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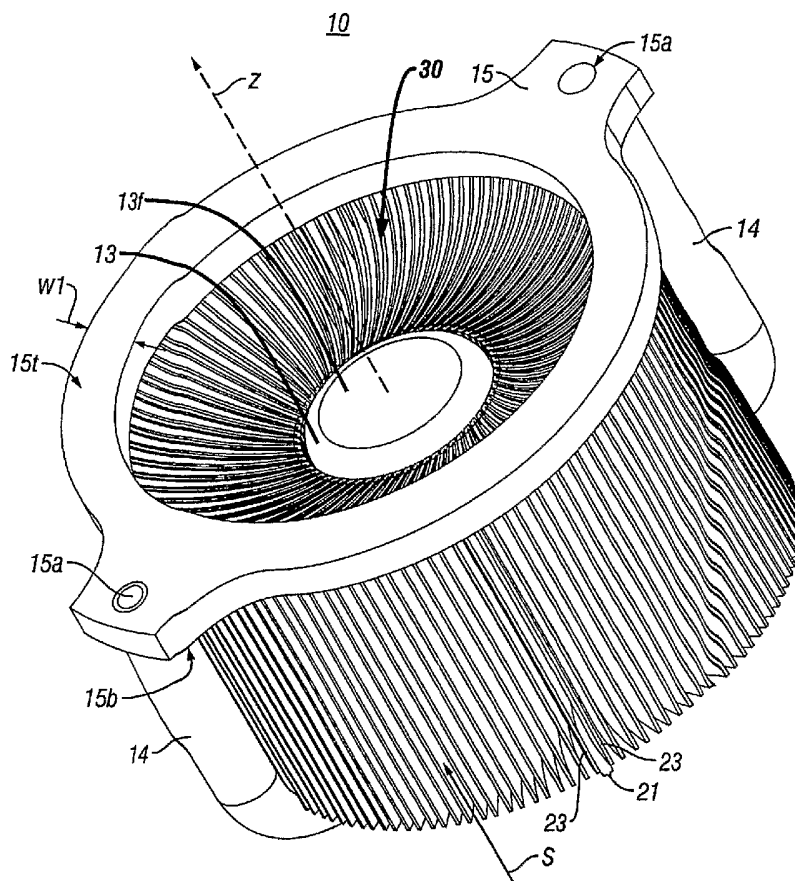
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[Continued on next page]

(54) Title: TWIN FIN ARRAYED COOLING DEVICE WITH HEAT SPREADER



(57) Abstract: A cooling device (10) including a split-core (11) with a plurality of twin fins (21) connected with a plurality of grooves (G) on the split-core (11) is disclosed. Each twin fin (21) includes a root (27) and a pair of vanes (23) extending from the root (27). Each root (27) is connected with one of the grooves (G) to mount the twin fins (21) to the split-core (11). A heat spreader (15) is in contact with a top portion (29) of the vanes (23) and a heat pipe (14) is connected with the heat spreader (15) and the split-core (11). A heat concentration (H_c) in the split-core (11) is dissipated by a thermal path (P1) through the heat pipes (14) to the heat spreader (15) and into the vanes (23) and also by a path (P2) upward into the split-core (11) and into the vanes (23) via the roots (27) of the twin fins (21).



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TWIN FIN ARRAYED COOLING DEVICE WITH HEAT SPREADER**FIELD OF THE INVENTION**

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The present invention relates generally to a cooling device for dissipating heat from a component in thermal communication with the cooling device. More specifically, the present invention relates to a cooling device with an array of twin fins with each twin fin including a root and a pair of vanes extending outward of the root. Each root is connected with a split-core that includes a heat spreader connected with a top portion of the vanes and a heat pipe connected with the split-core and the heat spreader. The heat pipe thermally transfers a portion of the heat concentrated in the split-core to the heat spreader where the heat is transferred to the top portion of the vanes.

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BACKGROUND OF THE INVENTION

It is well known in the electronics art to place a heat sink in contact with an electronic device so that waste heat generated by operation of the electronic device is thermally transferred to the heat sink thereby cooling the electronic device. With the advent of high clock speed electronic devices such as microprocessors (CPU's), digital signal processors (DSP's), and application specific integrated circuits (ASIC), the amount of waste heat generated by those electronic devices and the operating temperature of those electronic devices are directly proportional to clock speed. Efficient operation of a CPU as well as other high power dissipation electronic devices requires that waste heat be continuously and effectively removed.

However, as areal densities and clock speed of electronic devices continue to increase, a heat flux of the device also increases. Although air cooled heat sinks are commonly used to dissipate waste heat from the aforementioned electronic devices, the increased heat flux in high performance electronic devices is often concentrated in a small area. The ability to effectively dissipate ever increasing levels of heat flux in high performance electronic devices has challenged current heat sink designs where the entire heat sink is fabricated using processes such as machining, forging, casting, and extrusion. Those processes make it difficult to increase the number of fins or an area of the fins in order to effectively dissipate heat cause by the aforementioned heat flux. Typically, a heat mass with interface surface that is in thermal communication with the electronic device is used to thermally conduct the

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waste heat away from the device and into the heat mass. As a result, the heat flux from the electronic device is concentrated in the area of the heat mass near the interface surface. Ideally, it is desirable spread the heat flux in the heat mass over as much of the volume of the heat mass as possible so that the heat is efficiently transferred to the fins and dissipated by the air flow over the fins.

{Shankar, is the above an accurate statement of the problems associated with heat flux concentrated in a small volume of a heat mass?}

Heat flux is a thermal output per unit of area. For example, if a total thermal output is 100 Watts over a heat source having dimensions of 3.5 cm * 3.5 cm, then the heat flux is $100 \text{ W} / (3.5 \text{ cm} * 3.5 \text{ cm}) = 8.163 \text{ W/cm}^2$. At present, based on area and cost constraints, clock speeds in CPU's are being increase while the package area remains the same or is reduced. The higher clock speeds result in increased thermal output and a resulting increase in heat flux.

Consequently, there is a need for a cooling device with improved thermal conductivity that reduces heat flux concentration and efficiently dissipates waste heat from a component in thermal communication with the cooling device. There is also a need for a cooling device in which the number of fins and/or an area of the fins can be increased to dissipate heat from a component in thermal communication with the cooling device.

SUMMARY OF THE INVENTION

The cooling device of the present invention solves the aforementioned heat flux concentration problems. The cooling device includes a plurality of twin fins with each twin fin including a root and a pair of vanes extending outward of the root . The vanes are spaced apart to define a slot between the vanes and each vane includes a top portion, a leading edge, a trailing edge, and an outer edge. A split-core includes a plurality of grooves that are adapted to receive the roots of the vanes, a top face, a base, a mounting surface adapted to thermally connect the split-core with a component to be cooled, a heat spreader connected with the top portion of the vanes, and a heat pipe connected with the heat spreader and the split-core.

The aforementioned problems associated with heat flux concentration are addressed by the split-core because heat thermally conducted into the split-core via the mounting surface is dissipated over multiple thermal paths. In a first path, a portion of a heat flux concentration proximate the mounting surface is thermally

transferred by the heat pipe to the heat spreader where the heat is transferred to the top portion of the vanes and is dissipated by an air flow over the vanes. In a second path, the split-core conducts heat away from the component and upward towards the top face of the split-core where the heat spreads outward to the roots of the twin fins.

5 The vanes of the twin fins provide a large surface area for the heat in the split-core to dissipated by the air flow over vanes.

Another advantage of the split-core is that a length of the split-core need not span an entire length of the root of the vanes. As a result, a length and/or a
10 diameter of the split-core can be reduced with a concomitant reduction in weight and cost of the cooling device.

Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying
15 drawings, illustrating by way of example the principles of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1a and 1b are profile views depicting a cooling device.

FIGS. 1c and 1d are bottom and side profile views depicting a cooling device.

FIG. 1e is a cross-sectional view of a cooling device along a line I-I of **FIG. 1c**.

FIGS. 2a and 2b are profile views depicting a plurality of twin fins connected with a split-core.

FIG. 2c is a bottom profile view depicting plurality of twin fins connected with a split-core.

FIG. 3 is an enlarged top profile view depicting a plurality of twin fins connected with a plurality of grooves on a split-core.

FIG. 4 is a profile view depicting a twin fin connected with a split-core.

FIGS. 5a and 5b are cross-sectional views depicting an insertion of a twin fin into a groove.

FIGS. 6a through 6f are cross-sectional views depicting a split-core and examples of profiles of a top face of the split-core.

FIGS. 7a and 7b are side views depicting grooves in a split-core.

FIGS. 8a through 8e are profile views depicting a twin fin and the vanes of the twin fin.

FIGS. 9a and 9b are profile views depicting vanes of a twin fin.

FIG. 10a and 10b are profile views depicting an arcuate profile on vanes of a twin fin.

FIG. 10c depicts a tangential relationship between a curvature of a vane and a fan blade.

FIGS. 11a through 11c are top, cross-sectional, and bottom plan views of a base plate.

FIGS. 12a and 12b are bottom and top profile views depicting a cooling device connected with a base plate.

FIGS. 13a and 13b are cross-sectional views depicting a thermal interface material in thermal communication with a split-core.

FIG. 13c is a cross-sectional view depicting an example of a heat pipe.

FIG. 14 is a cross-sectional view depicting heat flow and air flow in a cooling device with a split-core.

FIG. 15 is a side profile view depicting a clamp for connecting a plurality of twin fins to a split-core.

FIG. 16 is a profile view depicting a clamp.

FIG. 17 is a side profile view depicting an air flow device mounted to a cooling device using a mounting ring.

FIG. 18 is a side view of a system for dissipating heat from a component.

DETAILED DESCRIPTION

In the following detailed description and in the several figures of the drawings, like elements are identified with like reference numerals.

As shown in the drawings for purpose of illustration, the present invention is embodied in a cooling device for dissipating heat from a component. The cooling device includes a plurality of twin fins with each twin fin including a root and a pair of vanes extending outward of the root. The vanes of the twin fins are spaced apart to define a slot between the vanes and each vane includes a top portion, a leading edge, a trailing edge, and an outer edge. The cooling device also includes a split-core including a plurality of grooves that are adapted to receive the root of the twin fins. The split-core includes a top face, a base, a mounting surface that is adapted to thermally connect the split-core with the component, a heat spreader connected with the top portion of the vanes, and a heat pipe connected with the split-core and the heat spreader and operative to thermally transfer a portion of the heat in the split-core to the heat spreader where the heat is transferred to the vanes.

Waste heat from the component is thermally conducted into the split-core via the mounting surface and is dissipated through multiple thermal paths. In a first path, a portion of a heat flux concentrated in the split-core proximate the mounting surface is thermally transferred by the heat pipe to the heat spreader where the heat is transferred to the top portion of the vanes and is dissipated by an air flow over the vanes. In a second path, the split-core conducts a remaining portion of the heat flux concentrated away from the component and upward towards the top face of the split-core where the heat spreads outward to the roots of the twin fins and is dissipated by the air flow over the vanes, the top face, the split-core, and through the slots.

In **FIGS. 1a** through **1e**, a cooling device **10** for dissipating heat from a component (not shown) includes a plurality of twin fins **21** with each twin fin **21** including a root **27** and a pair of vanes **23** extending outward of the root **27** and spaced apart to define a slot **S** between the vanes **23**. Each vane **23** includes a top portion **29**, a leading edge **26**, a trailing edge **24**, and an outer edge **25**. The cooling device **10** also includes a split-core **11** including a plurality of grooves **G** that are adapted to receive the roots **27** of the twin fins **21**, a top face **13**, a base **17**, a mounting surface **19** adapted to thermally connect the split-core **11** with the component, a heat spreader **15** connected with the top portions **29** of the vanes **23**, and at least one heat pipe **14** connected with the split-core **11** and the heat spreader

15. In FIGS. 1a, 1b, and 1e the heat pipe 14 can be connected with the heat spreader 15 and the split-core 11 by a variety of methods that include but are not limited to forming an aperture 15a in the heat spreader 15 and an aperture 17a in the split-core 11 and then inserting the heat pipe 14 into the apertures (15a, 17a).

5 Because heat concentration in the split-core 11 will be in a volume of the split-core 11 proximate the mounting surface 19 where waste heat from the component enters the split-core 11, it is desirable to position the connection of the heat pipe 14 with the split-core 11 at the base 17 of the split-core 11. Accordingly, the aperture 17a can be positioned in the base 17 as depicted in FIG. 1e. Preferably, the aperture 17a is not a through hole but rather an opening extending only partially into the split-core 11 as depicted in FIGS. 5a and 5b. The apertures 17a can be symmetrically disposed in the split-core 11 as depicted by a dashed symmetry line Y in FIG. 5a or they can be asymmetrically disposed as depicted in FIG. 5b by an offset distance Da relative to the symmetry line Y.

15 On the other hand, the aperture 15a can be a through hole extending between a top and bottom surfaces (15t, 15b) of the heat spreader 15 or a partial opening formed in the bottom surface 15b of the heat spreader 15. If a through hole is used, then the heat pipe 14 can include a threaded portion to receive a fastener 15f (see FIG. 1d) that connects the heat pipe 14 with the heat spreader 15. For example, a machine screw can be used for the fastener 15f. Those skilled in the art will appreciate that other means can be used to connect the heat pipe 14 with heat spreader 15, including but not limited to welding, brazing, soldering, and press fitting, just to name a few. As another example, the heat pipe can be inserted into the apertures 17a and then brazing the heat pipe to the base 17, followed by inserting the heat pipe 14 into the apertures 15a and then brazing the heat pipe 14 to the bottom surface 15b. If the aperture 15a is a through hole, then the heat pipe 14 can be brazed to both the top and bottom surfaces (15t, 15b).

30 In FIG. 1d, for some applications, it may be desirable to design the connection of the heat pipe 14 with the split-core 11 to include an offset distance d between a bottom of the heat pipe 14 and the mounting surface 19 so that a base plate as will be described below or some other means for mounting the cooling device 10 with the component can be effectuated without creating a mechanical interference with the heat pipe 14.

Referring to FIG. 1b, the heat spreader 15 can be connected (see dashed oval 15c) with the top portions 29 of the vanes 23 by a method including but not limited to soldering, brazing, welding, and a thermal interface material. Examples of

suitable thermal interface materials include but are not limited to thermally conductive pastes, paints, films, and coatings.

{Shankar, can thermal interface materials be used assuming there is enough pressure created by the connection of the heat spreader 15 to the heat pipes 14?}

A plurality of twin fins 21 connected with the split-core 11 sans the heat spreader 15 and heat pipes 14 are depicted in greater detail in FIGS. 2a, 2b, 2c, and 3. Turning to FIG. 3, a close up view of the device 10 depicts a plurality of the twin fins 21 with their respective roots 27 connected with the grooves G on the split-core 11 such that the twin fins 21 form an array of fins that surround the split-core 11. The leading edge 26 of the vanes 23 defines a chamber 30 that surrounds the top face 13. The top portion 29 of the vanes 23 can be a substantially planar surface for mounting the heat spreader 15 so that heat transferred to the heat spreader 15 via the heat pipes 14 is thermally transferred to the vanes 23. The top portion 29 can be a profiled surface that complements a profile of the bottom surface 15b of the heat spreader 15. The chamber 30 is preferable because it provides a space for an air flow F to circulate over the top face 13 to dissipate heat from the split-core 11 and for the air flow F to pass over the vanes 23 and through the slots S. The chamber 30 also allows for increased air circulation through the vanes 23 proximate the top portion 29 so that heat transferred to the vanes 23 from the heat spreader 15 is efficiently dissipated by the air flow F. The top face 13 of the split-core 11 may be substantially flush with the roots 27 of the twin fins 21, may extend outward the roots 23, or may be positioned below an upper most portion of the roots 27 as depicted respectively in FIGS. 2a, 2b, and 14.

In FIG. 2c, waste heat H_W from a component (not shown) is thermally conducted into the split-core 11 through the mounting surface 19. The waste heat H_W is dissipated by the air flow F that passes over the vanes 23, the top face 13, the split-core 11, and through the slots S between the vanes 23. The air flow F can be from an air flow source such as a fan, for example. Although the heat spreader 15 is not depicted in FIGS. 2c and 3, the top portions 29 of the vanes 23 are in thermal communication with the heat spreader 15 and heat transferred from the heat spreader 15 to the top portions 29 of the vanes is also dissipated by the air flow F. Preferably, the top portion 29 is sized to maximize its contact area with the heat spreader 15 (i.e. the bottom surface 15b) so that heat transfer from the heat spreader 15 to the vanes 23 is maximized. For example, in FIG. 1a, if the bottom surface 15b has a width of W1 and the top portion 29 has a length of L1 (see FIGS. 9b and 10a), then $L1 \approx W1$.

Turning to **FIG. 4**, grooves **G** are adapted to receive the root **27** of the twin fins **21**. The grooves **G** can be formed by a pair of spaced apart projections **12** that extend outward of a surface **11s** of the split-core **11**. A space between adjacent projections **12** is sufficient to receive a width **27w** of the root of the twin fin **21**.

Alternatively, in **FIGS. 5a** and **5b**, the groove **G** can extend inward of the surface **11s** and the groove **G** can include a width and a depth sufficient to receive the root **27** of the twin fins **21**. As will be described below, the grooves **G** can be aligned with an axis **Z** of the split-core **11** or the grooves **G** can be at an angle with the axis **Z**. Factors including a size of the split-core **11** (e.g. its circumference) and the width **27w** of the roots will determine a maximum number of the twin fins **21** that can be connected with the split-core **11** of the cooling device **10**.

Referring to **FIGS. 5a** and **5b**, the root **27** can be inserted into the groove **G** by using a tool **90**. The tool **90** can complement a shape of the slot **S** and the tool **90** can be used to urge the root **27** into the groove **G** so that the root **27** is firmly connected with the groove **G** and the root **27** is in contact with the groove **G** substantially over its entire length along the split-core **11**. As an example, the twin fin **21** can be fixedly connected with the groove **G** by applying a solder or the like to the root **27** and/or the groove **G** prior to the insertion, and then soldering the root **27** in the groove **G**. The tool **90** can be used to hold the root **27** in the groove **G** so that the twin fin **21** does not move during the connection process.

Similarly, a brazing process can be used to connect the root **27** with the groove **G**. To enhance thermally conductivity between the split-core **11** and the twin fin **21**, a thermal sealant or a thermal interface material can be positioned in the groove **G** or on the root **27** prior to insertion. Although not depicted in **FIGS. 5a** and **5b**, the above processes can be used when the groove **G** is formed by the projections **12** depicted in **FIG. 4**. Other methods can be used to connect the root **27** with the groove **G** and the present invention is not to be construed as being limited to the methods disclosed herein. For instance, welding, vacuum brazing, adhesives, and gluing are examples of other methods to effectuate a connection of the roots **27** with the grooves **G**.

In **FIGS. 6a** through **6f**, examples of various configurations for the top face **13** of the split-core **11** are depicted. The top face **13** can include a planar profile in **FIG. 6a**, an arcuate profile in **FIG. 6b**, and a sloped profile in **FIG. 6c**. In **FIGS. 6d** and **6e**, the sloped and arcuate profiles can terminate at a frustum **13f**. In **FIGS. 6f** and **6g**, the top face **13** includes concave arcuate and concave sloped profiles respectively, and those profiles can include the frustum **13f**. The profile of the top

face **13** can be selected based on air flow management in the chamber **30** and/or to increase the air flow **F** over the top face **13** to enhance heat transfer from the split-core **11** to the air flow **F**.

In **FIGS. 7a** and **7b**, the grooves **G** include a length **L** that can substantially span an entirety of a length of the surface **11s** of the split-core **11**. The root **27** of each twin fin **21** can have a length that is substantially equal to the length **L** of the grooves **G**. In **FIG. 7a**, the grooves **G** come short of extending all the way down to the mounting surface **19** by a distance **d1** so that the base **17** can be inserted into a mounting means as will be describe below. The distance **d1** can be 0.25 inches or less, for example. Accordingly, the length **L** spans a substantial entirety of the surface **11s**. As was described above, the distance **d** between the bottom of the heat pipe **14** and the mounting surface **19** should be sufficient to prevent a mechanical interference with the mounting of the cooling device **10** to the mounting means. The grooves **G** can be aligned with an axis **Z** of the split-core **11** or the grooves **G** can have an angular orientation β with the axis **Z**. In **FIG. 7b**, the base **17** can be inset from the surface **11s** of the split-core **11** as depicted by the distance **d2**. The inset distance **d2** narrows a width of the base **17** and can be sized to match a width of an aperture **102** in the mounting means.

In **FIGS. 8a** through **8d**, each twin fin **21** includes a root **27** that is common to both vanes **23**, an outer edge **25**, a trailing edge **24**, a leading edge **26**, and a top portion **29**. Optionally, the outer edge **25** of the vane **23** can include a lip **22** that extends outward of the outer edge **25**. The lip **22** provides a surface against which a mounting ring (see **80** in **FIG. 17**) can be mounted for connecting an air flow device with the cooling device **10**. The leading edge **26** of the vane **23** can include a profile that is straight (i.e. planar), arcuate, sloped, or a composite profile that is combination of one or more of the straight, arcuate (see **FIGS. 8a** and **8b**), and sloped profiles. The profile can be selected to control the air flow **F** in the chamber **30**, over the top face **13**, over the vanes **23**, and through the slots **S**. The profile may also be selected to complement a shape of a fan blade that is positioned in the chamber **30** to provide the air flow **F**. Although the trailing edge **24** is depicted as being substantially planar, the trailing edge **24** may also be profiled and can include a straight, an arcuate, a sloped, or a composite profile that is combination of one or more of the straight, arcuate, and sloped profiles. The slots **S** between the vanes **23** can diverge from the root **27** to the outer edge **25** so that the slot **S** widens in a direction from the root **27** to the outer edge **25**.

To facilitate connecting the heat pipes **14** with the split-core **11** and the heat spreader **15**, a cut-out **23c** can be formed in some of the vanes **23** to allow a portion of the heat pipes **14** to pass through the vanes **23** as depicted in **FIG. 1b**. The cut-out **23c** prevents a potential mechanical interference between the heat pipes **14** and the vanes **23** when the dimensions of the cooling device **10** will result in the heat pipes **14** passing through an area that would otherwise be occupied by a portion of the vanes **23**.

The root **27** and a portion **27c** (see dashed lines) of the vanes **23** may be coated with a material including but not limited to an adhesive, a glue, a solder, or a brazing compound to effectuate a connection of the twin fins **21** with the grooves **G** in the split-core **11**. Because the portion **27c** will come into contact with the projections **12** (see **FIG. 4**) or the a wall of the groove **G** (see **FIGS. 5a** and **5b**), it may be desirable to coat the portion **27c** with the aforementioned material to ensure the twin fin **21** is fixedly connected with the split-core **11**. Thermal transfer of waste heat **H_w** from the split-core **11** to the twin fins **21** can be reduced if the connection between the root **27** and the groove **G** is not snug and/or any portion of the root **27** is not in contact with the split-core **11**. As was described above, a width **27w** of the roots **27** should be selected to complement the inside dimensions of the grooves **G** or the projections **12** to ensure a snug fit.

In **FIGS. 9a** and **9b**, the vanes **23** of the twin fins **21** include a planar profile, that is, each vane **23** is a substantially flat surface from the root **27** to the outer edge **25**. On the other hand, in **FIGS. 10a** and **10b**, the vanes **23** include an arcuate profile denoted by arrows **23a**. The vanes **23** can also include an angular profile (see **FIG. 8e**) wherein the vanes **23** have one or more portions that are at an angle α with respect to another portion of the vane **23** or with respect to some predetermined reference point on the twin fin **21** or the split-core **11**.

The arcuate profile **23a** depicted in **FIGS. 10a** and **10b** can be selected to be tangential to a point on the split-core **11**, such as a circle of a predetermined diameter and centered about the axis **Z** of the split-core **11**. As an example, the arcuate profile **23a** can be selected to match a curvature of a fan blade (not shown) on a fan that is mounted over the chamber **30**. Matching a curvature of the vanes **23** with a curvature of the fan blade can result in lower air shock noise caused by the air flow **F** moving over the vanes **23** and through the slot **S**.

Turning to **FIG. 10c**, a circle **11c** centered about the axis **Z** of the split-core **11** has a tangent line **T_L** that is tangent to the circle **11c** and is tangent to a curvature of

the arcuate profile **23a** of vanes **23** as denoted by a second circle having a radius R_T that is equal to a distance from the root **27** to the outer edge **25** of the vanes **23**. A second radius R_F represents a radius of a fan blade **71** (shown superimposed over the vanes **23**) from a center of a hub of a fan (not shown). The curvature of the fan blade **71** matches the arcuate profile **23a** of the vanes **23** such that the two circles defined by radius lines (R_T and R_F) are concentric with each other.

In **FIGS. 11a** through **11c**, a base plate **100** includes a top surface **103**, a bottom surface **105**, and an aperture **102** between the top and bottom surfaces (**103**, **105**). The base plate **100** can include mounting holes **101** for receiving a fastener, such as a machine screw, for example. The fastener can be used to mount the base plate **100** on a PC board that carries the component to be cooled by the cooling device **10**. The base plate **100** positions the mounting surface **19** of the split-core **11** in thermal contact with the component. The aperture **102** is adapted to receive the base **17** of the split-core **11**. The base plate **100** can have any shape and is not limited to the rectangular shape depicted herein. The base plate **100** can have any shape that can accommodate a bore through which the cooling device **10** can be connected with the base plate **100** and mounting holes to mount the base plate **100** over the component to be cooled.

In **FIG. 12a**, the base **17** can be inserted into the aperture **102** and then retained in the aperture **102** by a variety of methods including but not limited to welding, friction stir welding, soldering, brazing, gluing, or by a friction fit between the base **17** and the aperture **102**. The mounting surface **19** may or may not be flush with the bottom surface **105**. In **FIG. 12b**, after mounting the cooling device **10** to the base plate **100** the distance d (see **FIG. 1d**) should be such that the bottom of the heat pipes **14** are positioned above the top surface **103** of the base plate **100** or bottom of the heat pipes **14** are in contact with the top surface **103**. Preferably, the bottom of the heat pipes **14** are positioned above the top surface **103** to prevent damage to the heat pipes and/or unwanted heat transfer from the heat pipes **14** to the base plate **100**.

In **FIG. 13a**, a thermal interface material **40** can be positioned on the mounting surface **19**. The thermal interface material **40** reduces thermal resistance between a surface **51** of a component **50** and can seal micro voids on the surface **51** thereby increasing waste heat H_W transfer from the component **50** to the split-core **11**. Alternatively, in **FIG. 13b**, the mounting surface **19** can include a cavity **18** inset from the mounting surface **19**. A thermal interface material **40** can be positioned in the cavity **18** and the thermal interface material **40** can be flush with the mounting

surface **19** or may extend inward or outward of the mounting surface **19**.

Referring to **FIG. 13c**, the heat pipe **14** can be implemented using a variety of heat pipe technologies that are well understood in the electronic arts. For example, the heat pipe **14** can be made from a solid piece of a high thermal conductivity material **14m** such as copper (**Cu**), for example. On the other hand, the heat pipe **14** can comprise the high thermal conductivity material **14m** with a sealed interior volume **14v** that contains a working fluid **14f**. The sealed interior volume **14v** can also include a wicking or capillary structure. Typically, the working fluid **14f** is sealed at a low pressure and is characterized by a high thermal conductivity, a high surface tension, and a high latent heat of vaporization. Dimensions **m1** and **m2** of the heat pipe **14** should be selected to complement the apertures **17a** and **15a** of the split-core **11** and the heat spreader **15**, respectively. For example, the dimensions **m1** and **m2** can be 8.0 mm in diameter and the apertures **17a** and **15a** can be sized to accommodate those dimensions. The heat pipe **14** can be an off-the-shelf commercially available model or a custom made model from companies such as **Thermacore®** or **YC-Tech Company®**, for example.

{Shankar, is the above correct? Does YC-Tech Company have a web site is there a model number for the heat pipe 14 that you used? What types of fluids or materials are used in an exemplary heat pipe 14?}

In **FIG. 14**, a component **50** is in thermal communication with the mounting surface **19** of the split-core **11**. The thermal communication can be by a direct contact between the component **50** and the mounting surface **19** as depicted or via an intermediate structure such as the thermal interface material **40**, for example. Waste heat H_W enters the split-core **11** via the mounting surface **19** and is concentrated near the base **17** where the heat pipes **14** are connected with the split-core **11**. Even though the waste heat H_W is thermally conducted throughout a volume of the split-core **11**, a heavy dashed oval depicts a region in split-core **11** where a heat flux concentration H_C is highest. The heat flux concentration H_C can be particularly problematic when the component **50** is a high power dissipation, state-of-the-art, microprocessor such as the type used in leading edge workstations, PC's, servers, and laptop computers and manufactured by companies such as **Intel™**, **AMD™**, **IBM™**, and **SUN Microsystems™**, for example. The heat flux concentration H_C is highest at a surface **51** of the component **50** and in the region depicted by the heavy dashed oval. To efficiently cool the component **50** it is desirable to reduce the heat flux concentration H_C in the split-core **11**.

The split-core **11**, the heat pipes **14**, and the heat spreader **15** effectively reduce the heat flux concentration H_C by providing multiple thermal paths to

dissipate the waste heat H_w . In a first path **P1**, a portion of the heat flux concentration H_c is thermally transferred by the heat pipe **14** to the heat spreader **15** where the heat is then transferred to the vanes **23** via the top portion **29** where the air flow **F** over the vanes **23** dissipates the heat.

In a second path **P2**, the split-core **11** thermally conducts a remaining portion of the heat flux concentration H_c upward towards the top face **13** where the heat spreads outward to the roots **27** of the twin fins **21** and is dissipated by the air flow **F** over the vanes **23**, the top face **13**, the split-core, and through the slots **S**. Another advantage of the multiple paths (**P1**, **P2**) is that a length of the split-core **11** need not span the length of the roots **27** of the twin fins **21**. Instead, the top face **13** of the split-core **11** can be recessed below an uppermost portion of the roots **27** as depicted in **FIG. 14**. As a result, the cooling device **10** can be made smaller with a lower mass and a lower cost.

An increase in heat removal efficiency of the cooling device **10** in comparison to a cooling device with a split-core **11** but without the heat pipes **14** or the heat spreader **15** is depicted below in **Table 1**. Both cooling devices had 60 twin fins **21** connected with their respective split-cores **11** and had a height of 50 mm and a diameter of 69 mm measured at the outer edges **25** of the twin fins **21**. However, the cooling device **10** included heat pipes **14** of 8.0 mm diameter. With 100 watts of power dissipation from the components **50**, the use of the cooling device **10** results in a 6 C lower case temperature and a 0.06 C/W lower thermal resistance for a 28% improvement compared with the cooling device without heat pipes **14** and heat spreader **15**.

{Shankar, please clarify the following in Table 1: Are the Delta Fans different from each other? Is the mass of the cooling device the total mass or the mass of the heat mass 11? Is the case temp. the temperature of the component being cooled? What is the thermal resistance? Is the diameter of 69 mm the diameter of the twin fins 21 or of the heat mass 11? Is the height of 50 mm the total height of the cooling devices? How is the 28% improvement measured?}

Data	A Cooling Device <u>without</u> Heat Pipes 14 or a Heat Spreader 15	Cooling Device 10 with Heat Pipes 14 and Heat Spreader 15
Mass of Cooling Device	900 grams	500 grams
Thermal Output of Component	100 Watts	100 Watts
Fan Type	Delta EFB0712E	Delta EFB0712EH
Temperature of Case	47 C	41 C
Ambient Temperature	25 C	25 C

Thermal Resistance	0.22 · C/W	0.16 · C/W
Improvement	0%	28%

TABLE 1

Referring to **FIG. 14**, the air flow **F** can be in a direction from the leading edge **26** to the trailing edge **24** or from the trailing edge **24** to the leading edge **26**.

Accordingly, an air flow source, such as a fan, can either push or pull air through the slots **S** and over the vanes **23**. The air flow **F** entering the chamber **30** can also circulate over the top face **13** to dissipate the waste heat **H_W** from the split-core **11**. The split-core **11** can have a length **L** that is long relative to a width **W** of the split-core **11** (see **FIG. 7b**) so that an aspect ratio ($L \div W$) of the split-core **11** is large and the waste heat **H_W** is thermally conducted up the split-core **11** along the second path **P2** towards the top face **13**. As described above, the roots **27** and grooves **G** can span substantially all of the length **L** so that the waste heat **H_W** is transferred from the split-core **11** to the twin fins **21** along the entire length of the roots **27**. The split-core **11** can be made from a high thermal conductivity material (e.g. copper or graphite) that efficiently conducts the waste heat **H_W** upward along the axis **Z** and outward towards the twin fins **21** so that the waste heat **H_W** is spread over a much larger area; thereby, reducing heat flux concentration **H_C** at the surface **51** of the component **50** and in the base **17**.

In **FIG. 15**, the roots **27** of the twin fins **21** can be connected with the grooves **G** using a clamp **41** that clamps around ears **27L** on the root **27**. The clamp **41** can be a C-clamp, a clamping ring, or the like and can exert a force on the roots **27** that urge the roots **27** into firm contact with the grooves **G**. As described above, a thermal interface material or a thermal sealant material can be applied to the roots **27** and/or the grooves **G** to reduce thermal resistance between the split-core **11** and the twin fins **21**.

One example of an implementation of the clamp **41** is depicted in **FIG. 16**, where the clamp **41** includes a clamp body **43** with a gap **43g** (see dashed line) in the clamp body **43**. At the gap **43g**, the clamp body **43** is split into two parts **43a** and **43b** with an aperture **41a** formed in both parts (**43a**, **43b**). The aperture **41a** can receive a fastener or the like to urge the two parts **43a** and **43b** together so that a clamping force is exerted on the roots **27** of the twin fins **21** by a clamping surface **41c** so that the roots **27** are urged into contact with the grooves **G**. As described above, in order to ensure a low thermal resistance connection between the roots **27** and the grooves **G** along the entire length of the grooves **G**, a thermal sealant or thermal interface material can be applied to the roots **27** and/or the grooves **G**.

In **FIG. 17**, as one example of an air flow device, a fan **70** can be mounted on the cooling device **10**. The mounting can be accomplished using a mounting ring **80** that abuts with the lips **22** on the outer edges **25** of the vanes **23**. Through holes (not shown) in the heat spreader **15** can accommodate fasteners **73** and **75** (e.g. a nut and bolt) that pass through the heat spreader **15** to connect the fan **70** with the mounting ring **80**. The blades of the fan **70** may be positioned inside the chamber **30** or outside the chamber **30**. Alternatively, in **FIG. 18**, the heat spreader **15** can include through holes that accommodate fasteners **73** and **75** (e.g. a nut and bolt) that pass through the heat spreader **15** to connect the fan **70** with the cooling device **10**. Latch pins (not shown) can also be used to mount the fan **70** on the heat spreader **15**. The fan **70** generates the air flow **F** and the fan **70** can push or pull air through the cooling device **10**.

In **FIGS. 17** and **18**, a system **200** for dissipating waste heat H_w from a component can include the cooling device **10** and the air flow source **70** as described above. The air flow source **70** can be an electrical fan, for example. Additionally, the system **200** can include the base plate **100** for mounting the system **200** with the component **50** so that the mounting surface **19** is in thermal communication with the component **50** to be cooled as was described above. The thermal interface material **40** can be used to thermally communicate the waste heat H_w from the component **50** to the mounting surface **19** and into the split-core **11**. The base plate **100** can be mounted on a substrate **60**, such as a PC board, for example, that carries the component **50**. The base plate **100** can be mounted with the substrate **60** using fasteners **65** inserted through the mounting holes **101** in the base plate **100**.

The twin fins **21** can be made from a variety of thermally conductive materials including but not limited to aluminum (**Al**), copper (**Cu**), silver (**Ag**), gold (**Au**), and alloys of those materials, and a high thermal conductivity resin. Preferably, the vanes **23** and the root **27** are a homogenous unit, that is, they are a unitary whole. The twin fins **21** can be manufactured using a pressing or stamping process. A bending or rolling process can be used to form the arcuate profile **23a** or to form an angular or non-planar profile on the vanes **23**. As an example, the twin fins **21** can be stamped from a sheet of material, such as a copper (**Cu**) or an aluminum (**Al**) sheet. As another example, the twin fins **21** can be molded from a high thermal conductivity material such as a resin or a carbon fiber re-aligned resin. The vanes **23** need not be identical among the twin fins **21**. Because the twin fins **21** are not a unitary whole with the split-core **11** and are attached by their roots **27** to the split-core **11**, twin fins **21** with vanes **23** that differ in size and shape can be connected

with the split-core **11** via the grooves **G**.

The split-core **11** can also be made from a variety of thermally conductive materials including but not limited to aluminum (**Al**), copper (**Cu**), silver (**Ag**), gold (**Au**), alloys of those materials, silicon (**Si**) substrate, thermally conductive resins, and graphite. The split-core **11** can be a casting or it can be machined to shape. The grooves **G** can be machined in the split-core **11** or they can be formed by the same casting process. The split-core **11** can have any shape and need not have a circular or cylindrical shape as depicted herein. The split-core **11** and the twin fins **21** can be made from dissimilar materials.

{Shankar, is the above correct for the manufacturing of the split-core **11** and the twin fins **21**?}

As an example, the split-core **11** can be made from graphite and the twin fins made from copper (**Cu**) or the split-core **11** can be made from copper (**Cu**) and the twin fins **21** from aluminum (**Al**). As another example, the split-core **11** can be made using a forging process or an impact forging process. A shape of the split-core **11** as well as the grooves **G** can be directly forged.

Although several embodiments of the present invention have been disclosed and illustrated, the invention is not limited to the specific forms or arrangements of parts so described and illustrated. The invention is only limited by the claims.

What is Claimed is:

1. A cooling device **10** for dissipating heat H_w from a component **50**, comprising:

a plurality of twin fins **21**, each twin fin **21** including a root **27** and a pair of vanes **23** extending outward of the root **27** and spaced apart to define a slot **S** between the vanes **23**, each vane **23** including a top portion **29**, a leading edge **26**, a trailing edge **24**, and an outer edge **25**; and

a split-core **11** including a plurality of grooves **G** adapted to receive the root **27**, a top face **13**, a base **17**, a mounting surface **19** adapted to thermally connect the split-core **11** with the component **50**, a heat spreader **15** connected with the top portion **29**, and a heat pipe **14** connected with the split-core **11** and the heat spreader **15**.

2. The cooling device as set forth in Claim 1, wherein the heat pipe is connected with the base of the split-core.

3. The cooling device **10** as set forth in Claim 1, wherein the grooves **G** extend inward of a surface **11s** of the split-core **11**.

4. The cooling device **10** as set forth in Claim 1, wherein each groove **G** comprises a pair of spaced apart projections **12** that extend outward of a surface **11s** of the split-core **11**.

5. The cooling device **10** as set forth in Claim 1, wherein the grooves **G** are a selected one of aligned with an axis **Z** of the split-core **11** or aligned at an angle β with the axis **Z** of the split-core **11**.

6. The cooling device **10** as set forth in Claim 1, wherein the vanes **23** include a profile selected from the group consisting of a planar profile, an arcuate profile **23a**, and an angular profile.

7. The cooling device **10** as set forth in Claim 6, wherein the arcuate profile **23a** of the vanes **23** matches a curvature of a fan blade **71**.

8. The cooling device **10** as set forth in Claim 7 and further comprising:

a base plate **100** including a top surface **103**, a bottom surface **105**, and an aperture **102** extending between the top and bottom surfaces (**103**, **105**), the aperture **102** is adapted to receive the base **17** of the split-core **11**, and the base plate **100** is operative to position the mounting surface **19** of the cooling device **10** in thermal communication with the component **50**.

9. The cooling device **10** as set forth in Claim 1 and further comprising a thermal interface material **40** positioned on the mounting surface **19**.

10. The cooling device **10** as set forth in Claim 1, wherein the mounting surface **19** includes a cavity **18** inset from the mounting surface **19** and adapted to receive a thermal interface material **40**.

11. The cooling device **10** as set forth in Claim 10 and further comprising a thermal interface material **40** positioned in the cavity **18**.

12. The cooling device **10** as set forth in Claim 1, wherein the root **27** of each twin fin **21** is fixedly connected with the groove **G**.

13. The cooling device **10** as set forth in Claim 12, wherein each root **27** is fixedly connected with the grooves **G** using a process selected from the group consisting of welding, brazing, vacuum brazing, soldering, adhesively connecting, and gluing.

14. The cooling device **10** as set forth in Claim 1, wherein the grooves **G** include a length **L** that substantially spans an entirety of a length of a surface **11s** of the split-core **11** and the root **27** of each twin fin **21** includes a length that is substantially equal to the length **L** of the grooves **G**.

- 15.** The cooling device **10** as set forth in Claim 1, wherein the leading edge **26** of the vanes **23** includes a profile selected from the group consisting of a straight profile, an arcuate profile, a slope profile, and a composite profile.
- 16.** The cooling device **10** as set forth in Claim 1, wherein the leading edges **26** of the vanes **23** form a chamber **30** surrounding the top face **13** of the split-core **11**.
- 17.** The cooling device **10** as set forth in Claim 1, wherein the top face **13** of the split-core **11** includes a profile selected from the group consisting of a planar profile, a sloped profile, and an arcuate profile.
- 18.** The cooling device **10** as set forth in Claim 1, wherein the outer edge **25** of each vane **23** includes a lip **22** extending outward of the outer edge **25** and adapted to receive a mounting ring **80** for connecting an air flow **70** source with the cooling device **10**.
- 19.** The cooling device **10** as set forth in Claim 1, wherein the twin fins **21** are made from a material selected from the group consisting of aluminum, copper, silver, gold, and alloys of those materials.
- 20.** The cooling device **10** as set forth in Claim 1, wherein the split-core **11** is made from a material selected from the group consisting of aluminum, copper, silver, gold, alloys of those materials, and graphite.
- 21.** The cooling device **10** as set forth in Claim 1, wherein the split-core **11** and the twin fins **21** are made from dissimilar materials.
- 22.** The cooling device **10** as set forth in Claim 1, wherein a shape of the vanes **23** varies among the plurality of twin fins **21**.
- 23.** The cooling device **10** as set forth in Claim 1 and further comprising a thermal interface material applied to a selected one of the root **27**, the grooves **6**, or the root

27 and the grooves **G** and operative to increase heat transfer from the split-core **11** to the twin fins **21**.

24. The cooling device **10** as set forth in Claim 1, wherein the base **17** is inset **d2** from a surface **11s** of the split-core **11**.

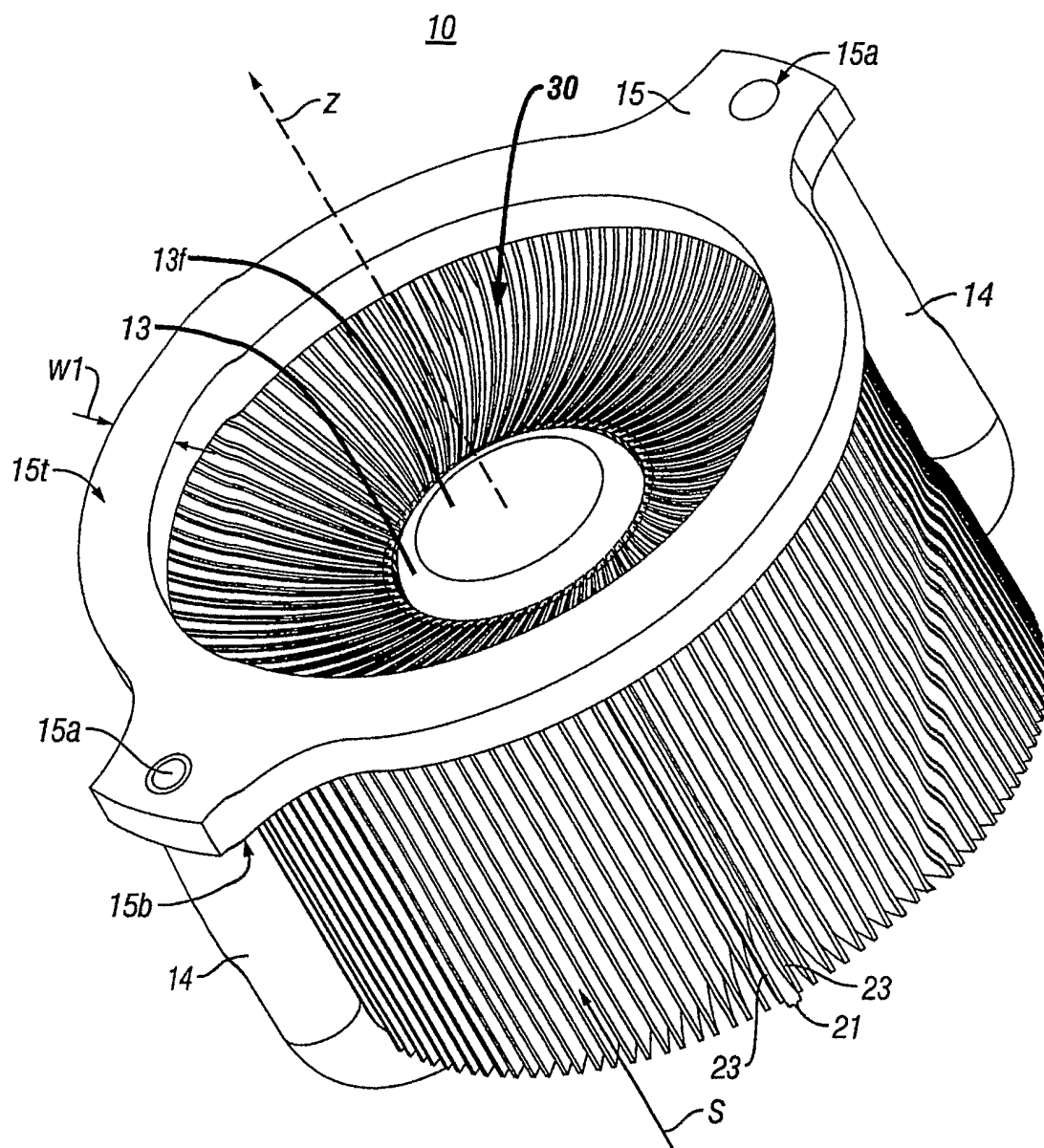


FIG. 1a

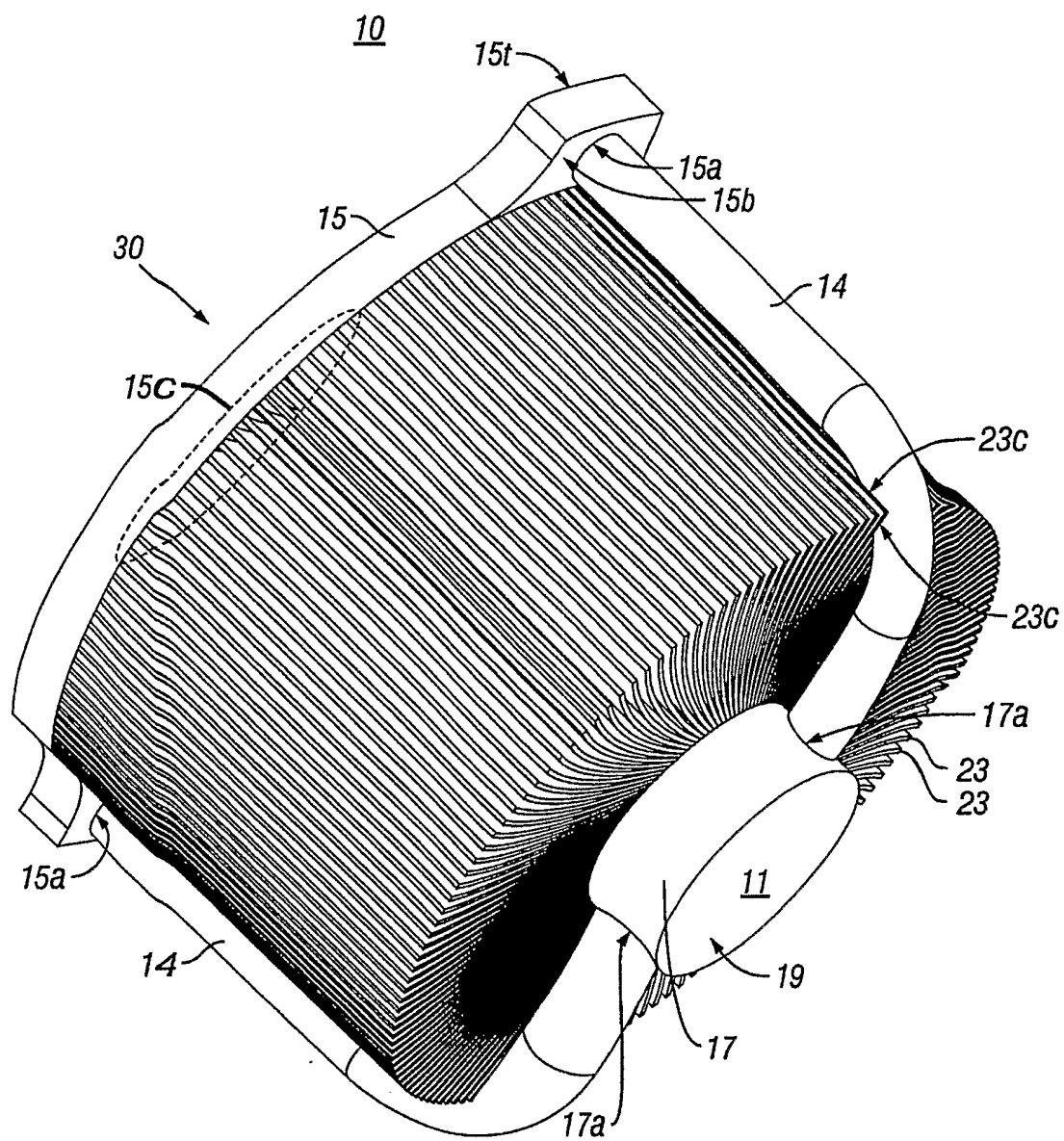
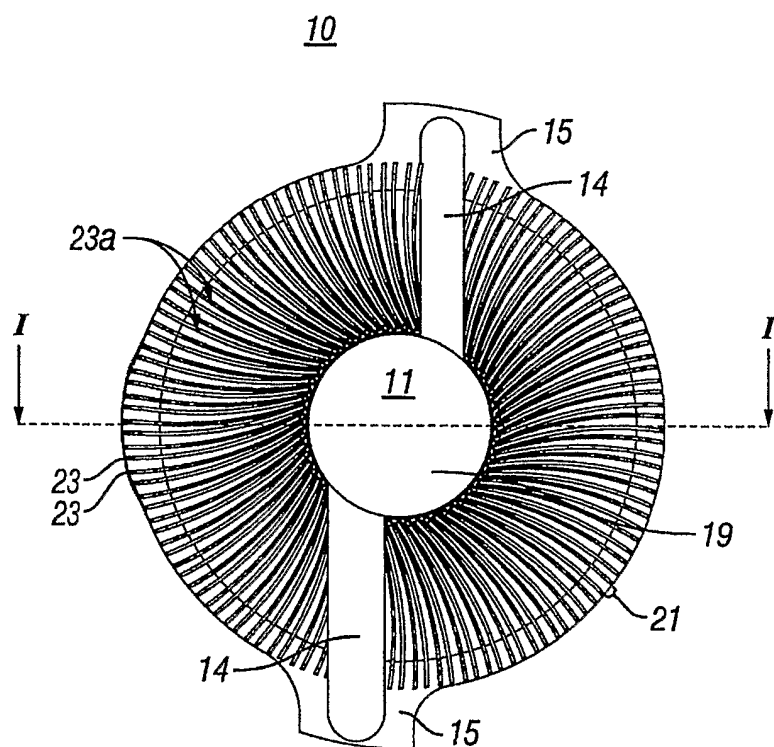
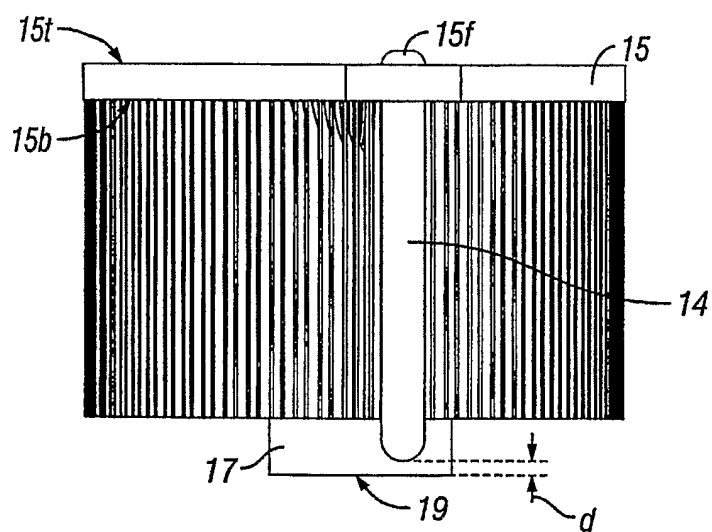
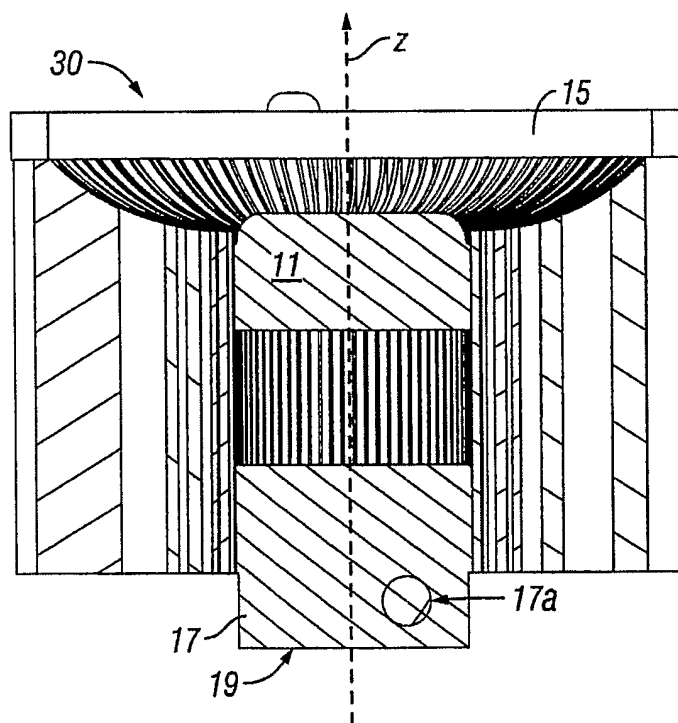


FIG. 1b

**FIG. 1c****FIG. 1d**

**FIG. 1e**

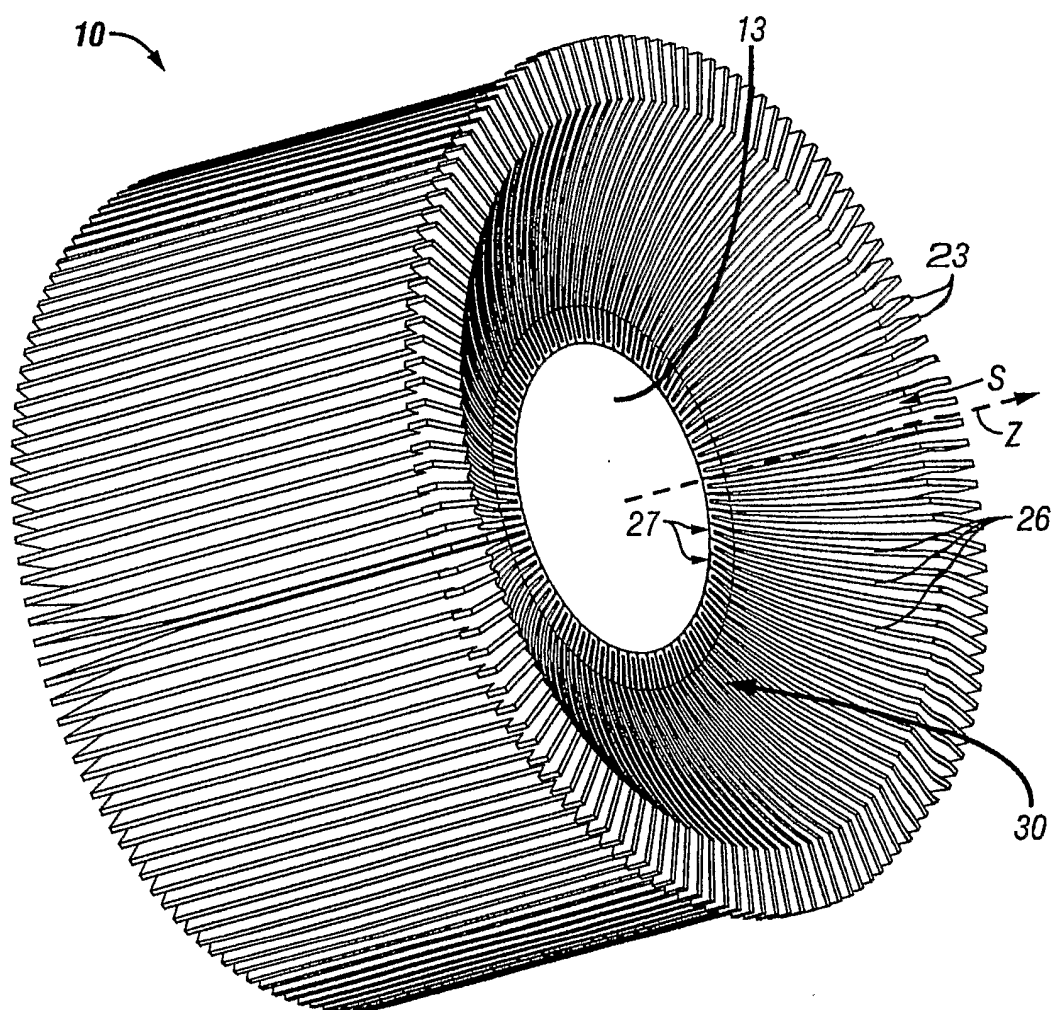
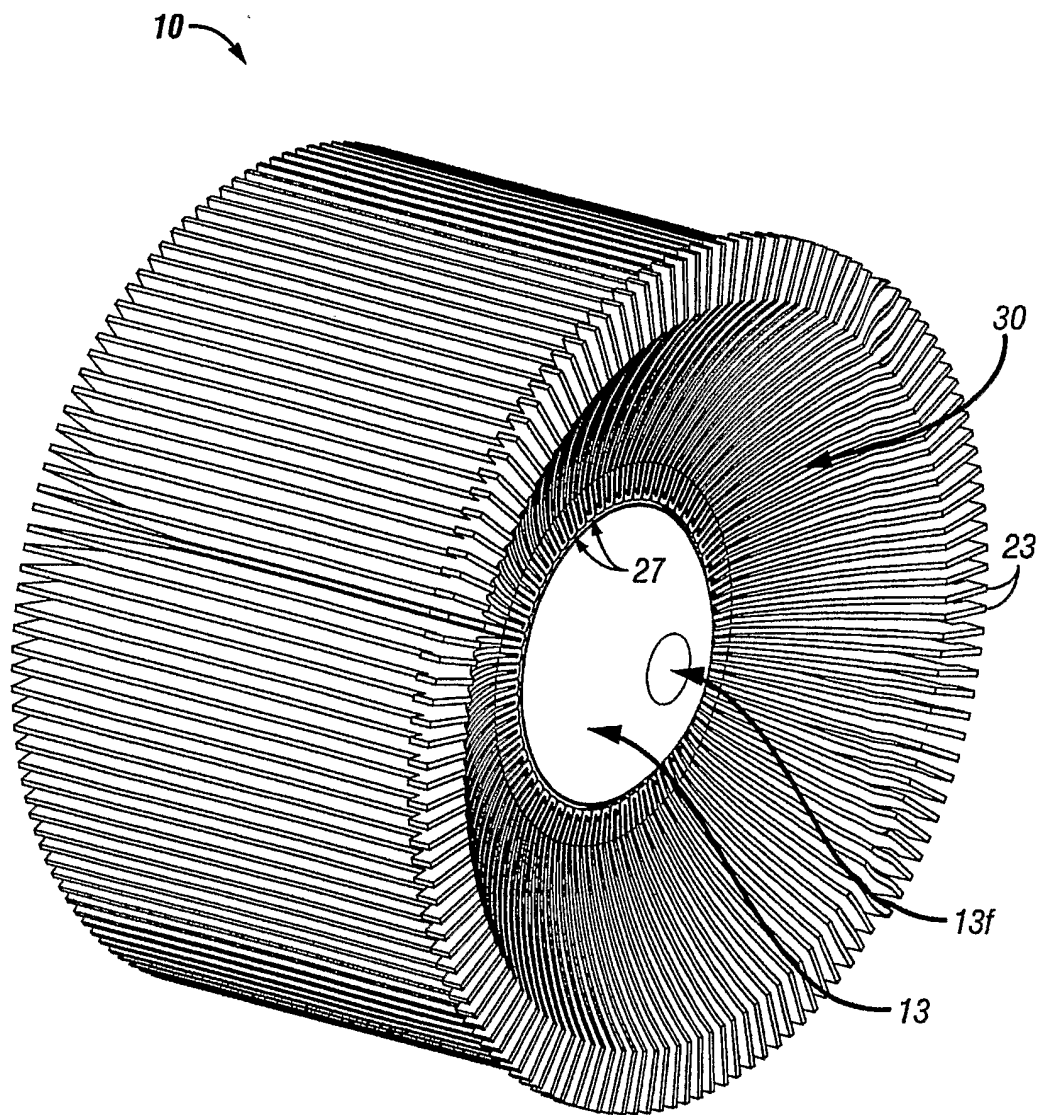


FIG. 2a

**FIG. 2b**

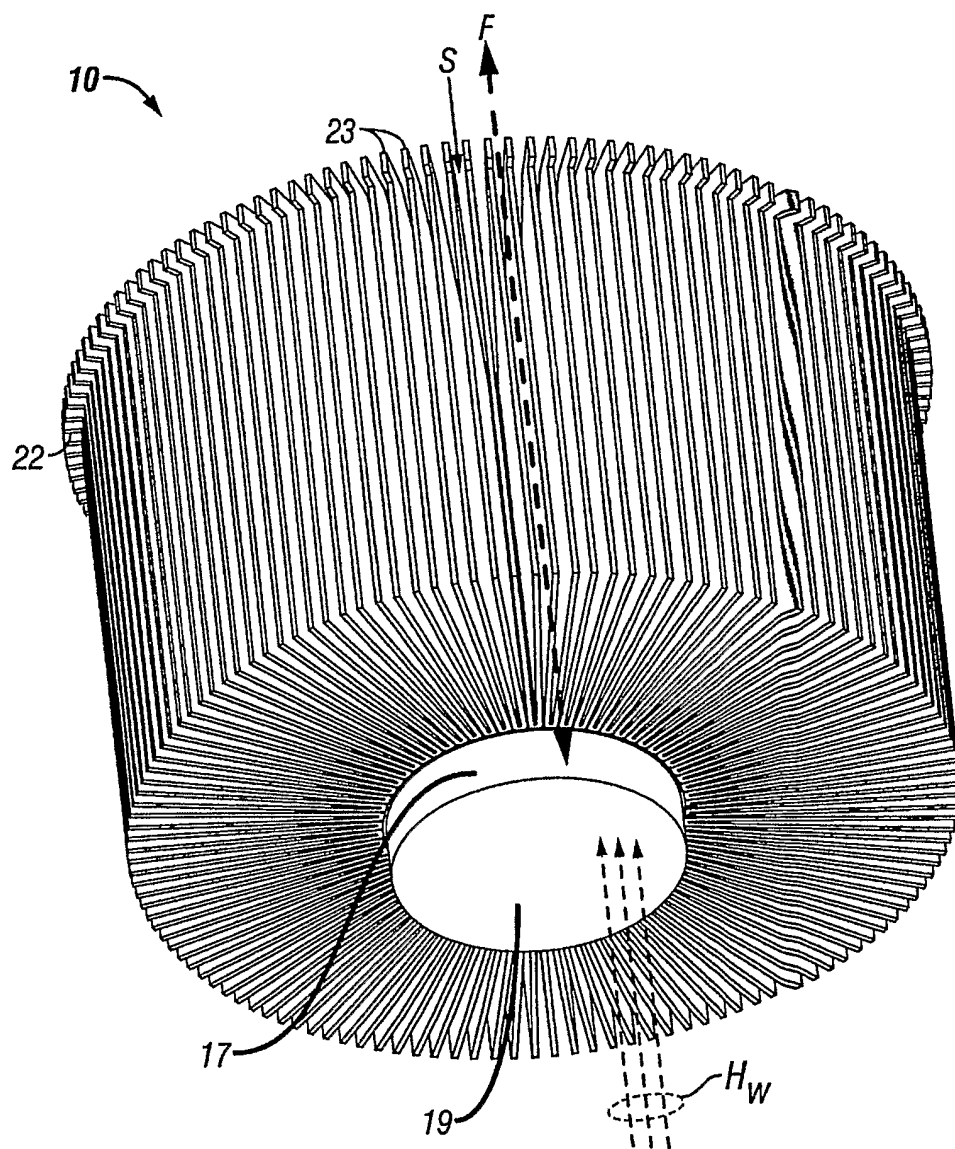


FIG. 2c

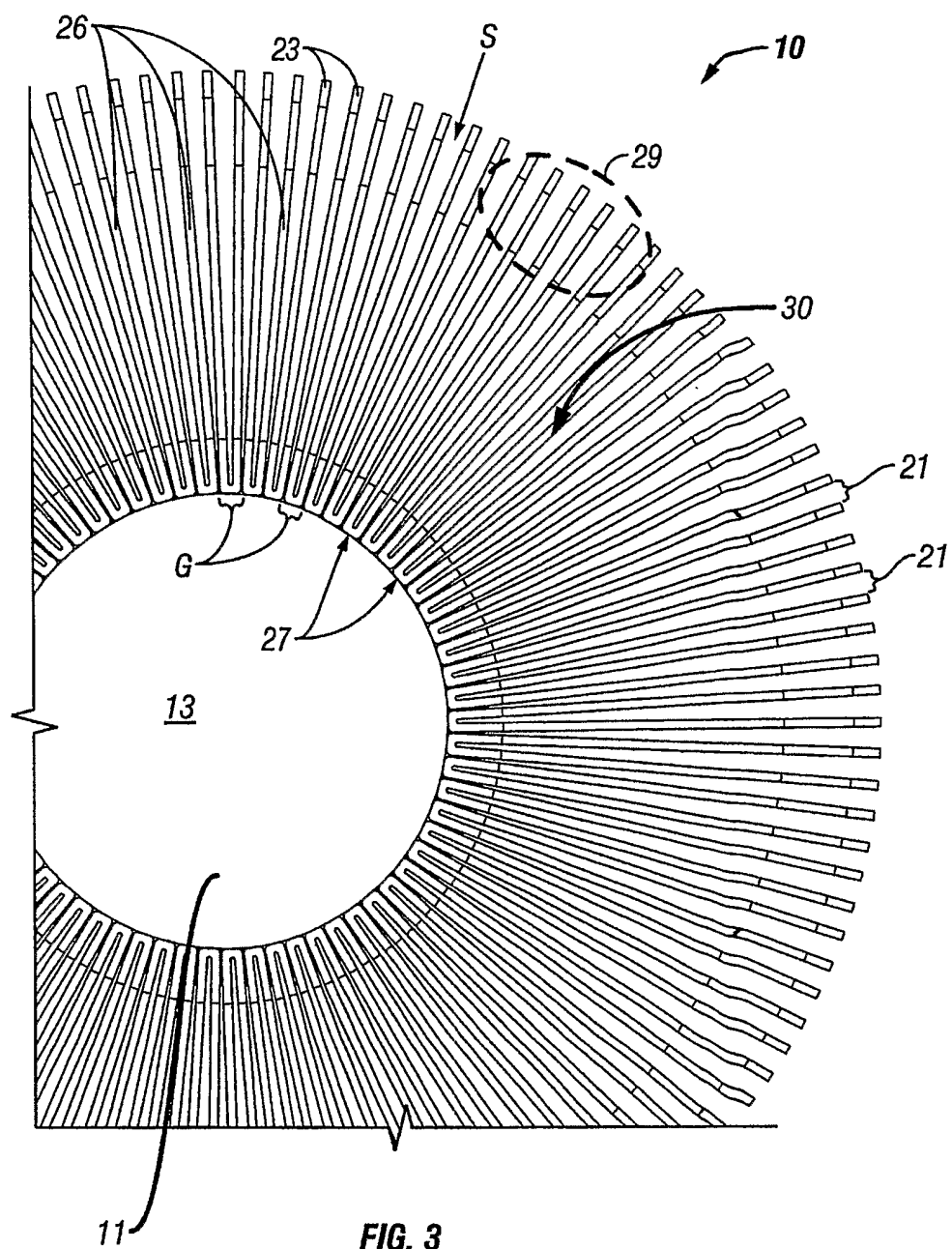
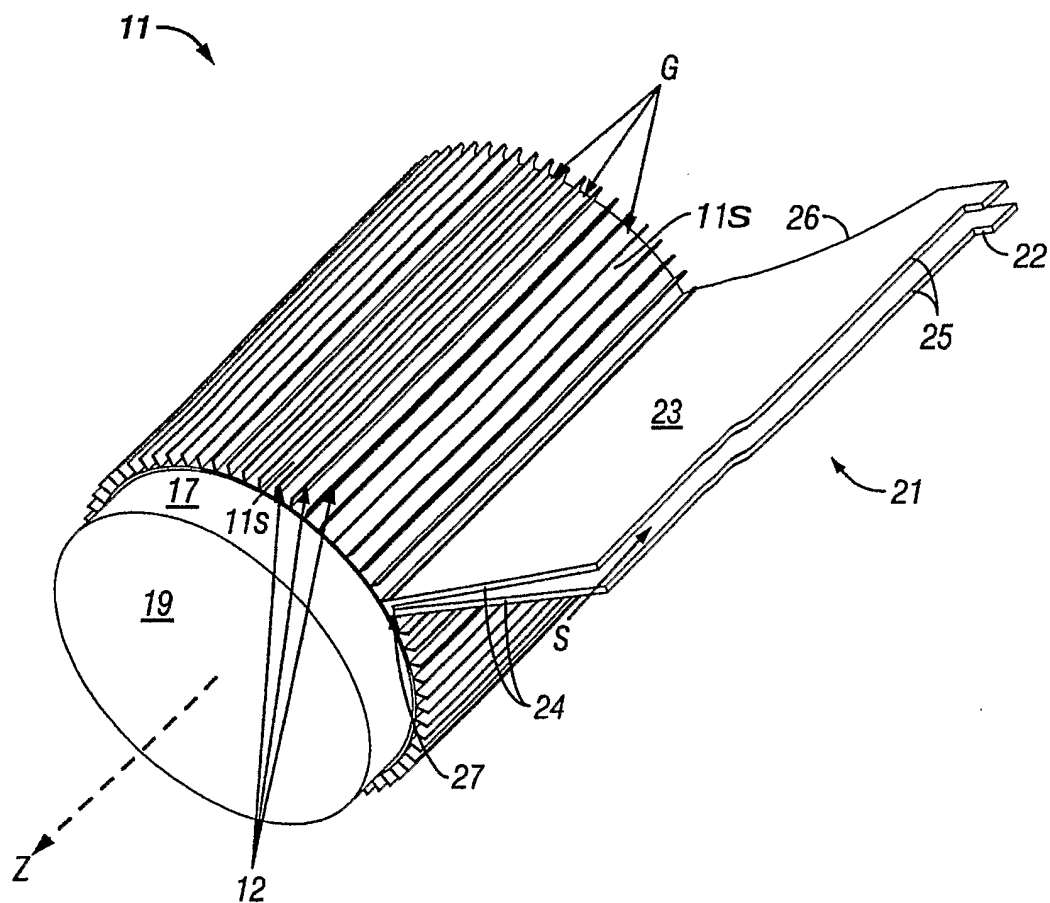


FIG. 3

**FIG. 4**

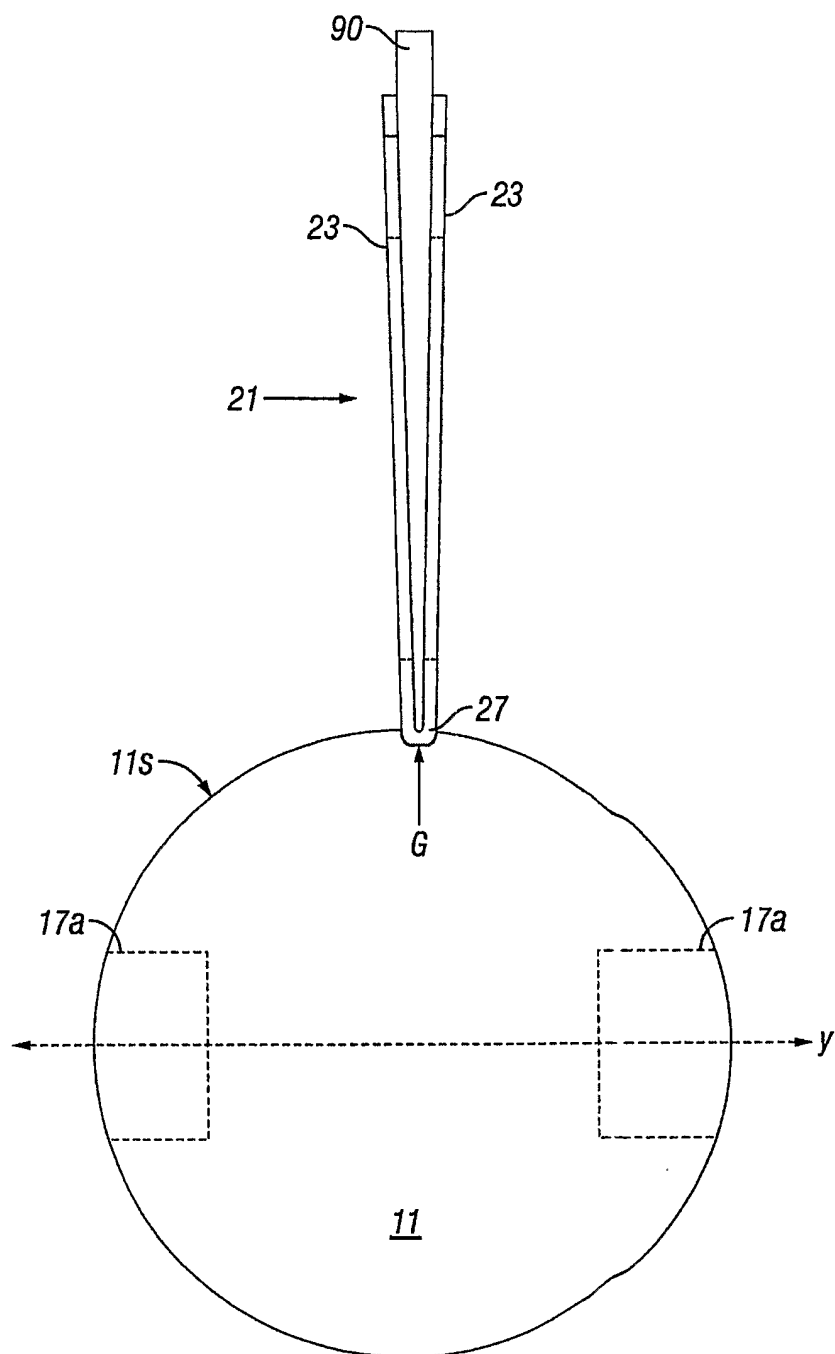


FIG. 5a

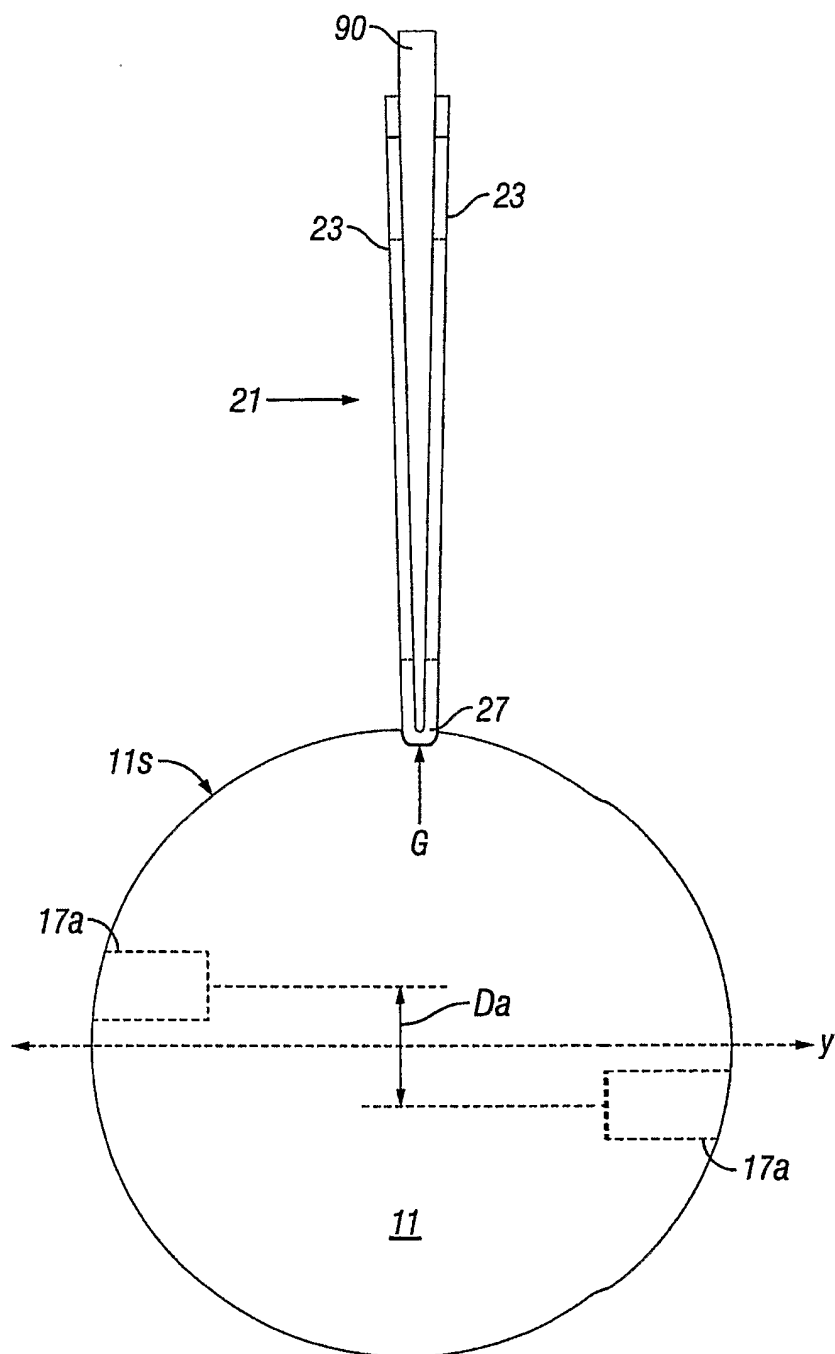


FIG. 5b

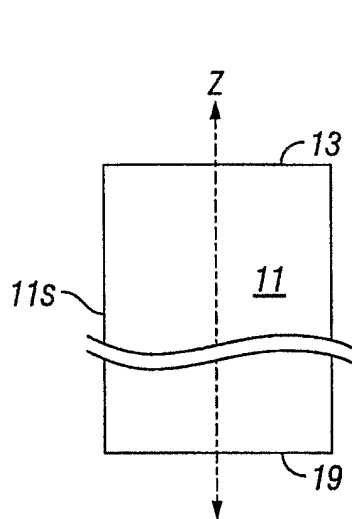


FIG. 6a

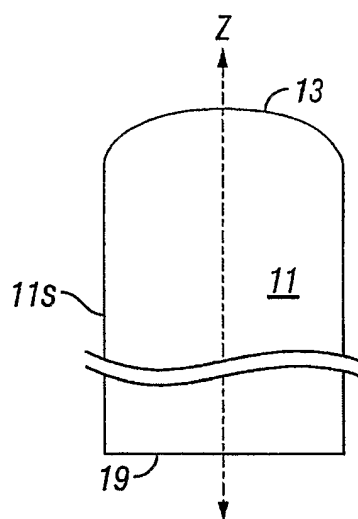


FIG. 6b

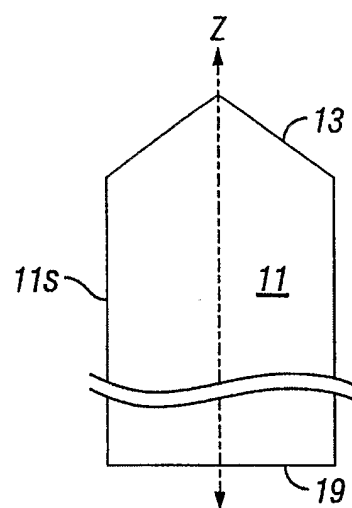


FIG. 6c

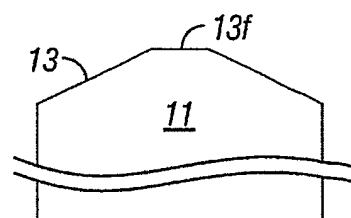


FIG. 6d

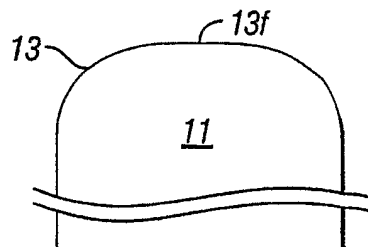


FIG. 6e

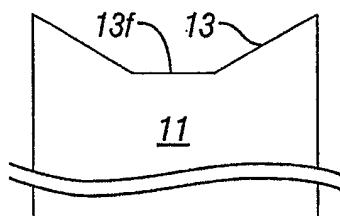


FIG. 6f

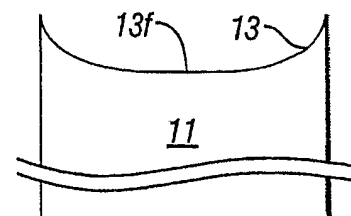


FIG. 6g

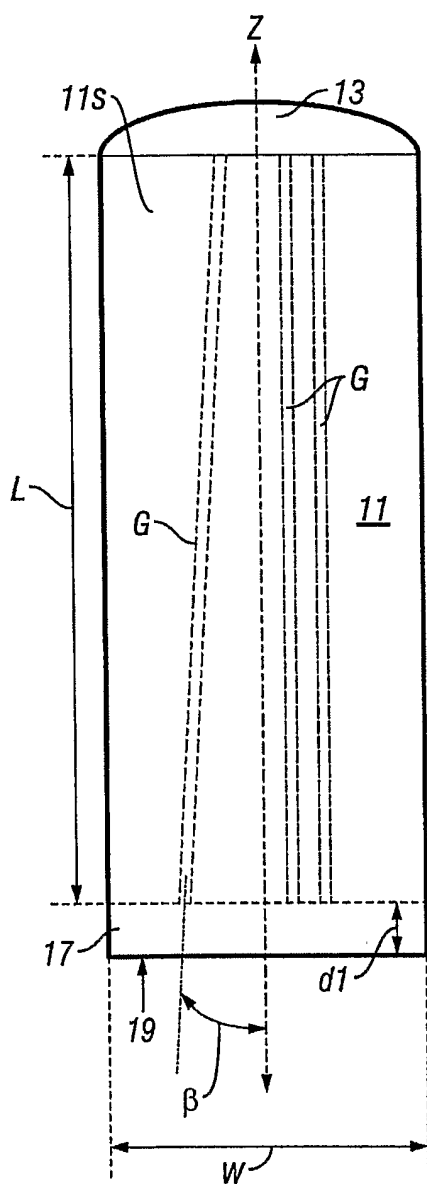


FIG. 7a

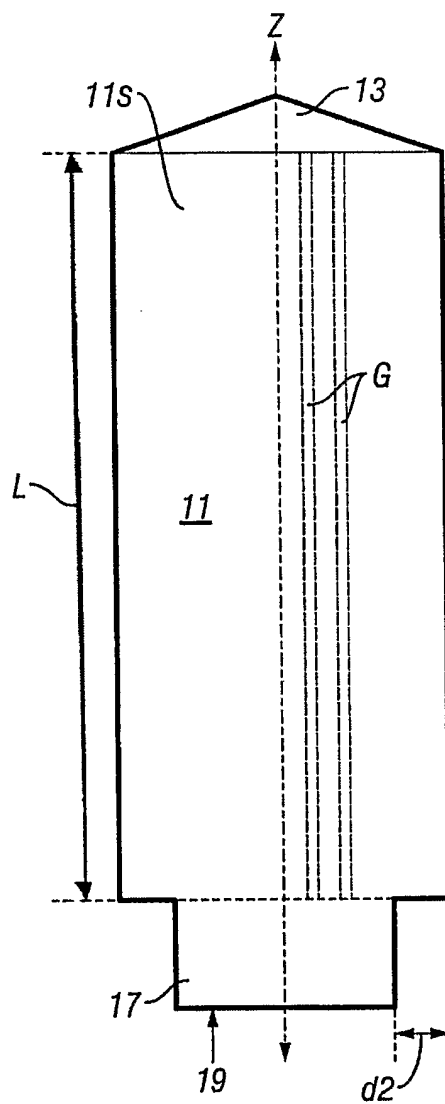


FIG. 7b

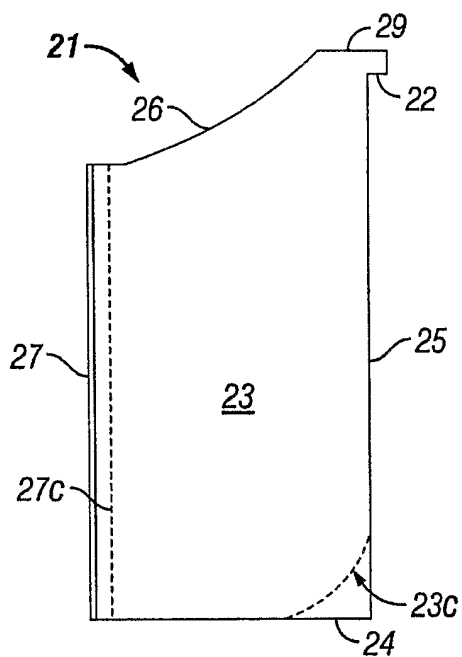


FIG. 8a

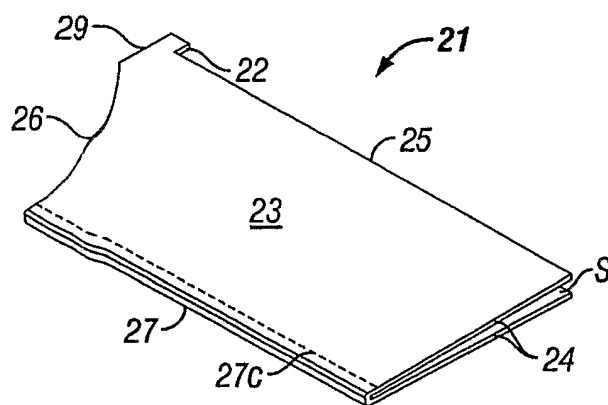


FIG. 8b

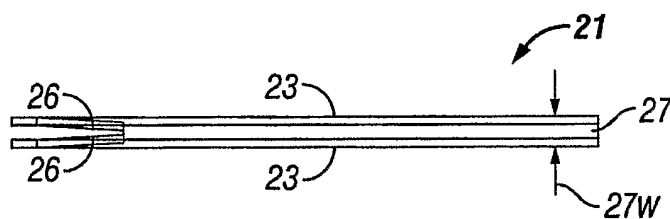


FIG. 8c

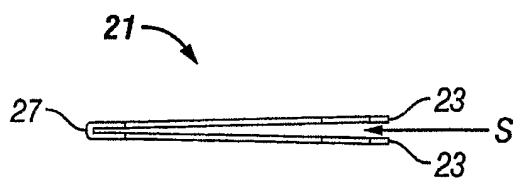
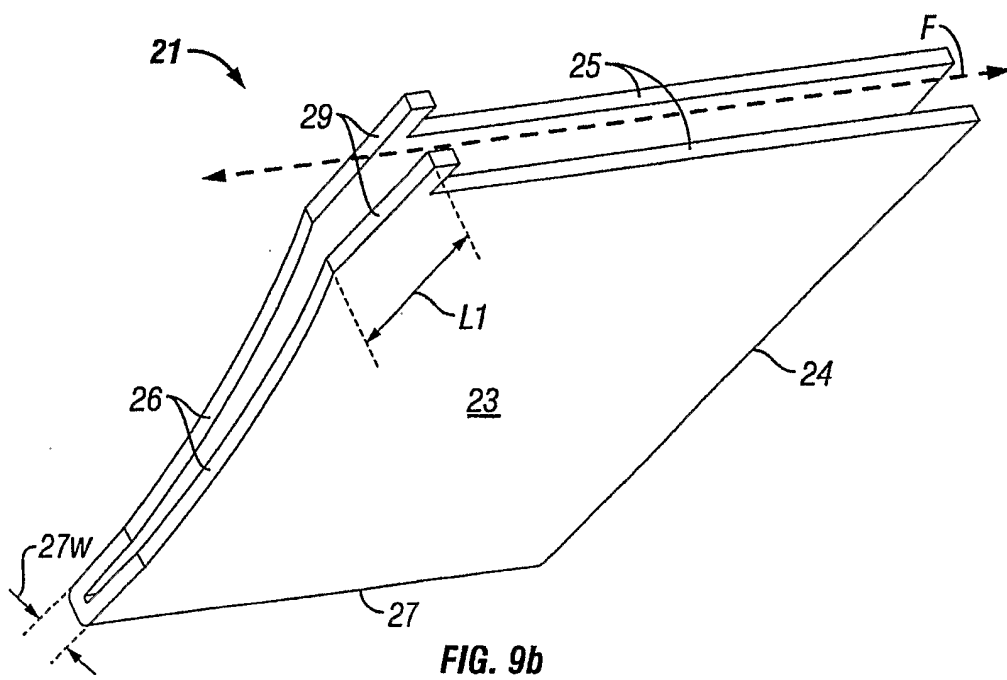
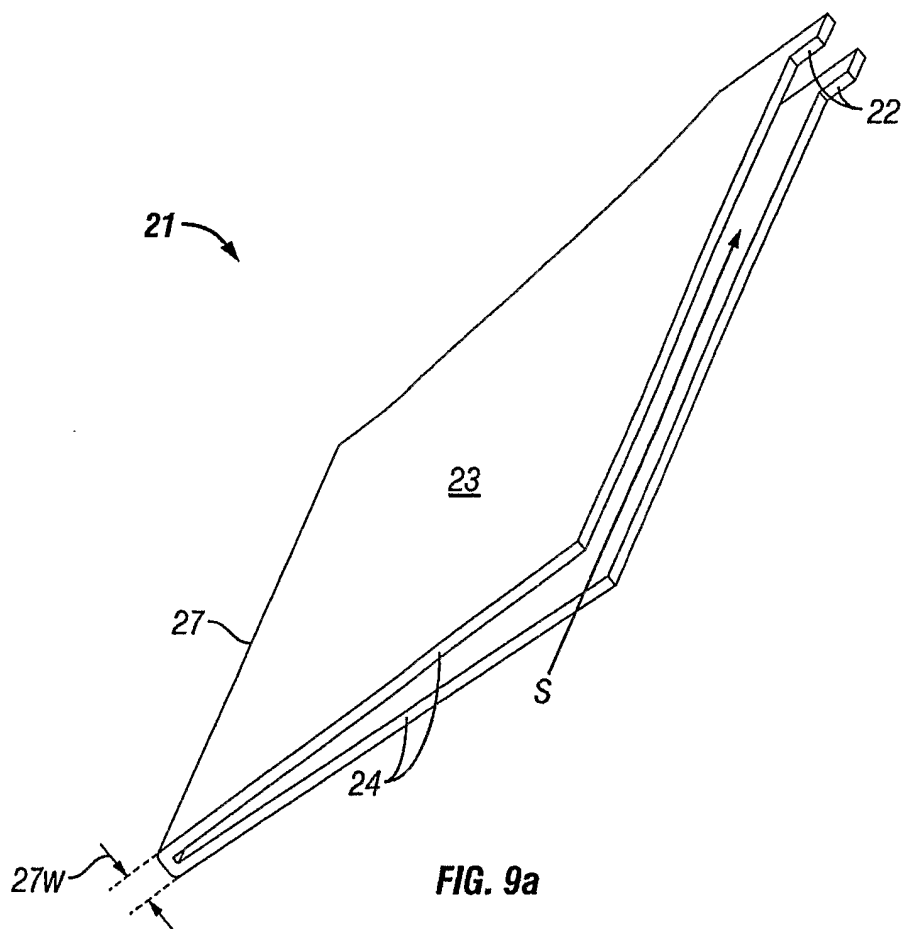
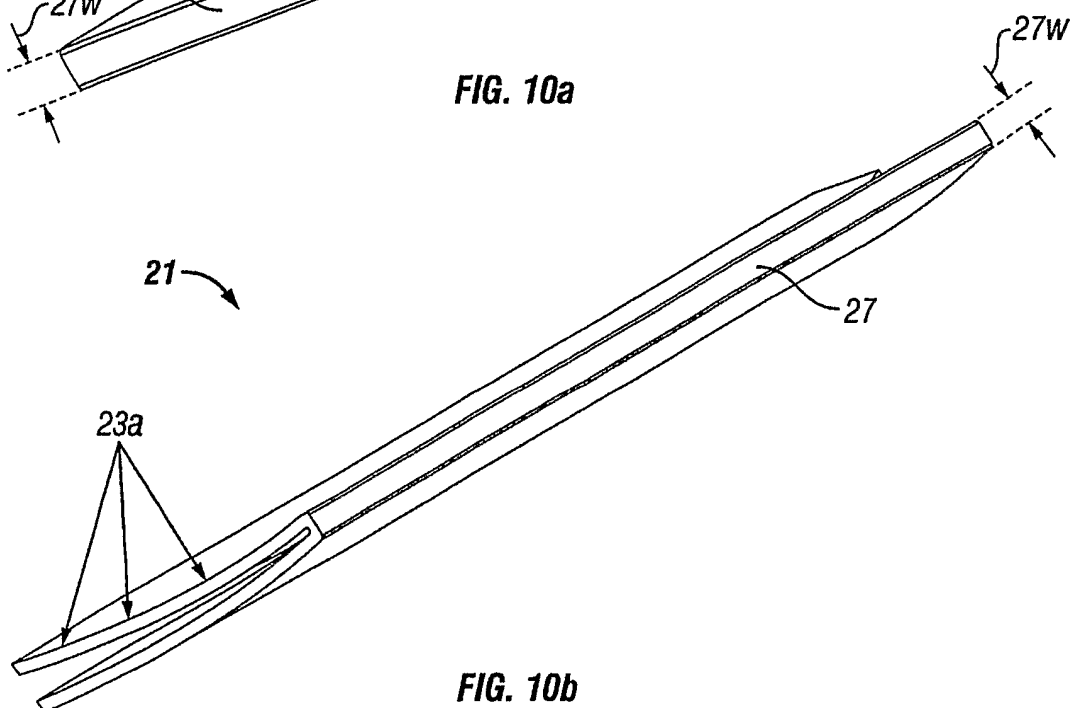
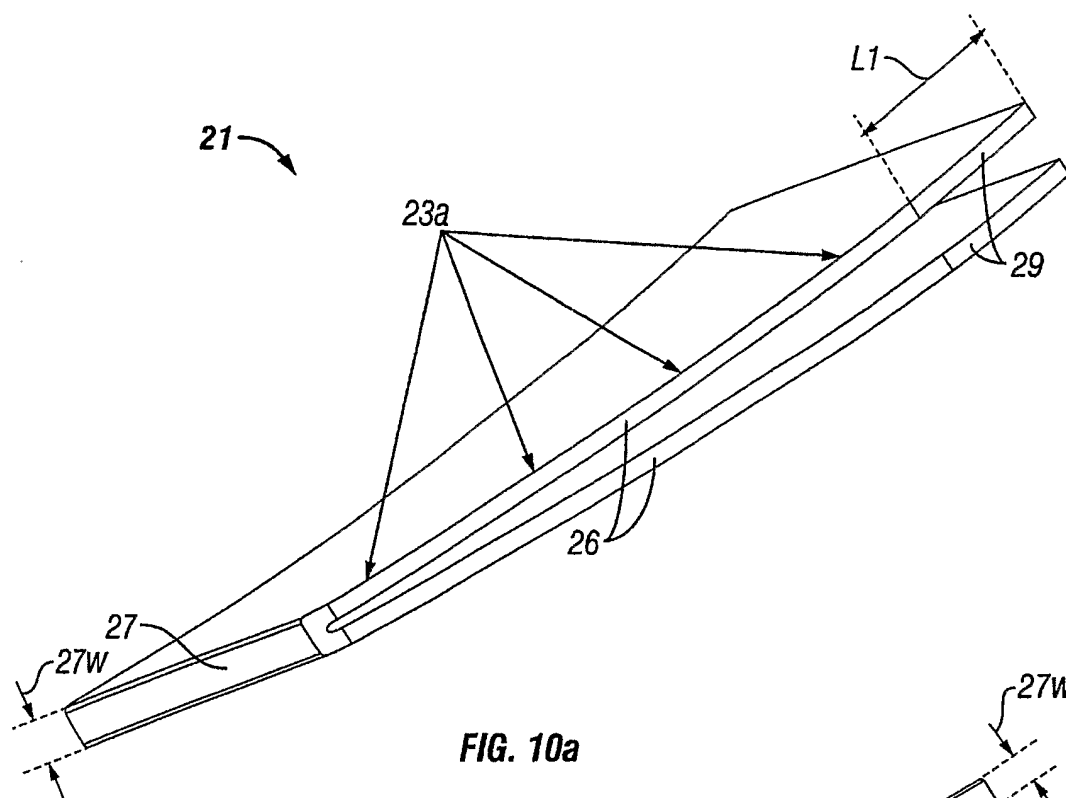


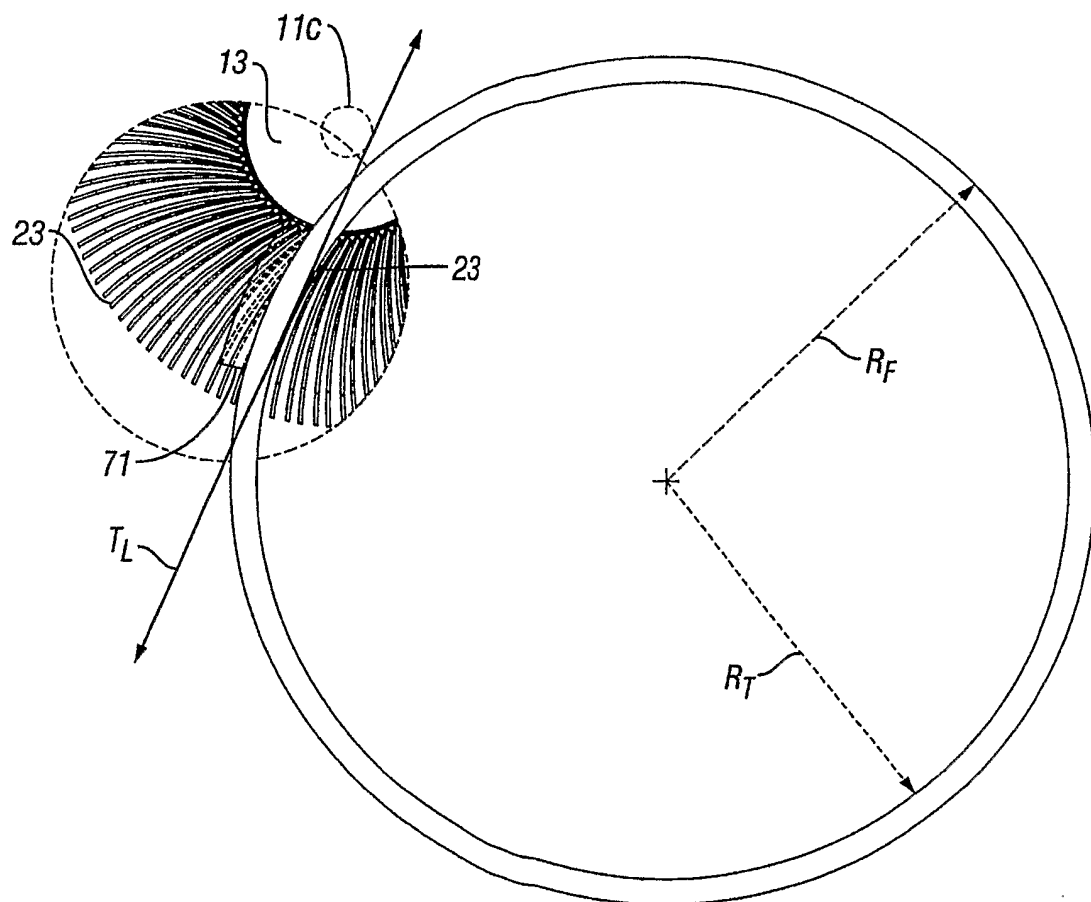
FIG. 8d

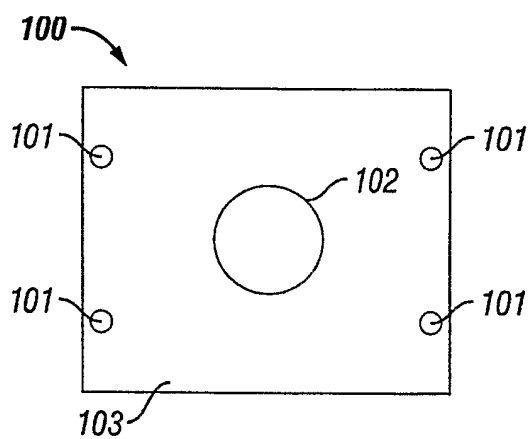
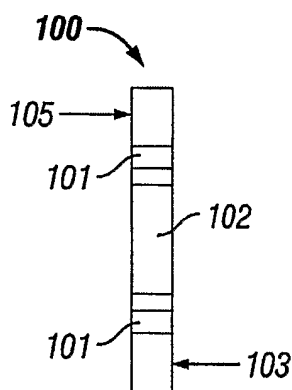
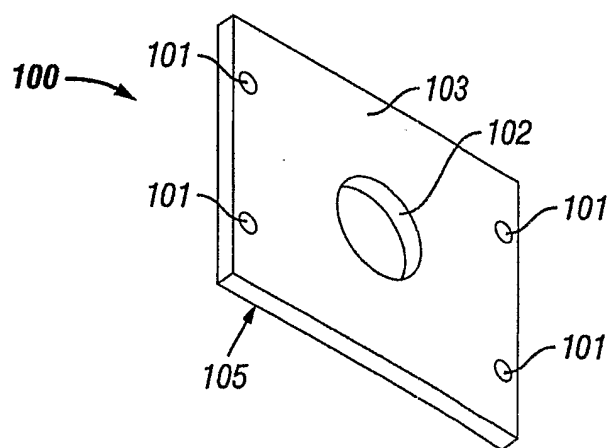


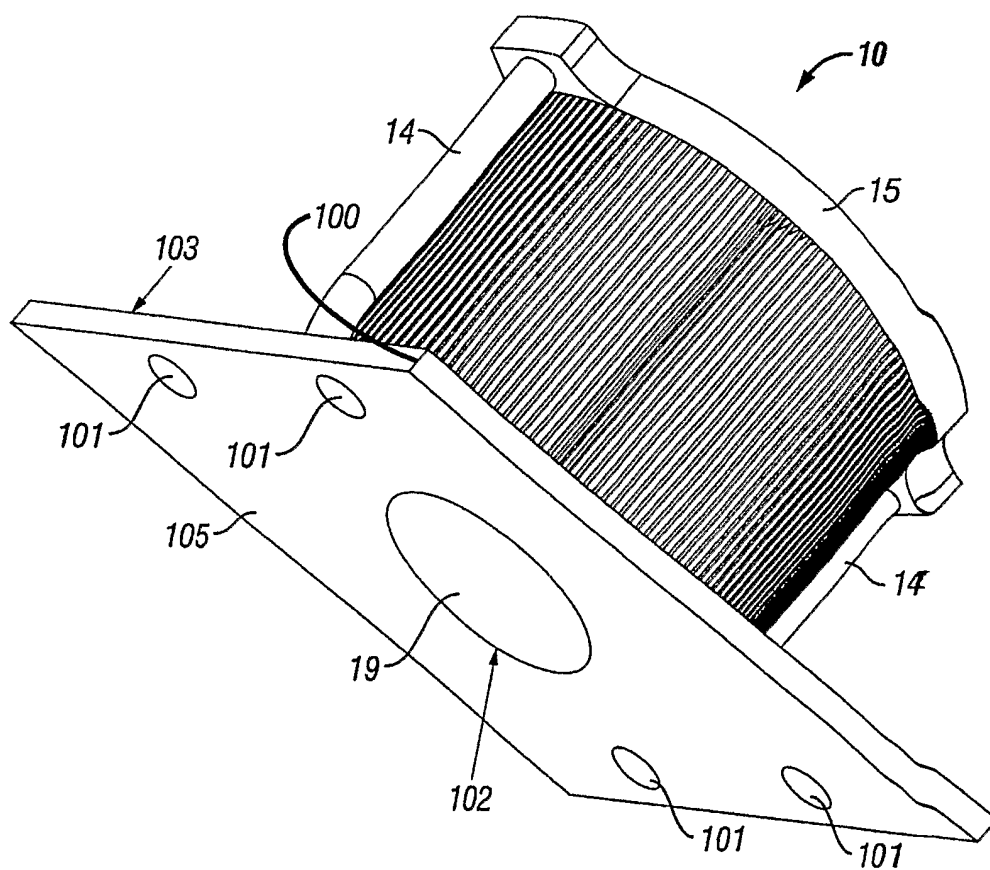
FIG. 8e

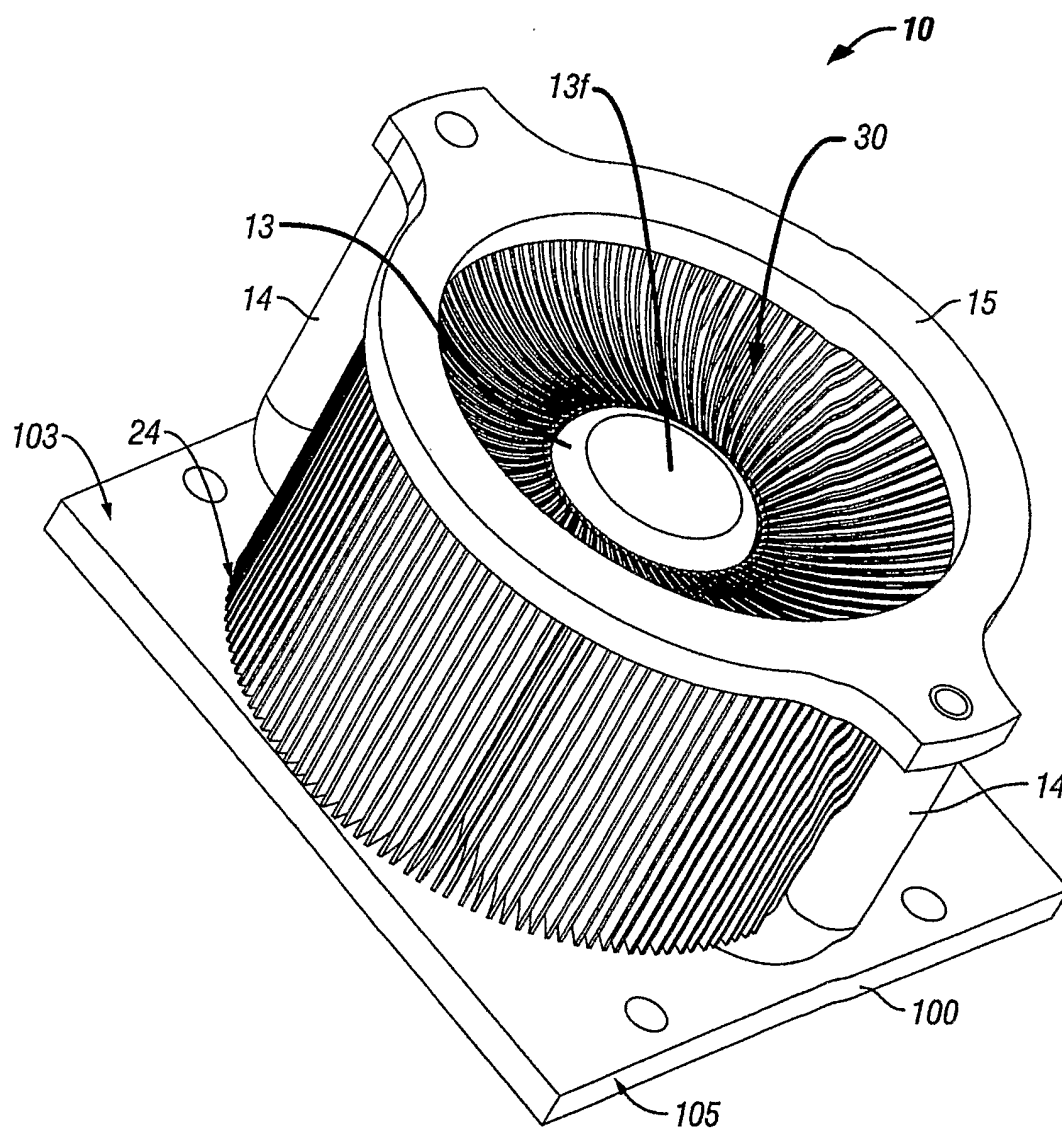




**FIG. 10c**

**FIG. 11a****FIG. 11b****FIG. 11c**

**FIG. 12a**

**FIG. 12b**

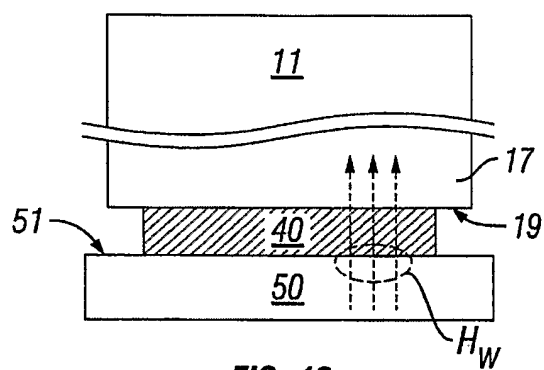


FIG. 13a

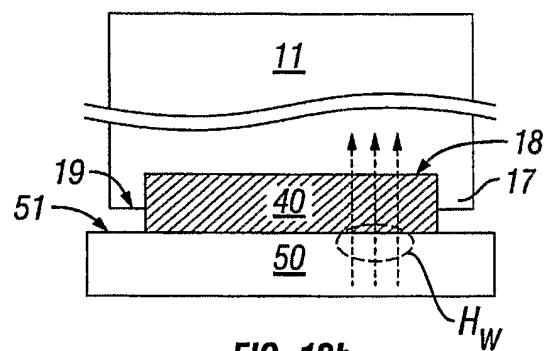


FIG. 13b

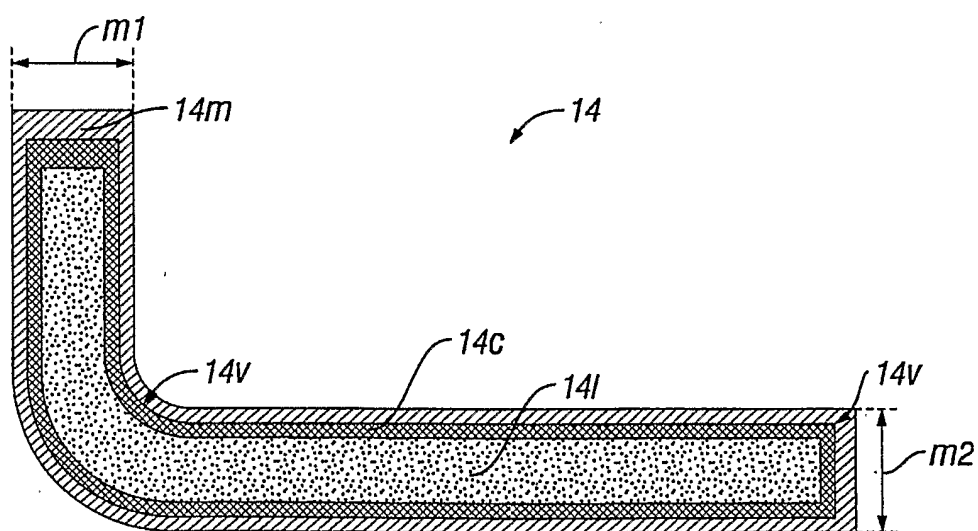


FIG. 13c

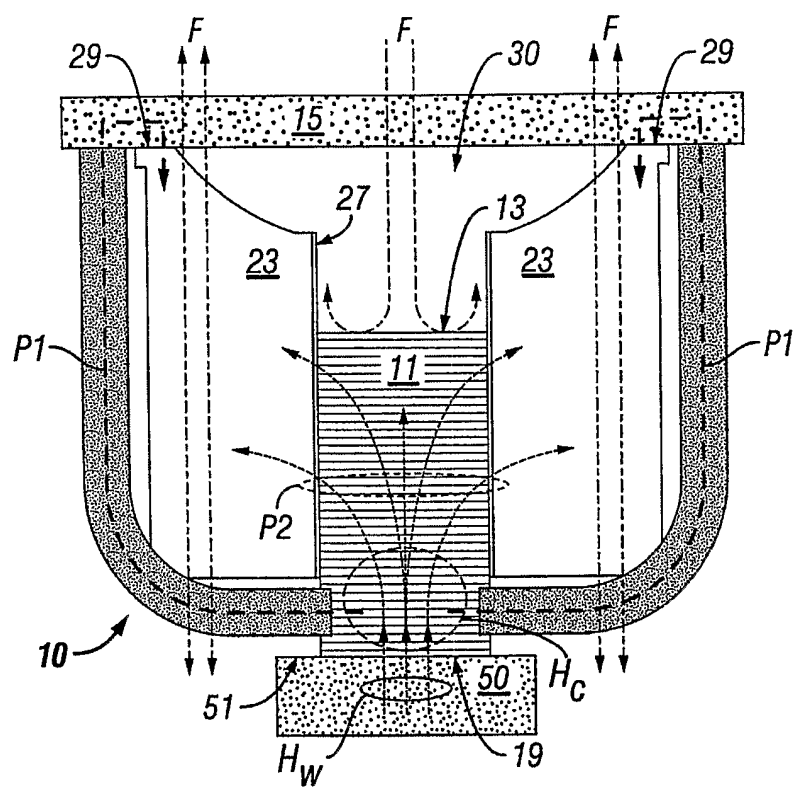


FIG. 14

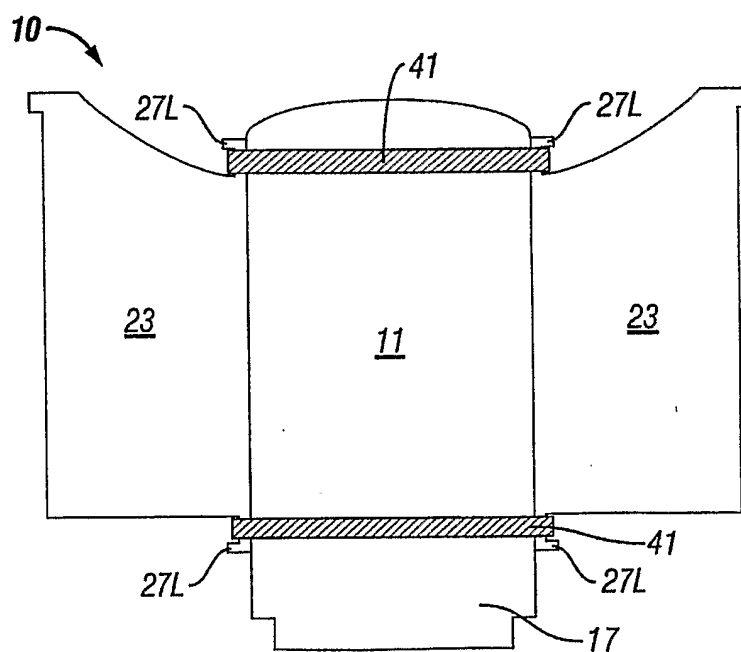
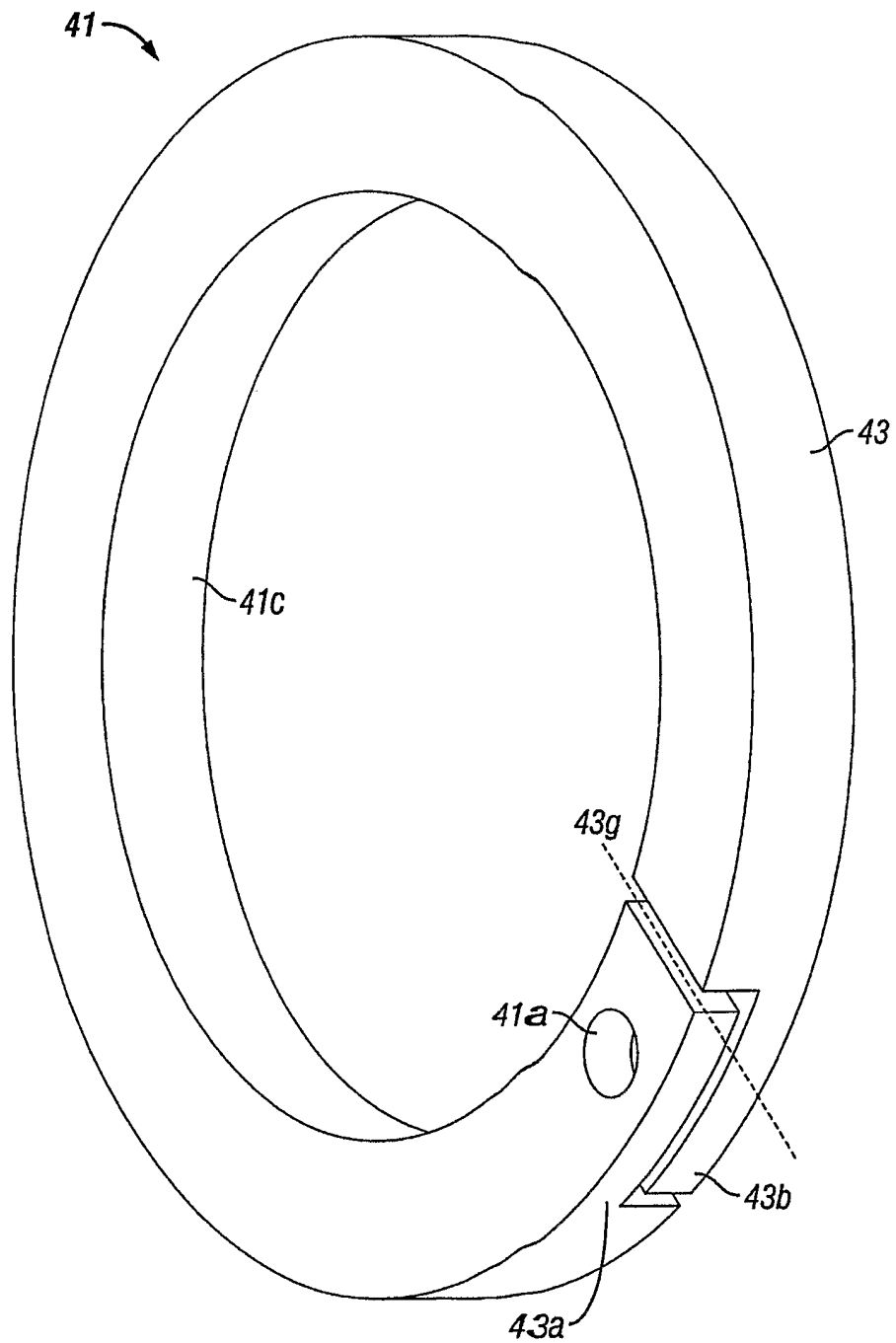


FIG. 15

**FIG. 16**

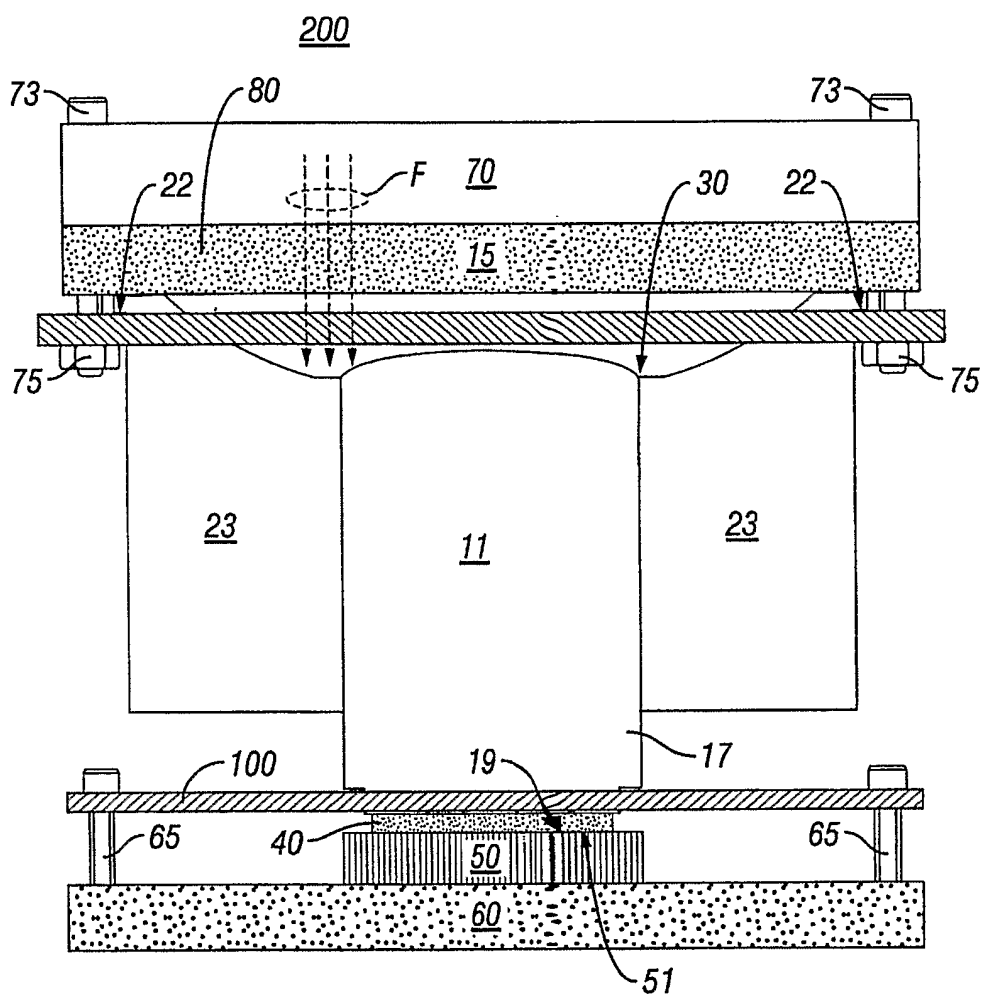
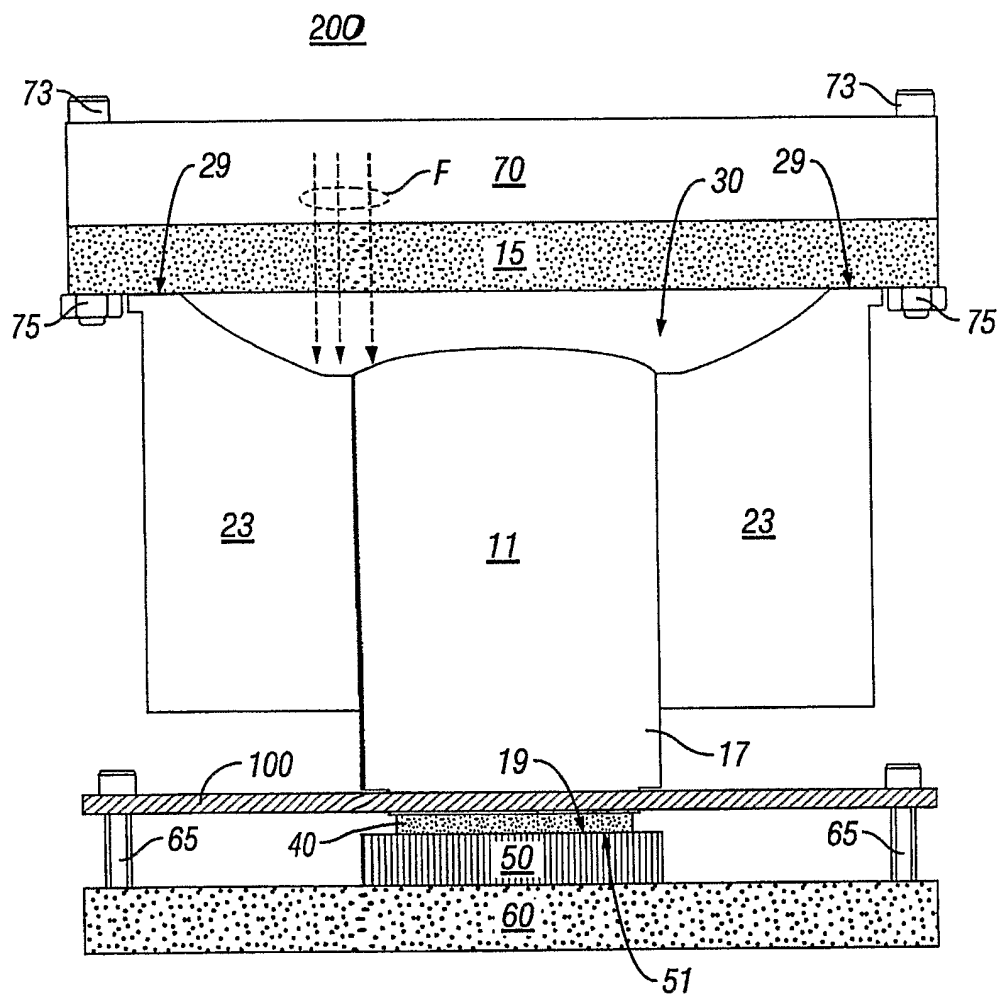


FIG. 17

**FIG. 18**

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2005/038031

A. CLASSIFICATION OF SUBJECT MATTER

H05K7/20 H01L23/367 H01L23/467 H01L23/473

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H05K H01L

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 081 760 A (MOLEX INCORPORATED) 7 March 2001 (2001-03-07) paragraph [0001] paragraph [0010] - paragraph [0016] figures 1,2	1,2
A	US 5 964 285 A (HUANG ET AL) 12 October 1999 (1999-10-12) column 1, lines 5-9 column 2, line 4 - line 52 figures 4-7	1
A	US 5 375 655 A (LEE ET AL) 27 December 1994 (1994-12-27) claim 1 figures 1-14	1

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

14 March 2006

Date of mailing of the international search report

23/03/2006

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Miot, F

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Information on patent family members

International application No

PCT/US2005/038031

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