US 20020159883A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2002/0159883 A1**

Simon et al. (43) **Pub. Date: Oct. 31, 2002**

(54) **COMBINATION AIRFLOW STRAIGHTENER AND FINGER GUARD FOR USE WITH A FAN**

(76) Inventors: **Glenn C. Simon**, Auburn, CA (US); **Douglas L. Davies**, Meadow Vista, CA (US); **Philip D. Langley**, Granite Bay, CA (US)

Correspondence Address:
HEWLETT-PACKARD COMPANY
Intellectual Property Administration
P.O. Box 272400
Fort Collins, CO 80527-2400 (US)

(21) Appl. No.: **09/846,059**

(22) Filed: **Apr. 30, 2001**

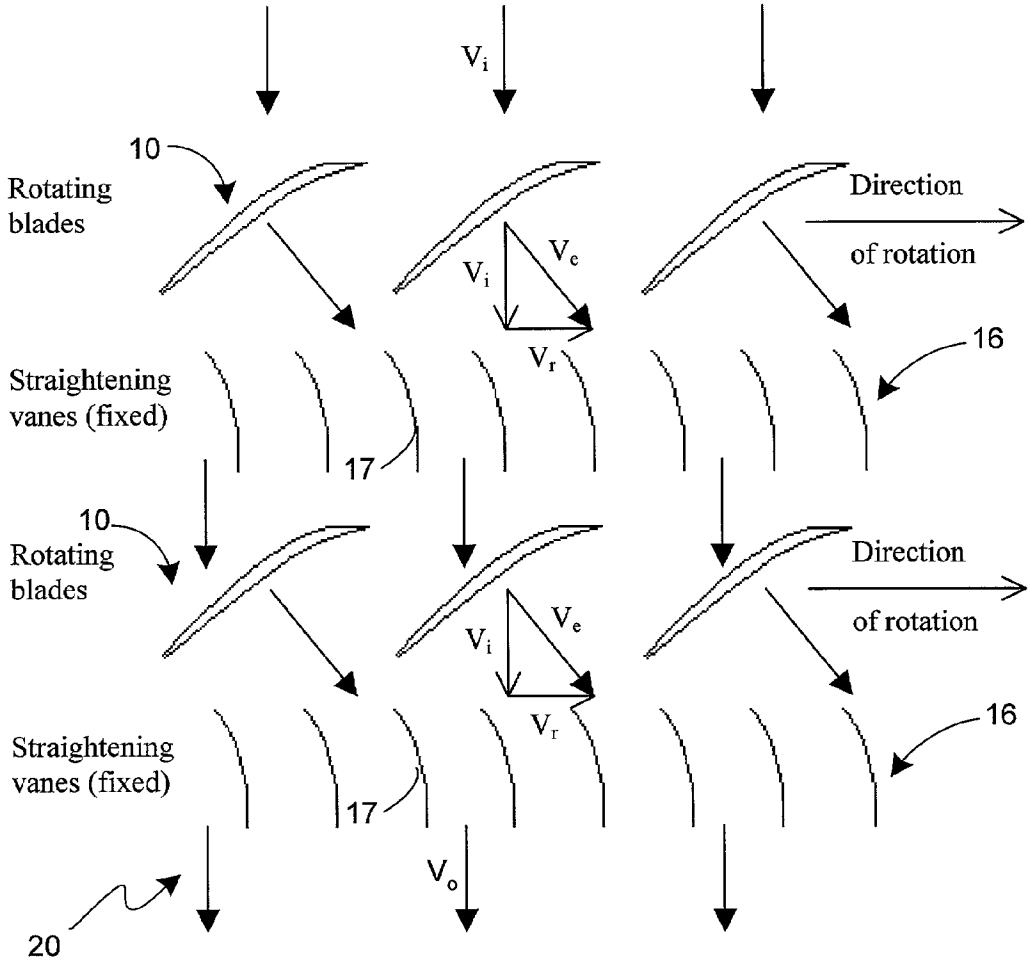
Publication Classification

(51) **Int. Cl.**[7] **F04D 29/54**

(52) **U.S. Cl.** ..... **415/193**; 415/191; 415/209.1; 415/211.2; 416/241 R

(57) **ABSTRACT**

A combination airflow straightener and finger guard straightens airflow and minimize the chance of fingers or other objects coming into contact with rotating blades of a fan, and includes a plurality of vanes that extend radially outward from a hub to an outer frame of the combination airflow straightener and finger guard. Each vane can be considered as having three portions. The first portion is closest to the fan and is parallel to the airflow leaving the fan. The second portion is farthest from the fan and is aligned with the axis of rotation of the fan (or some other desired exhaust vector). The third portion is curved to link the first portion to the second portion to straighten the airflow to the desired exhaust vector, with the space between each pair of vanes forming a plenum that straightens the airflow by removing the rotational components from the airflow.



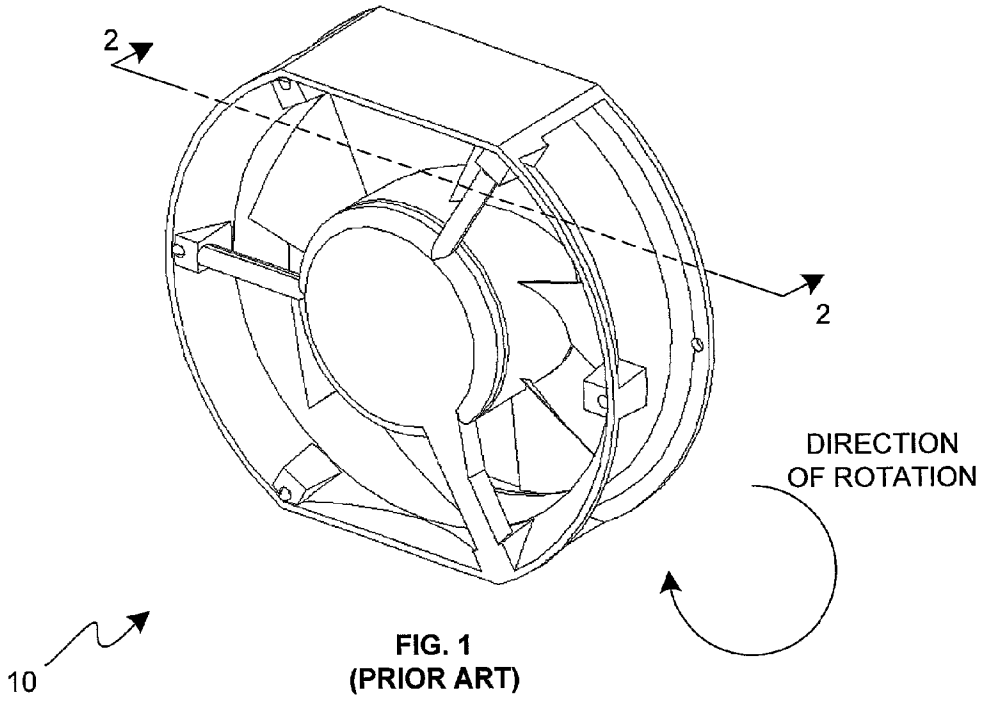


FIG. 1
(PRIOR ART)

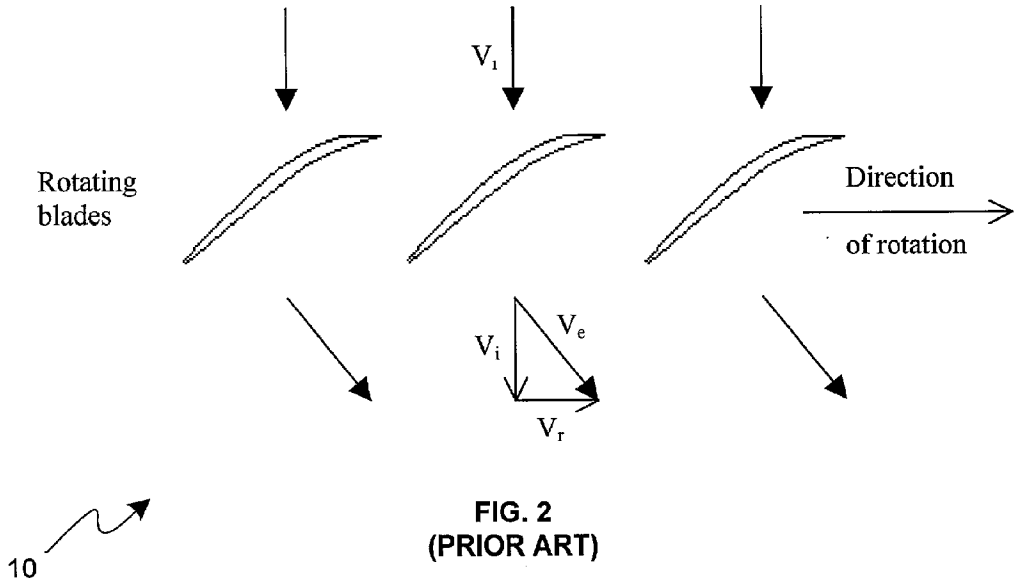


FIG. 2
(PRIOR ART)

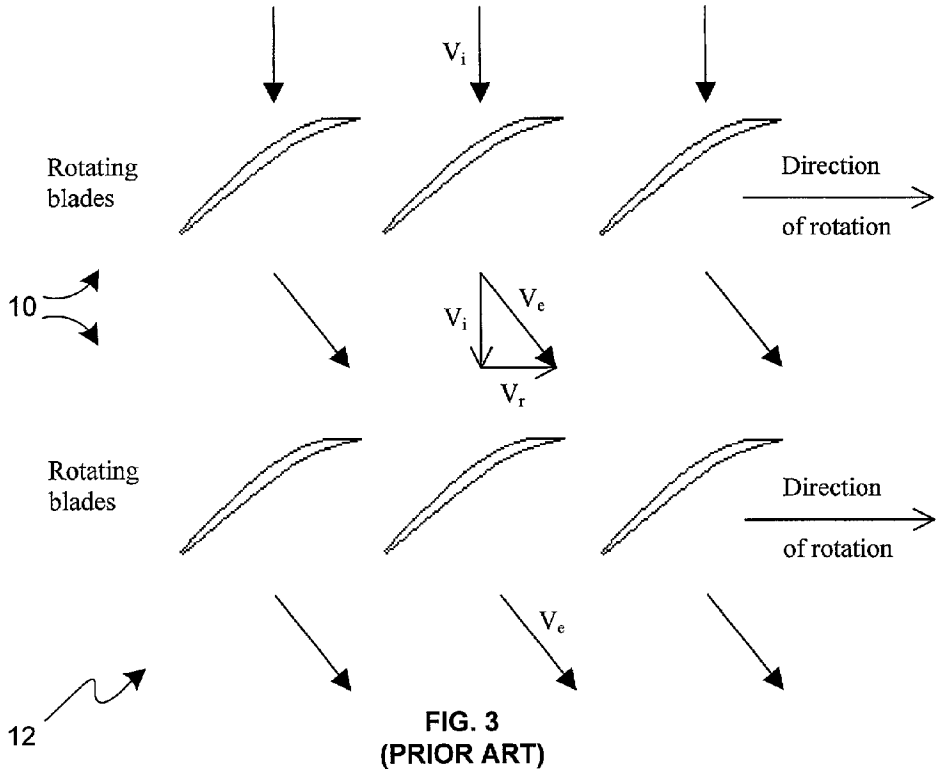


FIG. 3
(PRIOR ART)

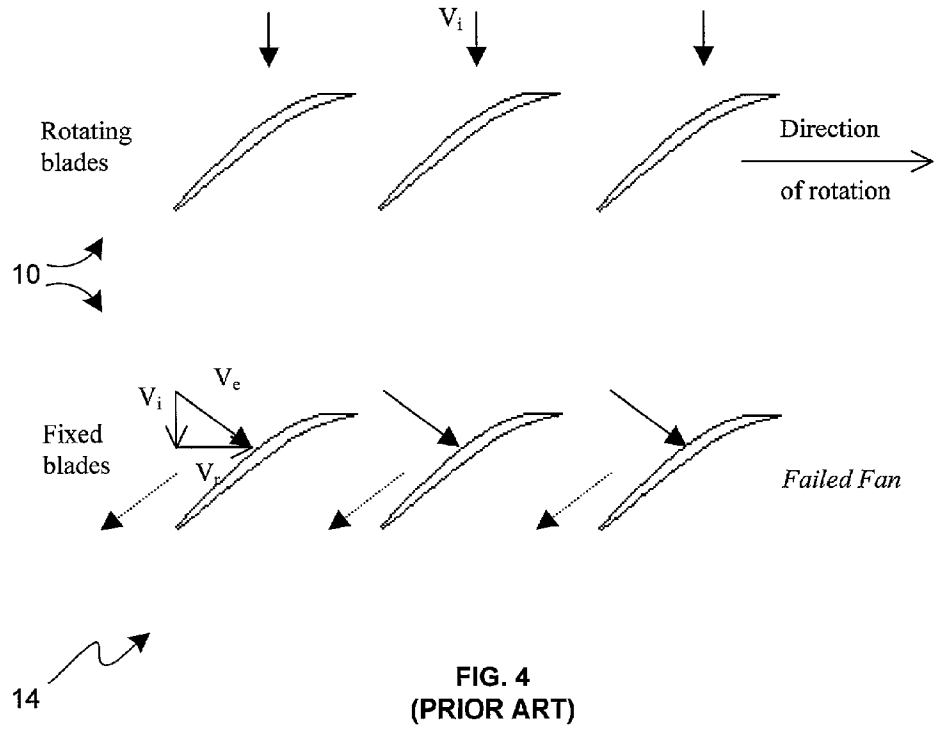


FIG. 4
(PRIOR ART)

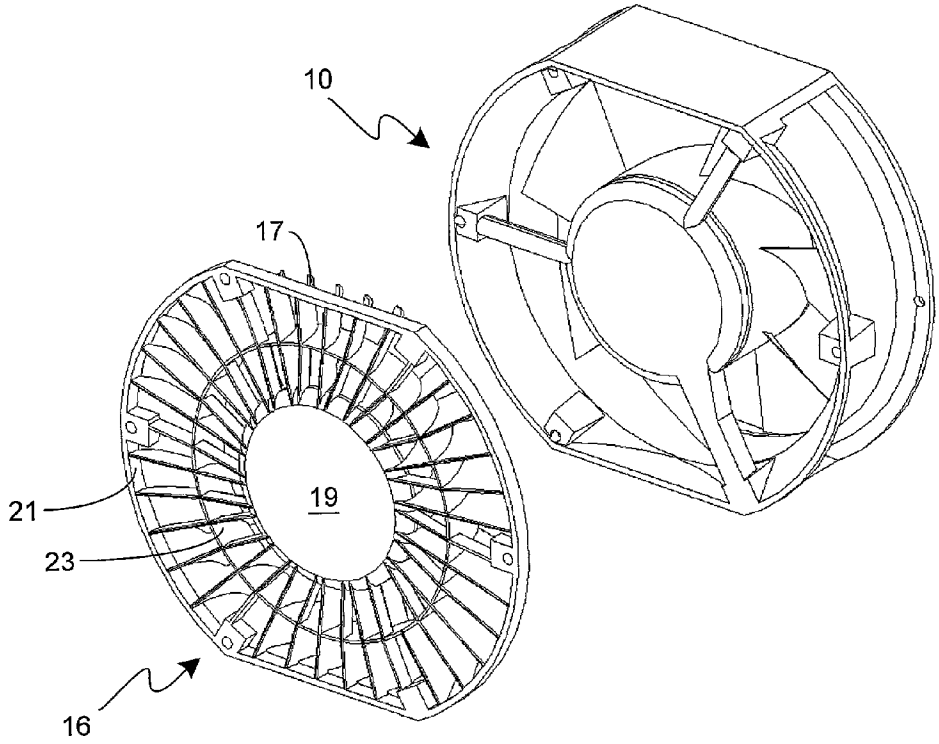


FIG. 5

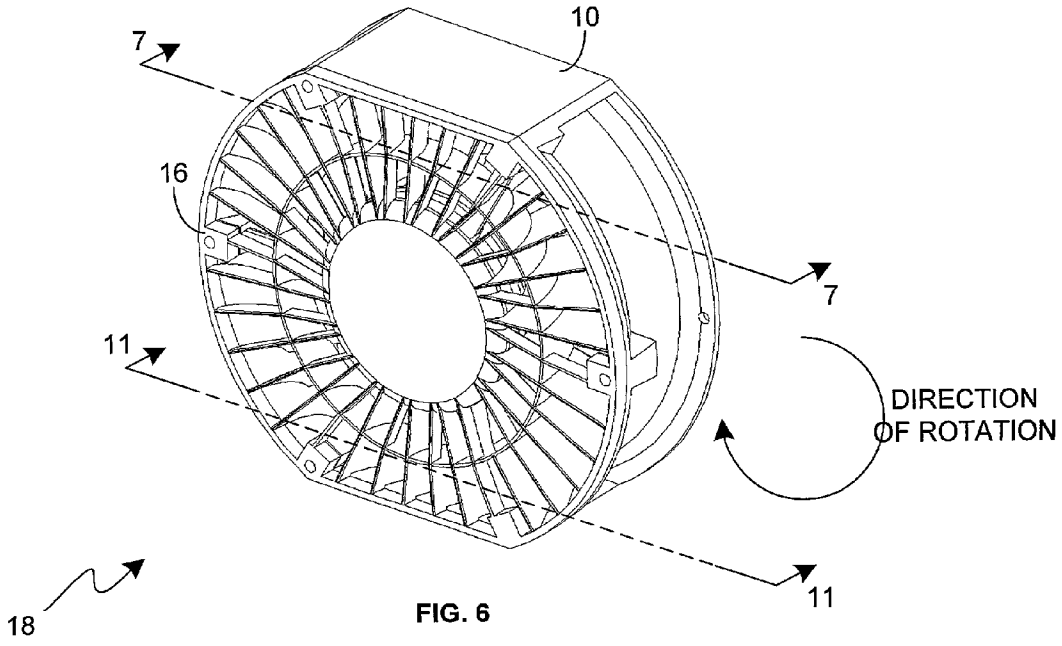


FIG. 6

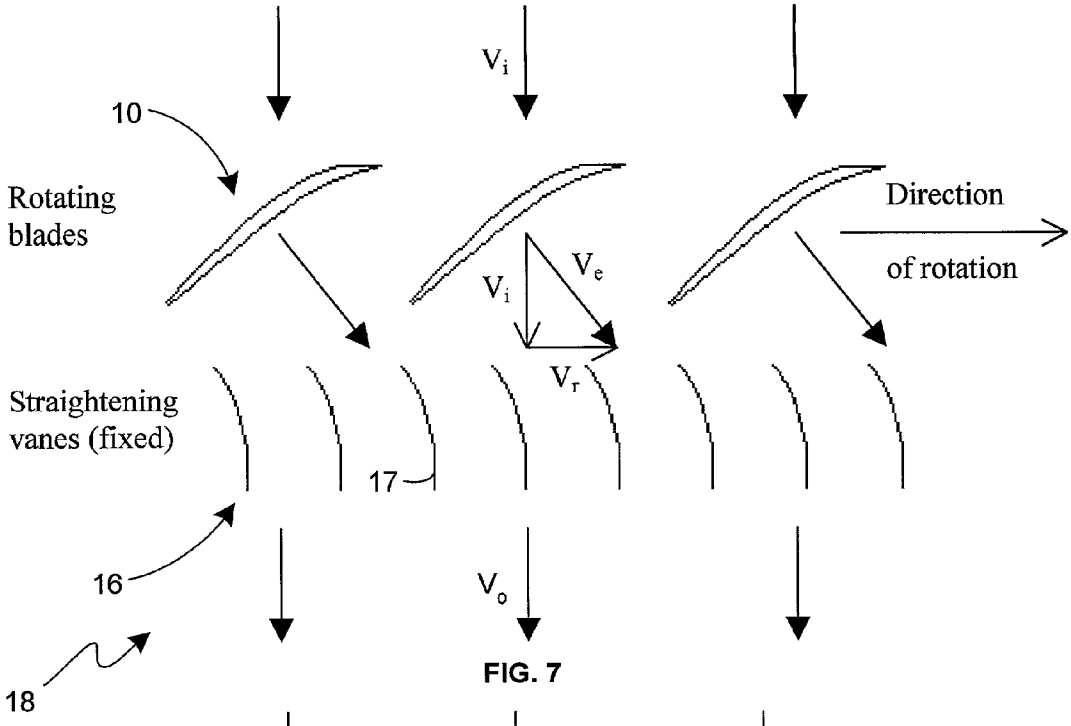

V_i
10
Rotating blades
Direction of rotation
V_i
V_e
V_r
Straightening vanes (fixed)
17
16
V_o
18

FIG. 7

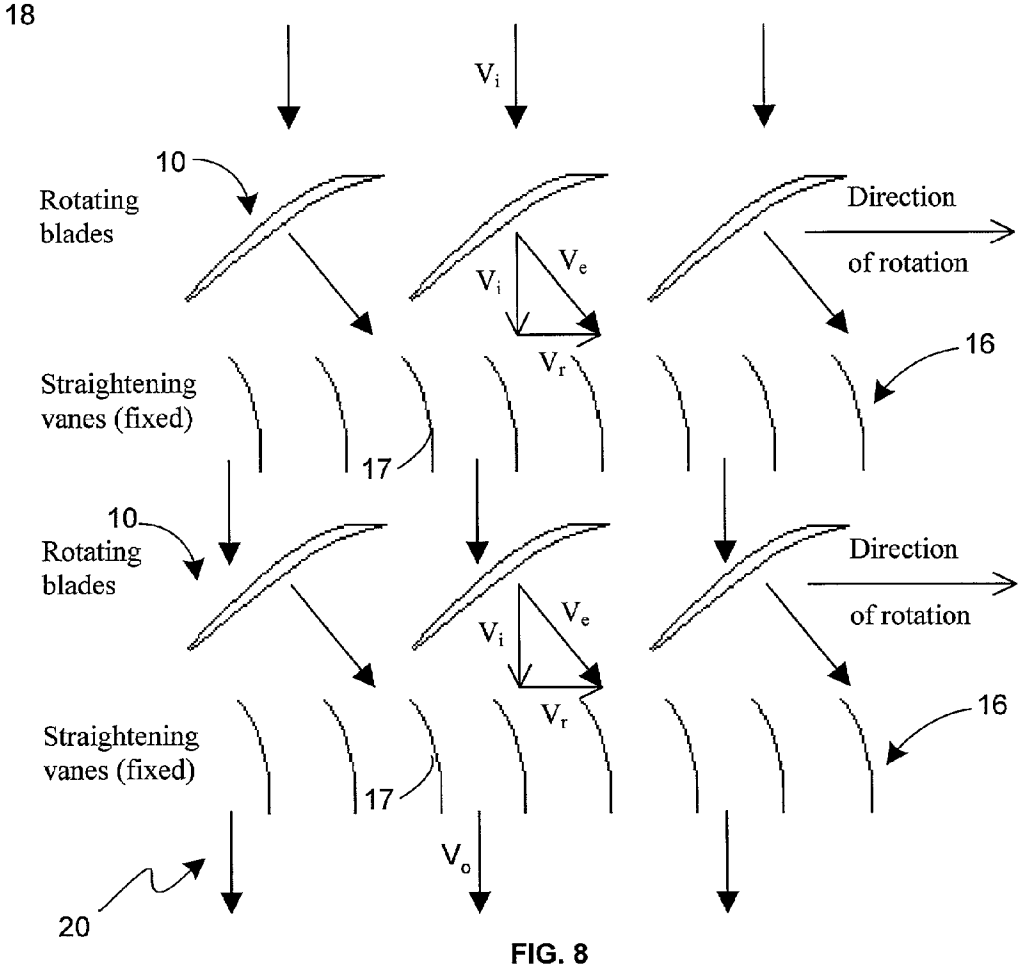

V_i
10
Rotating blades
Direction of rotation
V_i
V_e
V_r
16
Straightening vanes (fixed)
17
10
Rotating blades
Direction of rotation
V_i
V_e
V_r
16
Straightening vanes (fixed)
17
V_o
20

FIG. 8

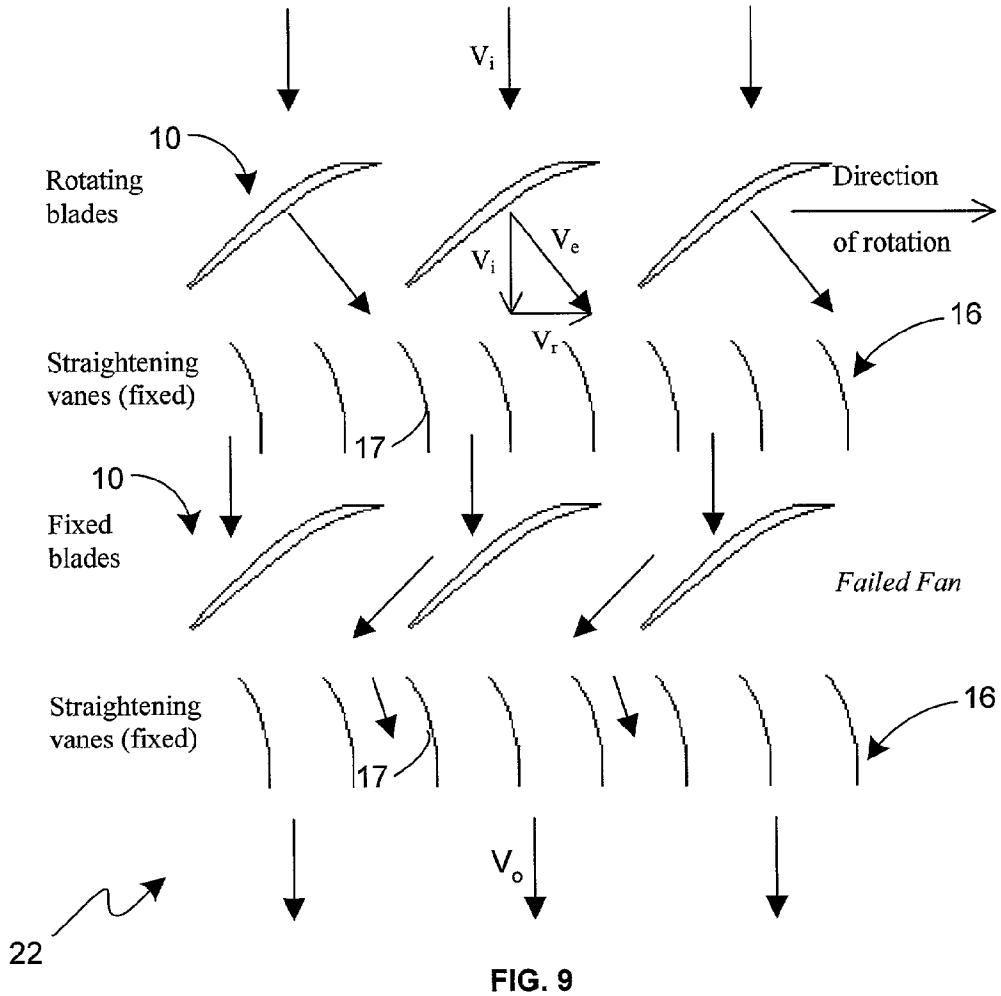

V_i
10
Rotating blades
Direction of rotation
V_i
V_e
V_r
16
Straightening vanes (fixed)
17
10
Fixed blades
Failed Fan
Straightening vanes (fixed)
16
17
V_o
22

FIG. 9

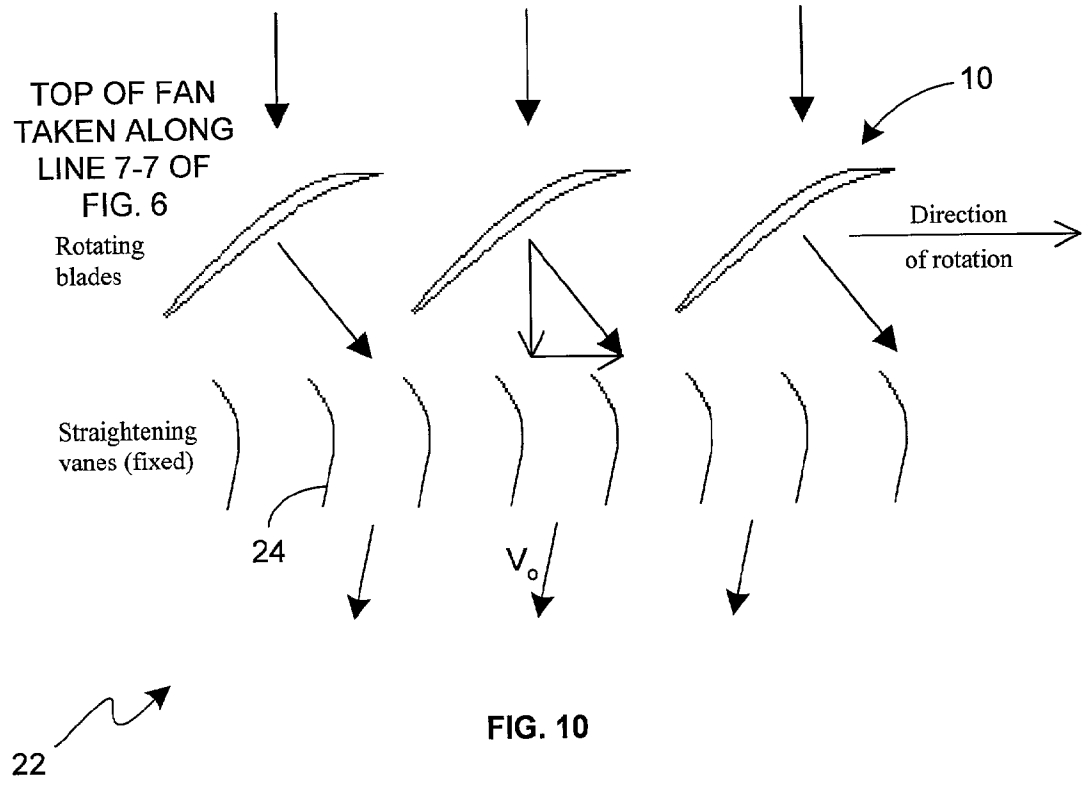

TOP OF FAN TAKEN ALONG LINE 7-7 OF FIG. 6
Rotating blades
10
Direction of rotation
Straightening vanes (fixed)
24
V_o
22

FIG. 10

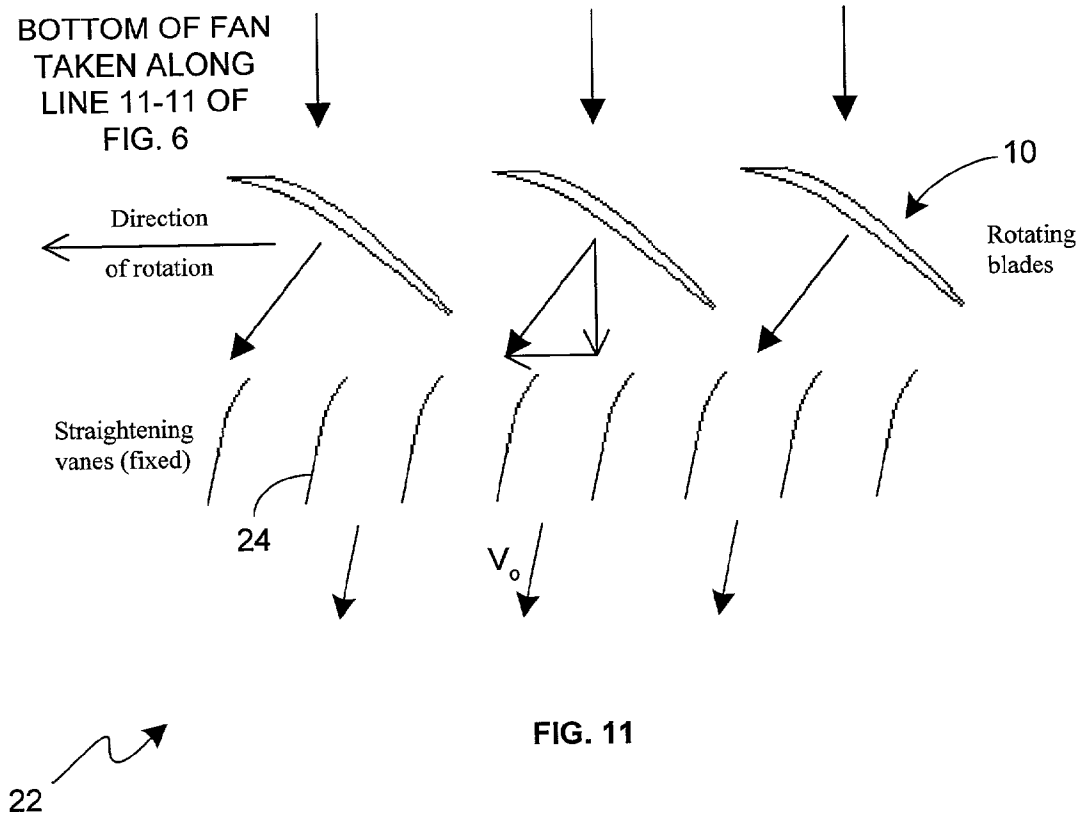

BOTTOM OF FAN TAKEN ALONG LINE 11-11 OF FIG. 6
Direction of rotation
10
Rotating blades
Straightening vanes (fixed)
24
V_o
22

FIG. 11

COMBINATION AIRFLOW STRAIGHTENER AND FINGER GUARD FOR USE WITH A FAN

FIELD OF THE INVENTION

[0001] The present invention relates generally to cooling fans, such as fans used to cool electronic equipment. More specifically, the present invention relates to a finger guard that also straightens the airflow provided by a cooling fan.

DESCRIPTION OF THE RELATED ART

[0002] In the electronic arts, fans are often used to cool electronic equipment, such as computer systems. Of course, fans are also used in many other applications. **FIG. 1** shows a prior art fan **10** similar to those used to cool computer systems. Such fans are often included in computer power supplies, and are also typically mounted in computer cases to remove hot air from the interior of the case. These fans are often referred to in the art as tubeaxial fans.

[0003] Often a finger guard is coupled to the fan to prevent fingers and other objects from coming in contact with the rotating blades of the fan. Finger guards are often made of metal or plastic, and typically have openings or gratings no larger than roughly ¼ of an inch along a single axis. For example, a finger guard may have many arcuate openings that are an inch or two long, and ¼ of an inch wide.

[0004] **FIG. 2** is partial cross sectional view of prior art fan **10** taken along line **2-2** of **FIG. 1**. In **FIG. 2**, the blades are shown as moving from left to right as the blades rotate through line **2-2**. Note that there is a certain amount of linear distortion in **FIG. 2**, as well as **FIGS. 3 and 4**, because all blades are shown as if they were positioned directly at the top of fan **10**.

[0005] Air enters fan **10** along the vector Vi, which is parallel to the axis of rotation of the fan. However, air leaves the fan along the vector Ve, which is perpendicular to the face of the fan blades. The vector Ve has a component Vi, which is the desired component, and a component Vr, which undesirable. Since the blades are rotating, Vr is rotational, and the air leaving the fan tends to have a whirling or circular motion similar to a vortex. This motion makes it difficult to predict where the air will go, leading to airflow where it is not wanted, and too little airflow where it is needed. Also, the swirling airflow tends to produce unpredictable eddies. These eddies sometimes lead to unpredictable accumulations of dust in certain areas.

[0006] In the art of computing, it is desirable to maximize the availability of a computer system. This is known in the art as high availability (HA) computing. Companies desiring to market HA computing systems have set very high goals. For example, Hewlett-Packard Company has announced a goal of achieving 99.999% availability for high-end server platforms. This translates to about five minutes of downtime per year.

[0007] The design of an HA computer encompasses many of the computer's subsystems. One popular redundancy technique is known in the art as "N+1" redundancy. The concept behind N+1 redundancy is that if N devices are needed to operate a system, N+1 devices are provided. If one of the devices fails, the failure is detected and the failed device can be replaced before one of the other devices fails. N+1 redundancy has been used successfully to provide redundancy for power supplies, hard disk drives in disk array subsystems, as well as many other devices.

[0008] N+1 redundancy has also been used to provide redundant cooling fans. For example, if one cooling fans is required to cool a power supply, then two cooling fans can be provided in series. The chances of both fans suffering a random failure at the same time are minuscule. Therefore, if one of the fans fail the other fan will continue to operate, and the failure can be detected and the computer system operator can be signaled. Thereafter, the failing fan can be replaced without have to interrupt the operation of the computer system.

[0009] **FIG. 3** illustrates a prior art configuration **12** wherein two prior art fans **10** are connected in series. The perspective of the view shown in **FIG. 3** is similar to that shown in **FIG. 2**, which is taken along line **2-2** of **FIG. 1**. In configuration **12**, when both fans **10** are operating, the downstream fan does not operate as efficiently because the airflow is already rotating in the same direction as the blades of the downstream fan, which affects the angle of attack between the air and fan blade of the downstream fan. One technique known in the art addresses this problem by having the two fans rotate in opposite directions, which of course requires that one of the fans have blades inclined in the opposite direction. However, this configuration tends to produce more noise. In addition, inexpensive tubeaxial fans, such as those used to cool computer systems, tend to only be available in one direction of rotation.

[0010] Furthermore, the problem becomes much worse if the downstream fan fails. **FIG. 4** illustrates a prior art configuration **14** that shows two prior art fans **10** connected in series, wherein the downstream fan has failed and no longer rotates. In all other respects, **FIG. 4** is identical to **FIG. 3**. Notice that when the downstream fan fails, the airflow from the upstream fan is nearly perpendicular to the blade surfaces of the failed downstream fan. Accordingly, the airflow from the upstream fan is severely impeded by the stationary blades of the failed fan, causing the airflow to be much worse than the airflow produced by a single, unimpeded fan.

[0011] Another type of prior art fan contains flow straighteners (or alternatively, vanes) that remove the rotational components from the airflow produced by a fan. Typically the flow straighteners are provided in a relatively long tube that is downstream from the fan. These types of fans are known in the art as vaneaxial fans. However, vaneaxial fans are not commonly used in cool electronic equipment because vaneaxial fans tend to be larger than tubeaxial fans (because of the tube that contains the flow straighteners), non-standard in size, and more costly than tubeaxial fans.

SUMMARY OF THE INVENTION

[0012] The present invention is a combination airflow straightener and finger guard for use with a fan, such as an axial fan. Axial fans are commonly used to cool electronic equipment, such as computer systems. Of course, the present invention may be advantageously employed in any application where it is desirable to straighten airflow and minimize the chance of fingers or other objects coming into contact with the rotating blades of a fan. The term "flow-guard" will be used herein to refer to a combination airflow straightener and finger guard in accordance with the present invention.

[0013] A flow-guard in accordance with the present invention includes a plurality of vanes that extend radially from a center hub to an outer frame of the flow-guard. The vanes straighten the airflow and protect fingers and other objects from coming in contact with rotating blades of the fan. Typically, adjacent vanes should be no farther apart than roughly ¼-½ of an inch to prevent a finger from coming in contact with a rotating blade.

[0014] Each vane can be considered as having three portions. The first portion is closest to the fan and is parallel to the airflow leaving the fan. The second portion is farthest from the fan and is aligned with the axis of rotation of the fan (or some other desired vector). The third portion is curved to link the first portion to the second portion to straighten the airflow to the desired exhaust vector. Accordingly, the space between each pair of vanes forms a plenum that straightens the airflow by removing the rotational components from the airflow, thereby eliminating the whirling or circular motion patterns produced by prior art tubeaxial fans.

[0015] Furthermore, the present invention can be used to enhance the performance of fans used in a redundant N+1 serial configuration. When both fans are operating normally, the flow-guard between the upstream and downstream fans produces a much better angle of attack for the blades of the downstream fan. If the downstream fan fails, the flow-guard between the upstream and downstream fans straightens the airflow from the upstream fan so that the airflow encounters the blade surfaces of the failed fan at a 45° angle, which is better than the perpendicular encounter angle produced by similar prior art configurations.

[0016] The present invention provides an inexpensive and effective method for removing rotational components from the airflow of an axial fan, while also effectively preventing fingers and other objects from coming in contact with the rotating blades of the fan. By removing the rotational components from the airflow, the airflow is much more predictable, thereby ensuring proper airflow over devices that need to be cooled.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] **FIG. 1** shows a prior art axial fan similar to fans used to cool computer systems.

[0018] **FIG. 2** is partial cross sectional view of the prior art fan of **FIG. 1** taken along line **2-2** of **FIG. 1**.

[0019] **FIG. 3** illustrates a prior art configuration wherein two prior art are fans are connected in series, with the perspective of the view shown in **FIG. 3** being similar to that shown in **FIG. 2**, which is taken along line **2-2** of **FIG. 1**.

[0020] **FIG. 4** illustrates a prior art configuration that is identical in all respects to **FIG. 3**, except that the downstream fan has failed and no longer rotates.

[0021] **FIG. 5** shows a combination airflow straightener and finger guard in accordance with the present invention (which will be referred to herein as a "flow-guard"), along with a prior art axial fan.

[0022] **FIG. 6** shows the flow-guard and fan of **FIG. 5** coupled together to form a flow-guard/fan assembly.

[0023] **FIG. 7** is a cross sectional view of the assembly of **FIG. 6** taken along line **7-7** of **FIG. 6**.

[0024] **FIG. 8** shows a pair of flow-guard/fan assemblies coupled into an N+1 redundant series configuration.

[0025] **FIG. 9** shows the flow-guard/fan assembly of **FIG. 8** after the downstream fan has failed and no longer rotates.

[0026] **FIGS. 10 and 11** show a flow-guard configured to direct airflow in a direction other than the axis of rotation of the fan.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] The present invention is a combination airflow straightener and finger guard for use with a fan, such as an axial fan. Axial fans are commonly used to cool electronic equipment, such as computer systems. Of course, the present invention my be advantageously employed in any application where it is desirable to straighten airflow and minimize the chance of fingers or other objects coming into contact with the rotating blades of a fan.

[0028] **FIG. 5** shows a combination airflow straightener and finger guard **16** in accordance with the present invention. The term "flow-guard" will be used herein to refer to a combination airflow straightener and finger guard in accordance with the present invention. Also shown in **FIG. 5** is prior art fan **10**, to which flow-guard **16** can be attached, as will be discussed below with reference to **FIG. 6**.

[0029] Flow-guard **16** includes a plurality of vanes, such as vane **17**, that extend radially outward from a hub **19** to an outer frame **21**. Flow-guard **16** also includes intermediate support member **23** radially disposed between hub **19** and frame **21**. Note that it may be desirable to provide fewer or additional intermediate support members based on the size of flow-guard **16**. Typically hub **19** and outer frame **21** are approximately the same size as the hub and outer frame, respectively, of the fan to which flow-guard **16** will be mounted.

[0030] The vanes straighten the airflow, as will be discussed in greater detail below with reference to **FIG. 7**. Furthermore, the vanes protect fingers and other objects from coming into contact with rotating blades of the fan **10**. As discussed above, prior art finger guards typically have openings or gratings no larger than roughly ¼ of an inch along a single axis. Note that the curved nature of the vanes tends to provide a certain amount of protection, and therefore the vanes can be spaced a little farther apart than prior art finger guard openings. Accordingly, to provide this function in the present invention, adjacent vanes should be no farther apart than roughly ¼-½ of an inch. Of course, those skilled in the art will appreciate that the separation between vanes can be varied to prevent objects of various sizes from coming in contact with the rotating blades of fan **10**.

[0031] Flow-guard **16** can be fabricated using a standard plastic injection molding processes. It is expected that the cost of a flow-guard in accordance with the present invention will be less than the cost of a typical prior art wire formed finger guard.

[0032] **FIG. 6** shows flow-guard **16** coupled to fan **10** to form flow-guard/fan assembly **18**. Flow-guard **16** can be coupled to fan **10** using methods known in the art, such as threaded screws or snap-in connectors. Note that although

flow-guard **16** is coupled to fan **10** in **FIG. 6**, the flow-guard can be mounted proximate to the fan in a number of different ways. For example, a fan assembly could be mounted to the exterior of a computer case and the flow-guard could be mounted to the interior of the case and aligned radially with the fan. Also note that in certain applications, it may be desirable to use a prior art finger guard on the intake side of a fan, and use a flow-guard on the exhaust side of the fan.

[**0033**] Two section lines are shown in **FIG. 6**. Views in **FIGS. 7, 8, 9**, and **10** are taken along line **7-7**. **FIG. 11** has a view taken along line **11-11**.

[**0034**] **FIG. 7** is a cross sectional view taken along line **7-7** of **FIG. 6**. Note that there is a certain amount of linear distortion in **FIG. 7**, as well as **FIGS. 8, 9, 10**, and **11**, because all blades and vanes are shown as if they were positioned directly at the top (or in the case of **FIG. 11**, the bottom) of assembly **18**.

[**0035**] In accordance with the present invention, air enters fan **10** along the vector Vi, which is parallel to the axis of rotation of the fan, and air leaves the fan along the vector Ve, which is perpendicular to the face of the fan blades.

[**0036**] Next, the airflow enters flow-guard **16**, which includes a plurality of straightening vanes, such as vane **17**. Note that the separation between the vanes is close enough to prevent objects, such as fingers, from coming into contact with the rotating blades of fan **10**. Flow-guard **16** straightens the airflow, and the air emerges from flow-guard **16** along vector Vo, which is parallel to input vector Vi.

[**0037**] Each vane can be considered as having three portions. The first portion is closest to the fan and is parallel to vector Ve. The second portion is farthest from the fan and is aligned with vector Vo. The third portion is curved and links the first and second portions to straighten the airflow from vector Ve to vector Vo. Accordingly, the space between each pair of vanes forms a plenum that straightens the airflow and removes the rotational components from the air leaving assembly **18**. Accordingly, the air leaving assembly **18** does not have the whirling or circular motion patterns of prior art tubeaxial fans. Therefore, it is easy to predict where the airflow will go, leading to airflow where it is wanted, and little or no airflow where it is not needed.

[**0038**] **FIG. 8** shows a pair of flow-guard/fan assemblies coupled into an N+1 redundant series configuration **20**. As discussed above, in the similar prior art configuration shown in **FIG. 3**, the downstream fan does not operate as efficiently because the airflow is already rotating in the same direction as the blades of the downstream fan, which affects the angle of attack between the air and fan blade of the downstream fan. However, as shown in **FIG. 8** and in accordance with the present invention, the upstream flow-guard **16** straightens the airflow from the upstream fan **10** so that when the airflow enters the downstream fan **10** the airflow is parallel to the axis of rotation of the fan. Accordingly, the angle of attack is much better and the downstream fan operates more efficiently than in the prior art configuration shown in **FIG. 3**.

[**0039**] As can be seen in **FIG. 8**, the beneficial flow-straightening effect of the flow-guard between the two fans can be achieved if the flow-guard is mounted to either the upstream fan or the downstream fan. While it may appear that the finger guard function of the present invention is not necessary for the flow-guard between the two fans shown in **FIG. 8**, if the downstream fan fails, a technician may be required to service the downstream fan while the upstream fan is operating. Since the two fans are in close proximity, it is important that the flow-guard between the two fans protect the fingers of the technician while the technician is servicing the downstream fan. Therefore, it is preferable that this flow-guard be coupled to the upstream fan.

[**0040**] **FIG. 9** shows a configuration **22** similar to configuration **20** of **FIG. 8**, except that the downstream fan **10** has failed. As discussed above, in the similar prior art configuration **14** shown in **FIG. 4**, the airflow from the upstream fan is nearly perpendicular to the blade surfaces of the failed fan, and the airflow from the upstream fan is severely impeded by the stationary blades of the failed downstream fan. However, as shown in **FIG. 9** and in accordance with the present invention, the upstream flow-guard **16** straightens the airflow from the upstream fan **10** so that the airflow encounters the blade surfaces of the failed downstream fan at a 45° angle, which is better than the perpendicular encounter angle shown in **FIG. 4**.

[**0041**] Note that in one configuration, it may be desirable to use a flow "straightener" in accordance with the present invention that actually introduces rotational components in the direction opposite to the direction of rotation of the fan. Such a flow "straightener" could be positioned over the upstream fan, and a flow-guard **16** as discussed above could be positioned over the downstream fan. Accordingly, the airflow from the upstream fan would have an excellent angle of attack for the downstream fan. Also, if the downstream fan fails, the airflow from the upstream fan would be parallel to the stationary fan blades of the failed downstream fan, thereby providing minimal resistance to the airflow.

[**0042**] Note that a flow-guard in accordance with the present invention can also be configured to direct airflow in a particular direction. For example, assume that a fan is mounted in a power supply, and a heat sink is mounted within the power supply to the left and off-center from the fan. **FIGS. 10 and 11** show such a flow-guard **24** configured to direct airflow to the left. **FIG. 10** would result from flow-guard **24** being used in assembly **18** of **FIG. 6** and is taken along line **7-7** of **FIG. 6**, and **FIG. 11** would result from flow-guard **24** being used in assembly **18** is taken along line **11-11** of **FIG. 6**.

[**0043**] Each vane has a first portion closest to the fan and parallel to the airflow leaving the fan and a second portion farthest from the fan and aligned with vector Vo. The third portion is curved to link the first portion to the second portion to straighten the airflow to vector Vo. Note that the angle of the first portion varies with the angular position of the vane. However, the angle of the second portion remains aligned with the vector Vo in all vanes.

[**0044**] In conclusion, the present invention provides an inexpensive and effective method for removing rotational components from the airflow of a fan, while also effectively preventing fingers and other objects from coming in contact with the rotating blades of the fan. By removing the rotational components from the airflow, the airflow is much more predictable, thereby ensuring proper airflow over devices that need to be cooled. In the prior art, rotational components in the airflow created eddies that made it difficult to predict whether any particular device would

receive proper airflow, which can lead to device failure. Furthermore, the present invention can be used to enhance the performance of fans used in a redundant N+1 serial configuration.

[0045] Although the present invention has 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 invention.

What is claimed is:

1. A combination airflow straightener and finger guard having a fan side and an exhaust side, for use with a fan, comprising:

a hub;

a frame; and

a plurality of vanes extending radially from the hub to the frame, wherein a maximum angular distance separating adjacent vanes is sufficiently small to provide effective protection against a finger being inserted between adjacent vanes from the exhaust side to the fan side, and two or more adjacent vanes each comprise a first portion originating at the fan side that is approximately parallel to airflow leaving the fan, a second portion ending at the exhaust side, and a third portion that links the first portion to the second portion to straighten airflow leaving the exhaust side.

2. The combination airflow straightener and finger guard of claim 1 wherein the maximum angular distance separating adjacent vanes is no more than ½ of an inch.

3. The combination airflow straightener and finger guard of claim 1 wherein the second portion of each vane is substantially parallel to an axis of rotation of the fan when the combination airflow straightener and finger guard is mounted to the fan.

4. The combination airflow straightener and finger guard of claim 1 wherein the second portion of each vane is angularly displaced by a common angle from an axis of rotation of the fan when the combination airflow straightener and finger guard is mounted to the fan.

5. An assembly comprising:

an axial fan; and

a combination airflow straightener and finger guard having a fan side and an exhaust side and mounted to the axial fan, the combination airflow straightener and finger guard comprising:

a hub;

a frame; and

a plurality of vanes extending radially from the hub to the frame, wherein a maximum angular distance separating adjacent vanes is sufficiently small to provide effective protection against a finger being inserted between adjacent vanes and coming into contact with rotating blades of the axial fan, and two or more adjacent vanes each comprise a first portion originating at the fan side that is approximately parallel to airflow leaving the axial fan, a second portion ending at the exhaust side, and a third portion that links the first portion to the second portion to straighten airflow leaving the exhaust side.

6. The assembly of claim 5 wherein the maximum angular distance separating adjacent vanes is no more than ½ of an inch.

7. The assembly of claim 6 wherein the second portion of each vane is substantially parallel to an axis of rotation of the axial fan.

8. The assembly of claim 6 wherein the second portion of each vane is angularly displaced by a common angle from an axis of rotation of the axial fan.

9. An assembly comprising:

an upstream axial fan;

a downstream axial fan coupled to the upstream fan in a redundant N+1 serial configuration; and

a combination airflow straightener and finger guard having a fan side and an exhaust side and mounted between the upstream and downstream axial fans, the combination airflow straightener and finger guard comprising:

a hub;

a frame; and

a plurality of vanes extending radially from the hub to the frame, wherein a maximum angular distance separating adjacent vanes is sufficiently small to provide effective protection against a finger being inserted between adjacent vanes and coming into contact with rotating blades of the upstream axial fan, and two or more adjacent vanes each comprise a first portion originating at the fan side that is approximately parallel to airflow leaving the upstream axial fan, a second portion ending at the exhaust side, and a third portion that links the first portion to the second portion to straighten airflow leaving the exhaust side.

10. The assembly of claim 9 wherein the maximum angular distance separating adjacent vanes is no more than ½ of an inch.

11. The assembly of claim 9 wherein the second portion of each vane is substantially parallel to an axis of rotation of the downstream axial fan.

* * * * *