid line to output cooled fluid from the multistage radiator.

12. The multistage fluid-to-air heat exchanger of claim 11 wherein the multistage fluid-to-air heat exchanger is a multistage radiator, and each individual fluid-to-air heat exchanger within the multistage radiator is a radiator.

13. The multistage fluid-to-air heat exchanger of claim 11 wherein the plurality of individual fluid-to-air heat exchangers are fluidically coupled in series.

14. The multistage fluid-to-air heat exchanger of claim 11 wherein the plurality of fluid-to-air heat exchangers are fluidically coupled in parallel such that each individual fluid-to-air heat exchanger receives a portion of the heated fluid provided to the multistage radiator.

15. The multistage fluid-to-air heat exchanger of claim 11 wherein each independent air duct includes an output air duct dedicated to the corresponding fluid-to-air heat exchanger.

16. The multistage fluid-to-air heat exchanger of claim 15 wherein each independent air duct is configured to form an isolated air pathway through the multistage fluid-to-air heat exchanger via one of the individual fluid-to-air heat exchangers.

17. The multistage fluid-to-air heat exchanger of claim 11 wherein each independent air duct is configured to form an isolated air pathway to the corresponding individual fluid-to-air heat exchanger.