

COOLING SYSTEM AND METHOD FOR THERMAL CYCLER

TECHNICAL FIELD

[0001] The present disclosure relates broadly, but not exclusively, to cooling systems and methods for thermal cyclers.

BACKGROUND

[0002] Biological analysis systems, such as polymerase chain reaction (PCR) systems, are useful tools for conducting diagnostics and research in biological or biochemical samples. A PCR system typically has a thermal cycler that heats and cools the samples over a number of cycles to achieve the desired amplification of one or more target molecules.

[0003] Such repeated heating and cooling by the thermal cycler can generate a significant amount of heat that needs to be expelled for safe and efficient operation. In some conventional systems, a fan or blower may be mounted near the front side to blow cooling air through the internal components of the thermal cycler. However, the fan or blower mounted in that manner may generate noise toward the user. In other conventional systems that employ a heated cover, the heat may be transferred to the top lid, posing a risk to a user who may touch the top lid.

[0004] It may be desirable to provide methods and devices that can improve cooling of thermal cyclers or comfort and safety of the user.

SUMMARY

[0005] According to an aspect of the present disclosure, a cooling system for a thermal cycler is provided. The cooling system includes an air inlet disposed at a front housing member of the thermal cycler, an air outlet disposed at a rear housing member of the thermal cycler, a plurality of air channels formed within the thermal cycler between the air inlet and the air outlet, and a suction fan mounted adjacent to an air outlet. The

suction fan is operable to draw an air flow from the air inlet through the air channels for cooling the thermal cyclers, and to discharge the air flow at the air outlet.

[0006] According to another aspect of the present disclosure, a method of cooling a thermal cyclers is provided. The method includes drawing, by a suction fan, an air flow from an air inlet disposed at a front housing member of the thermal cyclers through a plurality of air channels disposed within the thermal cyclers for cooling the thermal cyclers, and discharging, by the suction fan, the air flow at an air outlet disposed at a rear housing member of the thermal cyclers. The suction fan is mounted adjacent to the air outlet.

[0007] According to another aspect of the present disclosure, a method of manufacturing a cooling system for a thermal cyclers is provided. The method includes providing an air inlet at a front housing member of the thermal cyclers, providing an air outlet at a rear housing member of the thermal cyclers, forming a plurality of air channels within the thermal cyclers between the air inlet and the air outlet, and mounting a suction fan adjacent to an air outlet. The suction fan is operable to draw an air flow from the air inlet through the air channels for cooling the thermal cyclers, and to discharge the air flow at the air outlet.

[0008] There is also disclosed a thermal cyclers having the cooling system as described.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Embodiments of the disclosure will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

[0010] Figure 1A shows a thermal cyclers according to the present disclosure.

[0011] Figure 1B shows an exploded view of the thermal cyclers of Figure 1A.

[0012] Figures 2A-2D show various schematic diagrams illustrating a cooling system for cooling the thermal cyclers of Figure 1A.

[0013] Figure 3 shows a block diagram illustrating control of the suction fan of the cooling system of Figure 2A.

[0014] Figure 4A shows a heated cover assembly of the thermal cyclers of Figure 1A in a closed position according to an example embodiment.

[0015] Figure 4B shows a hinge mechanism of the heated cover assembly of Figure 4A.

[0016] Figure 4C graphically shows different stages of opening the heated cover assembly of Figure 4A.

[0017] Figure 5A shows a heated platen assembly of the heated cover assembly of Figure 4A.

[0018] Figure 5B shows an exploded view of the heated platen assembly of Figure 5A.

[0019] Figure 5C shows a partial sectional view of the heated cover assembly of Figure 4A.

[0020] Figure 6 shows a flow chart illustrating a method of cooling a thermal cyclers according to an example embodiment.

[0021] Figure 7 shows a flow chart illustrating a method of manufacturing a cooling system for a thermal cyclers according to an example embodiment.

[0022] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the illustrations, block diagrams or flowcharts may be exaggerated in respect to other elements to help to improve understanding of the present embodiments.

DETAILED DESCRIPTION

[0023] The present disclosure provides systems and methods for managing heat generated in a thermal cyclers. In example embodiments, waste heat can be efficiently and adaptively removed by a single fan installed near the rear side of the thermal cyclers. Meanwhile, heat transfer to the top lid of the device can be reduced.

[0024] Embodiments will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements

or equivalents. For brevity, certain components, e.g. wires, connectors, fasteners, etc., may be omitted from the drawings.

[0025] Figure 1A shows a thermal cycler 100 according to the present disclosure. Figure 1B shows an exploded view of the thermal cycler 100 of Figure 1A. For example, the thermal cycler 100 can be a PCR instrument capable of performing both thermal cycling operations and biological/chemical analysis. Alternatively, the thermal cycler 100 can be a standalone device, and the analysis of the amplified nucleic acids is carried out downstream on a different instrument, for example, a sequencing instrument.

[0026] The thermal cycler 100 includes a top housing 102, a bottom housing 104, a back panel 106 and a base plate 108. A heated cover assembly 110 and a display assembly 112 are mounted to the top housing 102. A heated block assembly 114 and circuit boards 116a, 116b are disposed within the bottom housing 104. A fan bracket assembly 118 including a suction fan is also disposed within the bottom housing 104 adjacent to the back panel 106. A fanless power supply unit 120 (i.e. without an integrated fan) is supported by the base plate 108. The housing 102, bottom housing 104, back panel 106 and base plate 108 are typically made of a rigid plastic material by injection moulding. While two circuit boards 116a, 116b are shown, it will be appreciated that different number of circuit boards may be used to support the electronic components in alternate embodiments.

[0027] To operate the thermal cycler 100 after calibration, a user lifts a handle 122 of the heated cover assembly 110 to open a lid 124, loads samples onto the heated block assembly 114, and presses on the handle 122 to close the lid 124. The user can select one or more settings of the thermal cycling operation through a touch screen interface provided by the display assembly 112. Thereafter, the thermal cycler 100 performs a series of heating and cooling with predetermined parameters using the heated block assembly 114. During operation, the heated cover assembly 110 is also heated to improve thermal uniformity among the samples. As described in further details below, the thermal cycler 100 includes a cooling system that can efficiently remove the waste heat generated by the heated block assembly 114 and power supply unit 120 to prevent overheating while the thermal cycler 100 is idle or active. In addition, the heated cover assembly 110 includes features that can reduce heat transfer to the handle 122 or lid 124, while assisting with heating and sealing of the samples.

[0028] Figures 2A-2D show various schematic diagrams illustrating a cooling system 200 for cooling the thermal cycler 100. With reference to Figure 2A, the cooling system 200 includes an air inlet 202 disposed at a front housing member of the thermal cycler 100, and an air outlet 204 disposed at a rear housing member of the thermal cycler 100. The front housing member may be integrally formed with the bottom housing 104 (Figures 1A-1B), while the rear housing member may be in the form of the back panel 106. A plurality of air channels 206, 208, 210 (shown by series of arrows in Figure 2A) are formed within the thermal cycler 100 between the air inlet 202 and the air outlet 204. The cooling system 200 also includes a suction fan 212 mounted adjacent to an air outlet 204, for example, in the fan bracket assembly 118 (Figure 1A).

[0029] In use, the suction fan 212 can draw an air flow from the air inlet 202 through the air channels 206, 208, 210 for cooling the thermal cycler 100, and to discharge the air flow at the air outlet 204. For example, air flowing through air channel 206 can cool the heated block assembly 114 (particularly a heatsink of the heated block assembly 114), air flowing through air channel 208 can cool the fanless power supply unit 120, and air flowing through air channel 210 can cool electronic components of the circuit boards 116a, 116b (Figure 1B).

[0030] As can be seen in Figure 2A, at least one opening 214 is provided between an upstream section of air channel 206 and an upstream section of air channel 208 to direct a first portion of the air flow from the upstream section of air channel 206 to the upstream section of air channel 208. The size and/or placement of the at least one opening 214 may be selected to control the first portion of the air flow. For example, the first portion of the air flow may be between 10% and 20% of the air flow. In one implementation, the first portion of the air flow is about 15% of the air flow.

[0031] Referring to Figure 2B, at least one opening 216 is provided between an upstream section of air channel 206 and an upstream section of air channel 210 to direct a second portion of the air flow from the upstream section of air channel 206 to the upstream section of air channel 210. The size and/or placement of the at least one opening 216 is also selected to control the second portion of the air flow. For example, the second portion of the air flow may be between 10% and 20% of the air flow. In one implementation, the second portion of the air flow is about 15% of the air flow. Further, it can be seen from Figures 2A-2B that air channel 210 includes a first (e.g. left) passage 210a and a second (e.g. right) passage 210b. The first passage 210a and second passage 210b are separated at the upstream section of air channel 210 and joined at a

downstream section of air channel 210 before the suction fan 212. Figures 2C-2D show various air holes 218, 220, 222 where air flowing through downstream sections of air channels 208, 210 join air flowing through downstream section of air channel 206 before being discharged by the suction fan 212.

[0032] In other words, most of the air flow (about 60% to 80% of the total volume) is directed through air channel 206 to provide the necessary cooling capacity for the heated block assembly 114. The exact proportions of air flowing through the air channels 206, 208, 210 may be determined through modelling and simulation based on actual cooling requirements of the heated block assembly 114, power supply unit 120 and circuit boards 116a, 116b, as will be appreciated by a person skilled in the art.

[0033] In example embodiments, the suction fan 212 has variable speeds that may be controlled by closed-loop feedback. Figure 3 shows a block diagram illustrating control of the suction fan 212 of the cooling system 200 according to one implementation. Here, sensor 302 is used to detect the temperature of the electronic components of circuit boards, sensor 304 is used to detect the heatsink temperature of the heated block assembly 114, and sensor 306 is used to detect the heatsink temperature of the power supply unit 120. The outputs from sensors 302, 304, 306 are provided to a fan controller 308 to control the operation of the suction fan 212. For example, even when the thermal cycler 100 is in an idle mode, if the detected temperature of the power supply unit 120 exceeds a preset threshold, the suction fan 212 is activated to cool the power supply unit 120. The speed of the suction fan 212 may be controlled to reduce the noise generated (about 43 to 50 dB(A) in one example), while providing sufficient cooling. The suction fan 212 may be **deactivated** while the thermal cycler 100 is in the idle mode and the detected temperature of the power supply unit 120 is below the preset threshold.

[0034] On the other hand, when the thermal cycler 100 is in an active mode (i.e. with thermal cycling operation ongoing), the suction fan 212 may operate continuously to meet the cooling requirements, and the detected temperature **from one or more of the sensors 302, 304, 306 is** used to control the speed of the suction fan 212. In a first thermal cycling mode with **normal instrument enclosure temperature during** thermal cycling operation, the speed of the suction fan 212 may be at a medium level such that a noise level measured at a front side of the thermal cycler 100 is less than about 55dB(A). In a second thermal cycling mode with **higher instrument enclosure temperature during** thermal cycling operation (e.g. more cycles, larger temperature

ranges and/or greater temperature ramp rates), the speed of the suction fan 212 may be increased to a high level such that a noise level measured at a front side of the thermal cyclers 100 is less than about 65dB(A).

[0035] As the suction fan 212 is mounted at the rear side of the thermal cyclers 100, the suction fan 212 faces away from the user, and the noise generated by the suction fan 212 is at least partially shielded by the thermal cyclers 100. Further, by incorporating temperature sensors and selecting the appropriate suction fan, it is possible to use a single suction fan to provide the required cooling capacity for various components within the thermal cyclers 100, instead of separate fans for the heat-generating components. As a result, the number of moving parts can be reduced and maintenance can be simplified.

[0036] Figure 4A shows the heated cover assembly 110 of the thermal cyclers 100 of Figure 1A in a closed position according to an example embodiment. Figure 4B shows a hinge mechanism 400 of the heated cover assembly 110 of Figure 4A. Figure 4C graphically shows different stages of opening the heated cover assembly 110 of Figure 4A.

[0037] The heated cover assembly 110 is disposed on a top side of the thermal cyclers. For example, the heated cover assembly 110 is mounted to the top housing 102 (Figures 1A-1B) by a plurality of fasteners. In one example implementation, the fasteners are accessible from a rear side of the thermal cyclers 100, by first removing the back panel 106. Once the fasteners are removed, the heated cover assembly 110 can be directly lifted up. This arrangement can facilitate removal and assembly of the heated cover assembly 110, e.g. for servicing or interchange with another heated cover assembly. Furthermore, since the components below the heated cover assembly 110 remain sealed and the drip pan is not disturbed during such removal and assembly, re-calibration of the system is not required, thereby saving time.

[0038] In use, the heated cover assembly 110 is pivotable between a generally horizontal closed position 402 and a generally upright open position 404 by lifting or pressing on handle 122. Further, the heated cover assembly 110 is configured to automatically pivot to the open position 404 once the handle 122 is lifted. For example, the heated cover assembly 110 is actuated by the hinge mechanism 400 which includes at least one biasing member 406 (e.g. a torsional spring) configured to push the assembly 110 from the closed position 402, and at least one dampener 408 configured to slow the assembly 110 toward the open position 404. As a result, the heated cover assembly 110 does not come to a sudden stop at the open position 404, and a soft

opening is achieved. Additionally, the at least one biasing member 406 can prevent the heated cover assembly 110 from accidentally falling back to the closed position 402, thereby avoiding damaging the components or trapping the user's hand.

[0039] In the closed position 402, the heated cover assembly 110 presses onto a sample holder disposed on the sample block assembly 114 (Figure 1B), to provide heating to the top side of the sample holder. Figure 5A shows a heated platen assembly 500 of the heated cover assembly 110 of Figure 4A. Figure 5B shows an exploded view of the heated platen assembly 500 of Figure 5A.

[0040] The heated platen assembly 500 includes a first metal member 502, a heating element 504, a second metal member 506, and a plastic insulator 508. The first metal member 502 is arranged to contact the top cover of the sample holder when the heated cover assembly 110 is in the closed position. The heating element 504, which may be in the form of a Peltier element, can heat the first metal member 502 based on operating requirements. The plastic insulator 508 is fastened to the first metal member 502, but is positioned to separate the first metal member 502 and heating element 504 from the second metal member 506. The presence of the plastic insulator 508 between the first metal member 502 and the second metal member 506 can prevent heat transfer from the first metal member 502 by conduction to the second metal member 506. Using the plastic insulator 508 instead of an epoxy-based foam can also avoid the issue of foul smells being generated after intense heating.

[0041] When the heated cover assembly 110 is in the closed position, the second metal member 506 can exert a pressure on the plastic insulator 508 and the first metal member 502. A plurality of compression springs 510 are disposed between the second metal member 506 and the plastic insulator 508 such that the compression springs 510 are arranged to act on selected positions on the plastic insulator 508 to evenly distribute the pressure. A plurality of extension springs 512 are arranged to suspend the second metal member 506 from the lid 124, as shown in Figure 5C. The use of the compression springs 510 and extension springs 512 can further reduce heat transfer upward to the lid 124 as compression springs 510 and extension springs 512 facilitate the creation of physical air gaps between the plastic insulator 508 and second metal member 506 and between the second metal member 506 and lid 124. These physical air gaps are capable of further reducing heat transfer to lid 124. In addition, the extension springs 512 can provide lateral positional adjustment for self-alignment of the heated cover assembly 110, as compared with rigid supports, before the pressure is applied.

[0042] Figure 6 shows a flow chart 600 illustrating a method of cooling a thermal cyclor according to an example embodiment. At step 602, an air flow is drawn by a suction fan from an air inlet disposed at a front housing member of the thermal cyclor through a plurality of air channels disposed within the thermal cyclor for cooling the thermal cyclor. At step 604, the air flow is discharged by the suction fan at an air outlet disposed at a rear housing member of the thermal cyclor. The suction fan is mounted adjacent to the air outlet.

[0043] Figure 7 shows a flow chart 700 illustrating a method of manufacturing a cooling system for a thermal cyclor according to an example embodiment. At step 702, an air inlet is provided at a front housing member of the thermal cyclor. At step 704, an air outlet is provided at a rear housing member of the thermal cyclor. At step 706, a plurality of air channels are formed within the thermal cyclor between the air inlet and the air outlet. At step 709, a suction fan is mounted adjacent to an air outlet. The suction fan is operable to draw an air flow from the air inlet through the air channels for cooling the thermal cyclor, and to discharge the air flow at the air outlet.

[0044] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present disclosure as shown in the specific embodiments without departing from the scope of the disclosure as broadly described. For example, the number of air channels and proportions of the air flow going into each air channel may be suitably adjusted depending on cooling requirements of the respective components of the thermal cyclor. The geometry of the various air channels may also varied if the size and/or positions of the components change. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A cooling system for a thermal cyclor, the cooling system comprising:
an air inlet disposed at a front housing member of the thermal cyclor;
an air outlet disposed at a rear housing member of the thermal cyclor;
a plurality of air channels formed within the thermal cyclor between the air inlet and the air outlet; and
a suction fan mounted adjacent to the air outlet, wherein the suction fan is operable to draw an air flow from the air inlet through the air channels for cooling the thermal cyclor, and to discharge the air flow at the air outlet.
2. The cooling system as claimed in claim 1, wherein the plurality of air channels comprise a first air channel configured to cool a heated block assembly of the thermal cyclor.
3. The cooling system as claimed in claim 2, wherein the plurality of air channels further comprise a second air channel configured to cool a power supply of the thermal cyclor, and wherein the power supply does not comprise a fan.
4. The cooling system as claimed in claim 3, wherein the plurality of air channels further comprise a third air channel configured to cool electronic components of the thermal cyclor.
5. The cooling system as claimed in claim 3, further comprising at least one first opening configured to direct a first portion of the air flow from an upstream section of the first air channel to an upstream section of the second air channel, wherein a size of the at least one first opening is selected to control the first portion of the air flow.
6. The cooling system as claimed in claim 5, wherein the first portion of the air flow comprises between 10% and 20% of the air flow.
7. The cooling system as claimed in claim 4, further comprising at least one second opening configured to direct a second portion of the air flow from an upstream section of the first air channel to an upstream section of the third air channel, wherein a size of the at least one second opening is selected to control the second portion of the air flow.

8. The cooling system as claimed in claim 7, wherein the second portion of the air flow comprises between 10% and 20% of the air flow.
9. The cooling system as claimed in claim 7, wherein the third air channel comprises a first passage and a second passage, wherein the first and second passages are separated at the upstream section of the third air channel and joined at a downstream section of the third air channel before the suction fan.
10. The cooling system as claimed in claim 3, further comprising a sensor configured to detect a temperature of the power supply when the thermal cycler is in an idle mode, wherein the suction fan is activated if the detected temperature exceeds a threshold.
11. The cooling system as claimed in any one of the preceding claims, wherein a speed of the suction fan is variable based on a detected temperature within the thermal cycler.
12. The cooling system as claimed in claim 11, wherein a noise level of the suction fan measured at a front side of the thermal cycler is less than 55dB(A) in a first thermal cycling mode.
13. The cooling system as claimed in claim 11, wherein a noise level of the suction fan measured at a front side of the thermal cycler is less than 65dB(A) during an in a second thermal cycling mode.
14. A thermal cycler comprising the cooling system as claimed in any one of the preceding claims.
15. The thermal cycler as claimed in claim 14, further comprising a heated cover assembly disposed on a top side, wherein the heated cover assembly is mounted to a top housing member by a plurality of fasteners, and wherein the fasteners are accessible from a rear side of the thermal cycler.
16. The thermal cycler as claimed in claim 15, wherein the heated cover assembly is pivotable between a generally horizontal closed position and a generally upright open position, and wherein the heated cover assembly comprises at least one biasing member configured to push the assembly from the closed position and at least one dampener configured to slow the assembly toward the open position.

17. The thermal cyclers as claimed in claim 16, wherein the heated cover assembly further comprises:

a first metal member configured to contact a top cover of a sample holder when the heated cover assembly is in the closed position;

a heating element configured to heat the first metal member;

a second metal member; and

a plastic insulator separating the first metal member and the second metal member, wherein the plastic insulator is fastened to the first metal member,

wherein the second metal member is configured to exert a pressure on the plastic insulator and the first metal member when the heated cover assembly is in the closed position.

18. The thermal cyclers as claimed in claim 17, wherein the heated cover assembly further comprises a plurality of compression springs disposed between the second metal member and the plastic insulator, and wherein the compression springs are configured to act on selected positions on the plastic insulator to evenly distribute the pressure.

19. The thermal cyclers as claimed in claim 17 or 18, wherein the heated cover assembly further comprises a plurality of extension springs configured to suspend the second metal member from a top lid member.

20. A method of cooling a thermal cyclers, the method comprising:

drawing, by a suction fan, an air flow from an air inlet disposed at a front housing member of the thermal cyclers through a plurality of air channels disposed within the thermal cyclers for cooling the thermal cyclers; and

discharging, by the suction fan, the air flow at an air outlet disposed at a rear housing member of the thermal cyclers,

wherein the suction fan is mounted adjacent to the air outlet.

21. The method as claimed in claim 20, wherein the plurality of air channels comprises a first air channel, and wherein cooling the thermal cyclers comprises cooling a heated block assembly disposed along the first air channel.

22. The method as claimed in claim 21, wherein the plurality of air channels further comprises a second air channel, wherein cooling the thermal cyclers further comprises

cooling a power supply disposed along the second air channel, and wherein the power supply does not comprise a fan.

23. The method as claimed in claim 22, wherein the plurality of air channels further comprises a third air channel, and wherein cooling the thermal cyclers further comprises cooling electronic components disposed along the third air channel.

24. The method as claimed in claim 22, wherein drawing an air flow from the air inlet through the plurality of air channels comprises directing a first portion of the air flow from an upstream section of the first air channel to an upstream section of the second air channel through at least one first opening, and wherein a size of the at least one first opening is selected to control the first portion of the air flow.

25. The method as claimed in claim 22, wherein the first portion of the air flow comprises between 10% and 20% of the air flow.

26. The method as claimed in claim 23, wherein drawing an air flow from the air inlet through the air channels comprises directing a second portion of the air flow from an upstream section of the first air channel to an upstream section of the third air channel through at least one second opening, and wherein a size of the at least one second opening is selected to control the second portion of the air flow.

27. The method as claimed in claim 26, wherein the second portion of the airflow comprises between 10% and 20% of the air flow.

28. The method as claimed in claim 26, further comprising separating the second portion of the air flow at the upstream section of the third air channel into sub-flows along a first passage and a second passage, and combining the sub-flows at a downstream section of the third air channel before the suction fan.

29. The method as claimed in claim 22, further comprising detecting a temperature of the power supply when the thermal cyclers are in an idle mode, and activating the suction fan if the detected temperature exceeds a threshold.

30. The method as claimed in any one of claims 20 to 29, further comprising varying a speed of the suction fan based on a detected temperature within the thermal cyclers.

31. The method as claimed in claim 30, wherein a noise level of the suction fan measured at a front side of the thermal cyclor is less than 55dB(A) in a first thermal cycling mode.

32. The method as claimed in claim 30, wherein a noise level of the suction fan measured at a front side of the thermal cyclor is less than 65dB(A) in a second thermal cycling mode.

33. A method of manufacturing a cooling system for a thermal cyclor, the method comprising:

providing an air inlet at a front housing member of the thermal cyclor;

providing an air outlet at a rear housing member of the thermal cyclor;

forming a plurality of air channels within the thermal cyclor between the air inlet and the air outlet; and

mounting a suction fan adjacent to the air outlet;

wherein the suction fan is operable to draw an air flow from the air inlet through the air channels for cooling the thermal cyclor, and to discharge the air flow at the air outlet.

34. The method as claimed in claim 33, wherein forming the plurality of air channels comprises forming a first air channel for cooling a heated block assembly disposed along the first air channel.

35. The method as claimed in claim 34, wherein forming the plurality of air channels further comprises forming a second air channel for cooling a power supply disposed along the second air channel, and wherein the power supply does not comprise a fan.

36. The method as claimed in claim 35, wherein forming the plurality of air channels further comprises forming a third air channel for cooling electronic components disposed along the third air channel.

37. The method as claimed in claim 35, wherein forming the plurality of air channels further comprises forming at least one first opening to direct a first portion of the air flow from an upstream section of the first air channel to an upstream section of the second air channel through the at least one first opening, and selecting a size of the at least one first opening to control the first portion of the air flow.

38. The method as claimed in claim 37, wherein the first portion of the air flow comprises between 10% and 20% of the air flow.

39. The method as claimed in claim 36, wherein forming the plurality of air channels further comprises forming at least one second opening to direct a second portion of the air flow from an upstream section of the first air channel to an upstream section of the third air channel through the at least one second opening, and selecting a size of the at least one second opening to control the second portion of the air flow.

40. The method as claimed in claim 26, wherein the second portion of the airflow comprises between 10% and 20% of the air flow.