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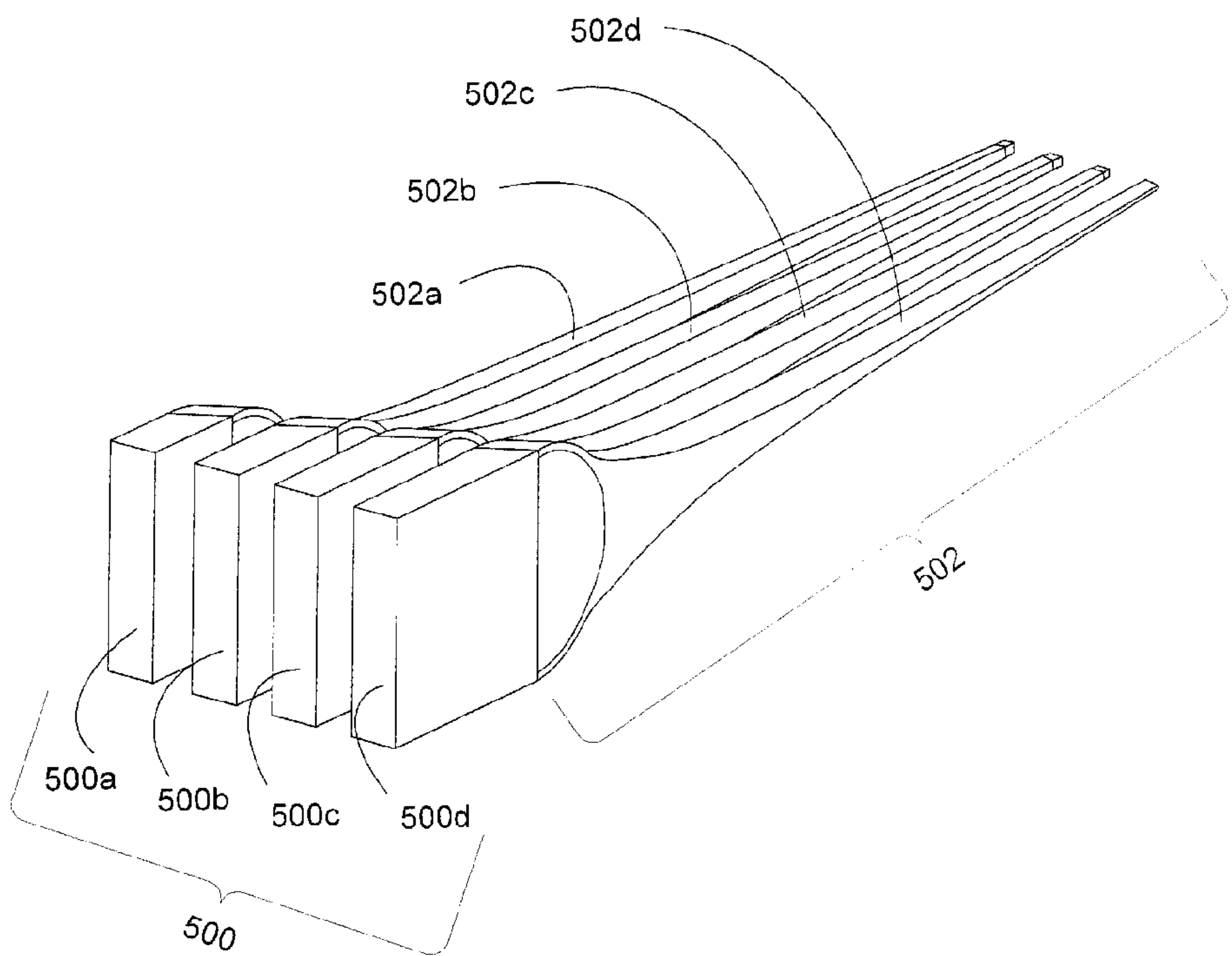

(57) Abrégé/Abstract:
There is provided a method of manufacturing an aircraft wing. The method comprises applying a plurality of filament wound bias-ply and uni-ply on each of a plurality of separated wing mandrels; abutting the plurality of separated wing mandrels to create a multi-box wing spar layup; abutting a plurality of wing surface tooling to the multi-box wing spar layup; compressing the plurality of wing surface tooling to apply pressure to the multi-box wing spar layup; and curing the multi-box wing spar layup to form the aircraft wing having a plurality of multi-box wing spars. Compressing the plurality of wing surface tooling further comprises applying tension to the plurality of filament wound bias-ply and uni-ply to minimize wrinkling of a plurality of fibers therein.

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Abstract

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MULTI-BOX WING SPAR AND SKIN

Background

Specific conventional aircraft wing construction varies from manufacturer to manufacturer, but typically has several manufacturing processes in common. One or more wing spars that run the entire length of the wing are placed and secured in a wing construction jig. One or more ribs are attached to the wing spars to give additional support to the wing. After attaching the ribs to the wing spars, a series of wing stringers are coupled to the wing spars, giving additional structural support as well as providing support to a wing skin. After the installation of one or more other features, such as fuel tanks, electronics, etc., as needed, the aircraft wing skin stiffened with stringers is attached to the wing spars and ribs. The wing skin may be attached using various methods, including, but not limited to, the use of rivets or other fasteners. Thereafter, other aircraft wing components are attached to the wing assembly, such as wing flaps, ailerons attached to an aft spar, as well as forward and aft wing control surfaces.

Conventional techniques for constructing wings may use a relatively significant number of parts and may be a time-consuming, laborious process. The number of parts may increase the weight of the wing as well as the complexity of building the wing.

In view of the foregoing, there exists a need in the art for a wing construction technique which uses fewer parts and is less time-consuming.

Summary

It should be appreciated that this Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to be used to limit the scope of the claimed subject matter.

Apparatus and methods provide for multi-box wing spars and skin using one or more forming mandrels. According to one aspect of the disclosure provided

herein, an aircraft wing may be constructed by applying one or more layers of composite material onto a plurality of wing mandrels. The wing mandrels, when placed together, form the shape of the wing. After the layers of composite material are applied to each individual mandrel, the mandrels are abutted together. Additional material may be added to form all or part of the skin of the wing or the top and/or bottom of the multi-box wing spars. Thereafter, the mandrels are compressed using wing surface tooling applied to the plurality of wing mandrels. In some examples, during mandrel compression, composite material may be tensioned to straighten fibers in the composite material. The composite material is thereafter cured. After curing, the wing surface tooling and mandrels are removed, resulting in a wing having multi-box wing spars and skins. If needed, one or more ribs are installed within the multi-box wing spar to provide for additional support.

According to another aspect, a wing may comprise several multi-box wing spars for attaching the wing to the fuselage of an aircraft. The wing may have an upper surface, lower surface, and several wing segments. The multi-box wing spars, upper wing surface and lower wing surface may be co-cured or co-bonded composite layers formed from substantially continuous fibers.

According to a still further aspect, a system for forming an aircraft wing may include several mandrels shaped according to the upper, lower, forward and aft surfaces of the aircraft wing. The system may also include a compression apparatus for compressing the several mandrels together to cure layers of composite material on the mandrels. The system may also include a tension block for maintaining tension on the composite material.

According to a still further aspect, there is provided a method of manufacturing an aircraft wing, the method comprising: applying a plurality of filament wound bias-ply and uni-ply on each of a plurality of separated wing mandrels; applying tension to the plurality of filament wound bias-ply and uni-ply on at least one of the plurality of separated wing mandrels by extending at least one tension block associated with the at least one of the plurality of separated wing mandrels away from the at least one of the plurality of separated wing mandrels to straighten fibers in the plurality of filament wound bias-ply and uni-ply; applying the plurality of separated wing mandrels to create a multi-box wing spar layup; abutting a plurality of wing surface tooling to the multi-box wing spar layup; compressing the plurality of wing surface tooling to apply pressure to the multi-box wing spar layup; and curing the multi-box wing spar layup to form the aircraft wing having a plurality of multi-box wing spars, wherein compressing the plurality of wing surface tooling further comprises applying tension to the plurality of filament wound bias-ply and uni-ply to minimize wrinkling of a plurality of fibers therein.

According to a still further aspect there is provided a wing comprising: a plurality of multi-box wing spars arranged to be attached to at least one beam of an aircraft fuselage; an upper wing surface; and a lower wing surface, wherein the plurality of multi-box wing spars are arranged to abutt each other so as to form a multi-box wing spar layup, wherein the plurality of multi-box wing spars, upper wing surface, and lower wing surface are composite layers comprising substantially continuous fibers, and wherein tension is applied to the fibers of at least one of the multi-box wing spars to straighten the fibers via extension of at least one tension block associated with the at least one of the multi-box wing spars away from the at least one of the multi-box wing spars.

According to a still further aspect there is provided a system for forming an aircraft wing, the system comprising: a plurality of mandrels comprising: an upper surface layer shaped according to an upper surface layer of the aircraft wing; a lower surface layer shaped according to a lower surface layer of the aircraft wing; and a forward surface layer and an aft surface layer abutted with one or more of the plurality of mandrels, wherein the upper surface layers of the plurality of mandrels are shaped according to an upper surface of the aircraft wing and the lower surface layers of the plurality of mandrels are shaped according to a lower surface of the aircraft wing, wherein the plurality of mandrels are arranged to abut each other so as form a mandrel layup, and wherein the fibers of the mandrels are under tension via at least one tension block associated with at least one of the plurality of mandrels by extending the at least one tension block away from the at least one of the plurality of mandrels; another tension block for maintaining tension on one or more layers of composite material forming the aircraft wing; and a compression apparatus for mechanically curing the one or more layers of composite material forming the aircraft wing, the compression apparatus comprising: an aft skin surface tool for applying pressure to the aft surface layer of the plurality of mandrels; a top skin surface tool for applying pressure to the upper surface layer of the plurality of mandrels; a lower skin surface tool for applying pressure to the lower surface layer of the plurality of mandrels; and a forward skin surface tool for applying pressure to the forward surface layer of the plurality of mandrels.

The features, functions, and advantages that have been discussed can be achieved independently in various configurations of the present disclosure or may be combined in yet other configurations, further details of which can be seen with reference to the following description and drawings.

Brief Description Of The Drawings

FIG. 1 is a top perspective view of an exemplary mandrel that may be used to form multi-box wing spars, according to various configurations presented herein;

FIG. 2 is a top perspective view of an exemplary mandrel that may be used to form a wing illustrating the application of a filament wound bias ply to the mandrel, according to various configurations presented herein;

FIG. 3 is a top perspective view of an exemplary mandrel that may be used to form a wing illustrating the application of a uni-ply to the mandrel, according to various configurations presented herein;

FIG. 4 is a top perspective view of an exemplary mandrel that may be used to form a wing illustrating a finished layup on the mandrel, according to various configurations presented herein;

FIG. 5 is a top perspective view of a plurality of exemplary mandrels that may be used to form a wing, according to various configurations presented herein;

FIG. 6 is a top perspective view of a plurality of exemplary mandrels that are abutted to each other, according to various configurations presented herein;

FIG. 7 is a top perspective view of wing surface tooling prior to compression, according to various configurations presented herein;

FIG. 8 is a top perspective view of wing surface tooling during compression, according to various configurations presented herein;

FIG. 9 is a top perspective view of wing surface tooling being removed after curing, according to various configurations presented herein;

FIG. 10 is a top perspective view of a wing having multi-box wing spars and skin after the removal of the wing surface tooling and mandrels, according to various configurations presented herein;

FIG. 11 is a top perspective view of a wing having multi-box wing spars and skin after the removal of the wing surface tooling and mandrels, further illustrating the installation of a vertical rib, according to various configurations presented herein;

FIG. 12 is a top perspective view of a fuselage section with two wings having multi-box wing spars, according to various configurations presented herein; and

FIG. 13 is an illustrative routine for manufacturing multi-box wing spars, according to various configurations presented herein.

Detailed Description

The following detailed description provides for wings having multi-box wing spars. As discussed briefly above, conventional aircraft wings are typically constructed using multiple components, including one or more spars, ribs and wing stringers, each performing individual functions. After the wing is constructed, the wing is typically attached to a wing box on the fuselage of the aircraft. In conventional aircraft, the wing box is a reinforced, structural component on the aircraft's fuselage to which the wings are attached. Conventional aircraft wing construction can be a time-consuming and costly process. Further, if the wing is constructed using certain materials, including polymers or, especially, composite materials, the multiple sections of the wing reduce the availability of relatively long lengths of un-broken material, reducing the strength of the polymers and/or composite materials. For example, when using carbon fiber reinforced thermoplastics, if the surface contains multiple breaks in the fibers, the benefit of using the composite can be reduced, as additional reinforcing structures or material may need to be used to make up for the loss in structural rigidity.

Utilizing the concepts described herein, an aircraft wing may be constructed using a series of forming mandrels that when placed together form the shape of the wing. Composite materials, or other suitable materials, may be applied to each forming mandrel, and thereafter compressed and cured to form a wing having multi-box wing spars. In other configurations, one or more layers of composite materials may be fully or partially cured prior to application of the layers to one or more parts of the forming mandrel. In that configuration, one or more partially or fully cured layers of composite material may be co-bonded with other partially or fully cured layers of composite materials. It should further be appreciated that the concepts described herein relating to an aircraft wing may also be used for other aircraft components, such as a vertical or horizontal stabilizer, without departing from the scope of this disclosure and the accompanying claims.

In the following detailed description, references are made to the accompanying drawings that form a part hereof, and which are shown by way of illustration, specific configurations, or examples. Referring now to the drawings, in which like numerals represent like elements through the several figures, the manufacture of wings having multi-box wing spars will be described. It should be appreciated that a multi-box wing spar constructed according to various configurations disclosed herein may have one or more spars and one or more skins, the present disclosure of which is not limited to any number of spars or skins.

Turning to FIG. 1, is a top perspective view of an exemplary mandrel that may be used to form a wing is illustrated. Forming (or wing) mandrel 100 may have upper surface layer 102 that is shaped according to an upper surface layer of an aircraft wing (shown by way of example in Figure 12). Forming (or wing) mandrel 100 may also have lower surface layer 104 that is shaped according to a lower surface layer of an aircraft wing. Upper surface layer 102 and lower surface layer 104 may be shaped so that when one or more layers of composite material, such as carbon fiber reinforced thermoplastic, is applied to mandrel 100, the resulting shape is in the shape of an aircraft wing. Further, upper surface layer 102 and lower surface layer 104 may be shaped so that there are little to no bends or breaks in the fibers of the composite material, providing for increased rigidity from the composite material. Forming (or wing) mandrel 100 may also have a forward surface layer and an aft surface layer abutted with one or more of a plurality of mandrels.

As will be described in more detail below, when forming a structure using composite materials, it is typically preferable to not only avoid unnecessary bends or breaks in the material, but also to maintain the straightness of the fibers running in one or more portions of the material. In typical composite materials, it may be preferable to have straight fibers in the composite material matrix. It should be appreciated that the present disclosure is not limited to the use of straight fibers in a composite matrix. Various configurations of the present disclosure may be implemented in the construction of wings having composite matrices using curved or straight fibers, or combinations thereof.

If it is desired or necessary to straighten the fibers in a composite fiber matrix prior to curing, mandrel 100 may also have tension blocks 106 and 108. Tension blocks 106 and 108 may be used separately or in conjunction with one another to "pull" the fibers of a composite matrix, thus providing for a straightened fiber matrix. In some configurations, fibers in a composite matrix (described in more detail below) may be attached to one or both of tension blocks 106 and 108 or may be formed around tension blocks 106 and/or 108. Tension blocks 106 and 108 may be configured to extend outwards from mandrel 100 at various pressures to provide for a tension on the fibers in the fiber matrix.

A configuration of the construction of the fiber matrix, as discussed briefly above, and the forming of a wing having multi-box wing spars are now described in relation to Figures 2-12. In FIG. 2, a first layer of filament wound bias ply 200 (illustrated in a cross-hatch pattern over the surface of mandrel 100) is wrapped or applied to mandrel 100. If needed or desired, filament wound bias ply 200 may have tension applied thereto using tension block 106 and/or tension block 108 to help straighten the fibers in filament wound bias ply 200.

After the filament wound bias ply 200 is applied to mandrel 100, a uni-ply layer is applied, as shown in FIG. 3. Uni-ply layer 300 is applied to mandrel 100 and may be tightened using tension block 106 and/or tension block 108. It should be understood that the present disclosure is not limited to any specific configuration of bias-ply or uni-ply. For example, one or more layers of a bias-ply layer may be added prior to the addition of a uni-ply layer. In the same manner, one or more layers of uni-ply may be added between the applications of the one or more bias-ply layers.

Further it should be understood that the present disclosure is not limited to any number of layers of either type of layer, as various combinations may be used to achieve structural or cost goals. For example, and not by way of limitation, it may be desirable or necessary to add sufficient layers of wound bias-ply and/or uni-ply to achieve a desired wing thickness or structural rigidity. Additionally, it should be understood that the present disclosure is not limited to a layer having a single type of ply, as some configurations may use a combination of bias- and uni-ply within the same layer. Various combinations may be used according to various configurations without departing from the scope of this disclosure and the accompanying claims.

FIG. 4 illustrates a completed composite matrix 400 on mandrel 100. Composite matrix 400 may be formed using various layering and application techniques, such as, by way of example, the method described above in relation to Figures 2 and 3.

FIG. 5 is a top perspective view of a series of mandrels having fully formed composite matrices applied thereon. Mandrel apparatus 500 has individual mandrels 500a-d. Mandrels 500a-d have disposed thereon composite matrix 502, having individual composite matrices 502a-d. Composite matrix 502 may be formed from one or more layers, various combinations of plies, and may be fully or partially uncured at this point. As illustrated in FIG. 5, the general shape of an aircraft wing may be seen when viewing mandrel apparatus 500.

According to various configurations, after composite matrix 502 is applied to mandrel apparatus 500, mandrels 500a-d are abutted against each other, as shown in FIG. 6. Individual mandrels (illustrated by way of example as mandrels 500a-d in FIG. 5) are abutted to form a contiguous, multi-box wing spar layup, having composite matrix 502, which is formed from multiple composite matrices (illustrated by way of example as composite matrices 502a-d in FIG. 5).

In order to partially or fully cure and form the multi-box wing spar configuration according to various configurations of the present disclosure, a curing system may be used. As discussed above, one or more layers of composite material may be fully or partially cured prior to use in a forming mandrel. In that configuration, the partially or fully cured composite layers may be co-bonded to other partially or fully cured composite layers using one or more layers of adhesive to secure the layers of composite material within a composite matrix. An example of a system for forming multi-box wing spars is shown in FIG. 7. After the individual mandrels forming mandrel apparatus 500 are abutted to each other, thus forming composite matrix 502 from a series of individual composite matrices, a series of surface tools may be applied to the various surfaces of mandrel apparatus 500. It should be appreciated that additional material may be added across the surface of the spar after the mandrels that form mandrel apparatus 500 are abutted. The additional material may be used to form the skin of the wing, reinforce the composite material already in place, or provide for various aerodynamic or physical properties, by way of example.

Various processes for adding the additional bias-ply and uni-ply are known to those in the art, to which the various configurations disclosed herein are not dependent on any one particular method of applying composite materials. In one configuration, a curable upper wing skin, a curable lower wing skin, a curable leading wing edge and a curable trailing wing edge may be applied (or laid-up) after the initial plies are added to the composite matrix 502, prior to the application of surface tools to the composite matrix 502.

Compression apparatus 504 has forward skin surface tool 506, lower skin surface tool 508, aft skin surface tool 510 and top skin surface tool 512. It should be further appreciated that not all of the material added is "curable" material, as non-curable material may be added to composite matrix 502. Surface tools 506, 508, 510 and 512 are individually or collectively compressed, thus applying pressure, onto the respective surfaces of mandrel apparatus 500 to help form and cure composite matrix 502. In some configurations, heating element 514 may be applied to one or more of surface tools 506-512. The combination of pressure and heat may fully or partially cure composite matrix 502 in a desired amount of time or may provide for additional structural rigidity. Heating element 514 may use various means of applying heat to composite matrix 502, including steam and electrical current. FIG. 8 illustrates compression apparatus 504 in a compressed state, with mandrel apparatus 500 shown outside of compression apparatus 504.

Once composite matrix 502 is cured to a desired level, compression apparatus 504 is removed, illustrated in greater detail in FIG. 9. Compression apparatus 504 surface tools 506, 508, 510 and 512 are removed from the surface of now-cured composite matrix 502 and individual mandrels of mandrel apparatus 500 are extracted from composite matrix 502. The resulting structure is illustrated in FIG. 10. It should be appreciated that the present disclosure is not limited to fully curing composite matrix 502, as it may be desired or necessary in some configurations to remove the curing mechanisms (e.g. compression apparatus 504 or heating element 514) prior to composite matrix 502 being fully cured. Various degrees of curing may be used according to various configurations of the present disclosure without departing from the scope of this disclosure and the accompanying claims.

FIG. 10 is a top perspective illustration showing composite matrix 502 with multi-box wing spar. By using composite materials formed over abutting mandrels, composite matrix 502 has disposed therein spars 600a-e that extend internally to composite matrix 502 along axis X-Y, thus forming multi-box wing spars. By using a mandrel apparatus, such as mandrel apparatus 500 of FIG. 7, it can be seen that composite matrix 502 may be formed having fibers disposed therein that can be straightened and uncut (or undesirably terminated). After curing, composite matrix 502 may be considered a singular, contiguous structure. If it is desirable or necessary to further reinforce composite matrix 502, one or more ribs (or rib segments) may be installed in composite matrix 502, an example of which is shown by rib 700 in FIG. 11.

Further, utilizing the concepts described herein, a wing formed according to various configurations disclosed herein may be coupled to a fuselage section of an aircraft without the need for a conventional wing box. Exemplary techniques are described in U.S. Patent Application No. 13/685024 entitled, “Vertically Integated Stringers,” filed on November 26, 2012. FIG. 12 illustrates one such configuration in which a wing formed according to the techniques described herein is attached to a fuselage without the use of a traditional wing box. It should be appreciated that the concepts presented herein may also be used to form a wing according to the techniques described herein to be attached to a traditional wing box.

Composite matrices 800 and 802, which are constructed according to various configurations disclosed herein, have multiple wing spars that can be coupled to fuselage section 804. It should be appreciated that composite matrices 800 and 802 may be formed in various shapes with various features, the present disclosure of which is not limited to any one particular configuration. Exemplary wing spar 806 is identified in FIG. 12 for the sake of clarity, though it should be understood that composite matrices 800 and 802 may have additional wing spars. Exemplary wing spar 806 may have elliptical aperture 808.

Depending on the angular displacement between composite matrices 800/802 and fuselage section 804, elliptical aperture 808 may vary in circumference and shape, i.e. the foci of elliptical aperture 808 may change as well as the radii. For example, in a straight-wing profile aircraft in which spar 806 may be affixed to fuselage section 804 at approximately a 90 degree angle, elliptical aperture 808 may be circular. In another example, such as the one illustrated in FIG. 12, spar 806 may be attached to fuselage section 804 in a swept-wing profile. Thus, elliptical aperture 808 may be more oval in shape in order to provide for interior space in the aircraft and to be attached to the fuselage circumferentially. One or more circumferential fuselage stringers, such as stringers disclosed in copending application entitled "Vertically Integrated Stringers" and identified as circumferential stringers 810, may provide additional structural support to fuselage section 804. The multi-box wing spars formed by composite matrices 800 and/or 802 may be attached to one or more beams of an aircraft fuselage, such as crown beam section 812. It should be appreciated that fuselages may have one or more types of beams including, but not limited to, crown beam 812 or a keel beam (not shown).

FIG. 12 also illustrates the various sections of a wing that may be formed using various configurations disclosed herein. Composite matrix 802 is illustrated as having a leading wing edge 814, trailing wing edge 816, upper surface layer 818 and lower surface layer 820. One or more of the leading wing edge 814, the trailing wing edge 816, the upper surface layer 818 and the lower surface layer 820 may be curable or bondable according to various configurations disclosed herein. Further, one or more of the leading wing edge 814, the trailing wing edge 816, the upper surface layer 818 and the lower surface layer 820 may be formed separately from the others and attached afterwards. In some configurations, the leading wing edge 814 and/or the trailing wing edge 816 may be formed with the upper surface layer 818 and/or the lower surface layer 820. Thus, in a compression apparatus, such as compression apparatus 504 of FIG. 7, the leading wing edge 814 may be a forward skin formed using the forward skin surface tool 506 of FIG. 7 and the trailing wing edge 816 may be an aft skin surface formed using the aft skin surface tool 510.

Turning now to FIG. 13, an illustrative routine 900 for constructing multi-box wing spars is described in detail. Unless otherwise indicated, it should be appreciated that more or fewer operations may be performed than shown in the figures and described herein. Additionally, unless otherwise indicated, these operations may also be performed in a different order than those described herein.

Routine 900 begins at operation 902, where one or more bias- and/or uni-plies are applied to a series of forming mandrels. In some configurations, the fibers in the bias- and/or uni-plies can be tightened through the use of one or more tension blocks on the mandrel. From operation 902, routine 900 continues to operation 904, whereby the forming mandrels are abutted to each other to create a multi-box wing spar layup. In some configurations, the multi-box wing spar layup comprises a composite matrix formed from one or more layers of the bias- and/or uni-plies. As noted above, additional plies may be added at various stages of the forming process.

From operation 904, routine 900 continues to decision 906, wherein a determination is made if additional layers of uni-ply or bias-ply are to be added prior curing of the composite matrix. In one configuration, it may be desirable to form and cure together the multi-box wing spars and one or more portions of the wing skin. In another configuration, a desired wing thickness or structural rigidity may require that additional plies be added. If the determination 906 is that additional ply layers are to be added, routine 900 continues to operation 908, wherein the additional layers are applied to the layup.

If it was determined 906 that no additional layers to the layup are to be applied 908, or after the additional layers to the layup have been applied 908, routine 900 continues to operation 910, whereby surface tooling is applied (abutted) to the various surfaces of the composite matrix. The surface tooling, in some configurations, may serve several functions. For example, surface tooling may have one or more surfaces configured to create certain shapes in the surface of the composite matrix. Surface tooling may also be used to apply pressure and/or heat to a composite matrix to cure the composite matrix as well as, in some examples, provide for debulking of the composite matrix during layup.

From operation 910, routine 900 continues to operation 912, whereby the surface tooling is compressed onto the composite matrix to being the curing process. In some configurations, it may be desirable to, in addition to pressure, apply heat to one or more surface tools, heating various surfaces of the composite matrix. Thus, operation 912 may also include a heating operation.

From operation 912, routine 900 continues to operation 914, whereby the composite matrix in the multi-box wing spar layup is cured. In some further configurations, it may be desirable at operation 912 and/or operation 914 to apply tension to the plies within the composite matrix from one or both ends of the composite matrix to reduce the amount of wrinkles of fibers within the composite matrix and to increase the straightness of the fibers within the composite matrix. Once the curing cycle is completed, routine 900 continues to operation 916, whereby the surface tooling (and heat) is removed from the composite matrix. Further, the mandrels are extracted from the composite matrix, forming wing sections having multi-box wing spars.

Based on the foregoing, it should be appreciated that technologies for constructing wing sections having multi-box wing spars have been presented herein. The subject matter described above is provided by way of illustration only and should not be construed as limiting. Various modifications and changes may be made to the subject matter described herein without following the example configurations and applications illustrated and described, and without departing from the true spirit and scope of the present disclosure, which is set forth in the following claims.

What is claimed is:

1. A method of manufacturing an aircraft wing, the method comprising:

applying a plurality of filament wound bias-ply and uni-ply on each of a plurality of separated wing mandrels;

applying tension to the plurality of filament wound bias-ply and uni-ply on at least one of the plurality of separated wing mandrels by extending at least one tension block associated with the at least one of the plurality of separated wing mandrels away from the at least one of the plurality of separated wing mandrels to straighten fibers in the plurality of filament wound bias-ply and uni-ply;

abutting the plurality of separated wing mandrels to create a multi-box wing spar layup;

abutting a plurality of wing surface tooling to the multi-box wing spar layup;

compressing the plurality of wing surface tooling to apply pressure to the multi-box wing spar layup; and

curing the multi-box wing spar layup to form the aircraft wing having a plurality of multi-box wing spars,

wherein compressing the plurality of wing surface tooling further comprises applying tension to the plurality of filament wound bias-ply and uni-ply to minimize wrinkling of a plurality of fibers therein.

2. The method of Claim 1, wherein curing the multi-box wing spar layup further comprises applying heat to the multi-box wing spar layup.

3. The method of Claim 1 to 2, further comprising removing each of the plurality of separated wing mandrels after curing the multi-box wing spar layup.

4. The method of any one of Claims 1 to 3, wherein applying the plurality of filament wound bias-ply and uni-ply comprises adding sufficient layers of wound bias-ply or uni-ply to achieve a desired wing thickness or structural rigidity.

5. The method of any one of Claims 1 to 4, further comprising laying-up a curable upper wing skin and a curable lower wing skin after applying the plurality of

filament wound bias-ply and uni-ply, wherein curing the multi-box wing spar layup co-cures the multi-box wing spar layup, the upper wing skin and the lower wing skin.

6. The method of any one of Claims 1 to 5, further comprising installing a plurality of rib segments after curing the multi-box wing spar layup.

7. The method of any one of Claims 1 to 6, further comprising installing a leading wing edge or a trailing wing edge after curing the multi-box wing spar layup.

8. The method of any one of Claims 1 to 7, further comprising laying-up a curable leading wing edge and a curable trailing wing edge after applying the plurality of filament wound bias-ply and uni-ply, wherein curing the multi-box wing spar layup co-cures the multi-box wing spar layup, the leading wing edge and the trailing wing edge.

9. A wing comprising:

a plurality of multi-box wing spars arranged to be attached to at least one beam of an aircraft fuselage;

an upper wing surface; and

a lower wing surface,

wherein the plurality of multi-box wing spars are arranged to abut each other so as to form a multi-box wing spar layup,

wherein the plurality of multi-box wing spars, upper wing surface, and lower wing surface are composite layers comprising substantially continuous fibers, and

wherein tension is applied to the fibers of at least one of the multi-box wing spars to straighten the fibers via extension of at least one tension block associated with the at least one of the multi-box wing spars away from the at least one of the multi-box wing spars.

10. The wing of Claim 9, wherein the wing further comprises a plurality of ribs disposed within the plurality of multi-box wing spars.

11. The wing of Claims 9 or 10, wherein the wing further comprises a leading wing edge and a trailing wing edge comprising composite layers co-cured with the plurality of multi-box wing spars, upper wing surface, and lower wing surface.

12. The wing of any one of Claims 9 to 11, wherein at least one of the multi-box wing spars comprises an elliptical aperture.

13. The wing of Claim 12, wherein an outer surface of the elliptical aperture is proximate to an inside surface of the aircraft fuselage.

14. The wing of Claim 12, wherein foci of the elliptical aperture provide an angular displacement between the aircraft fuselage and the wing, and wherein the angular displacement provides for a straight-wing or swept-wing profile.

15. The wing of any one of Claims 9 to 14, wherein at least one of the plurality of multi-box wing spars is attached to at least one of a plurality of multi-box wing spars of a second wing.

16. The wing of any one of Claims 9 to 15, further comprising a wing skin co-cured with the plurality of multi-box wing spars.

17. The wing of any one of Claims 9 to 16, wherein the composite layers comprising substantially continuous fibers are co-cured or co-bonded composite layers.

18. A system for forming an aircraft wing, the system comprising:

a plurality of mandrels comprising:

an upper surface layer shaped according to an upper surface layer of the aircraft wing;

a lower surface layer shaped according to a lower surface layer of the aircraft wing; and

a forward surface layer and an aft surface layer abutted with one or more of the plurality of mandrels, wherein the upper surface layers of the plurality of mandrels are shaped according to an upper surface of the aircraft wing and the lower surface layers of the plurality of mandrels are shaped according to a lower surface of the aircraft wing, wherein the plurality of mandrels are arranged to abut each other so as form a mandrel layup, and wherein fibers of the mandrels are under tension via at least one tension block associated with at least one of the plurality of mandrels by extending the at least one tension block away from the at least one of the plurality of mandrels;

another tension block for maintaining tension on one or more layers of composite material forming the aircraft wing; and

a compression apparatus for mechanically curing the one or more layers of composite material forming the aircraft wing, the compression apparatus comprising:

an aft skin surface tool for applying pressure to the aft surface layer of the plurality of mandrels;

a top skin surface tool for applying pressure to the upper surface layer of the plurality of mandrels;

a lower skin surface tool for applying pressure to the lower surface layer of the plurality of mandrels; and

a forward skin surface tool for applying pressure to the forward surface layer of the plurality of mandrels.

19. The system of Claim 18, further comprising a heating element for thermally curing the one or more layers of composite material forming the aircraft wing.

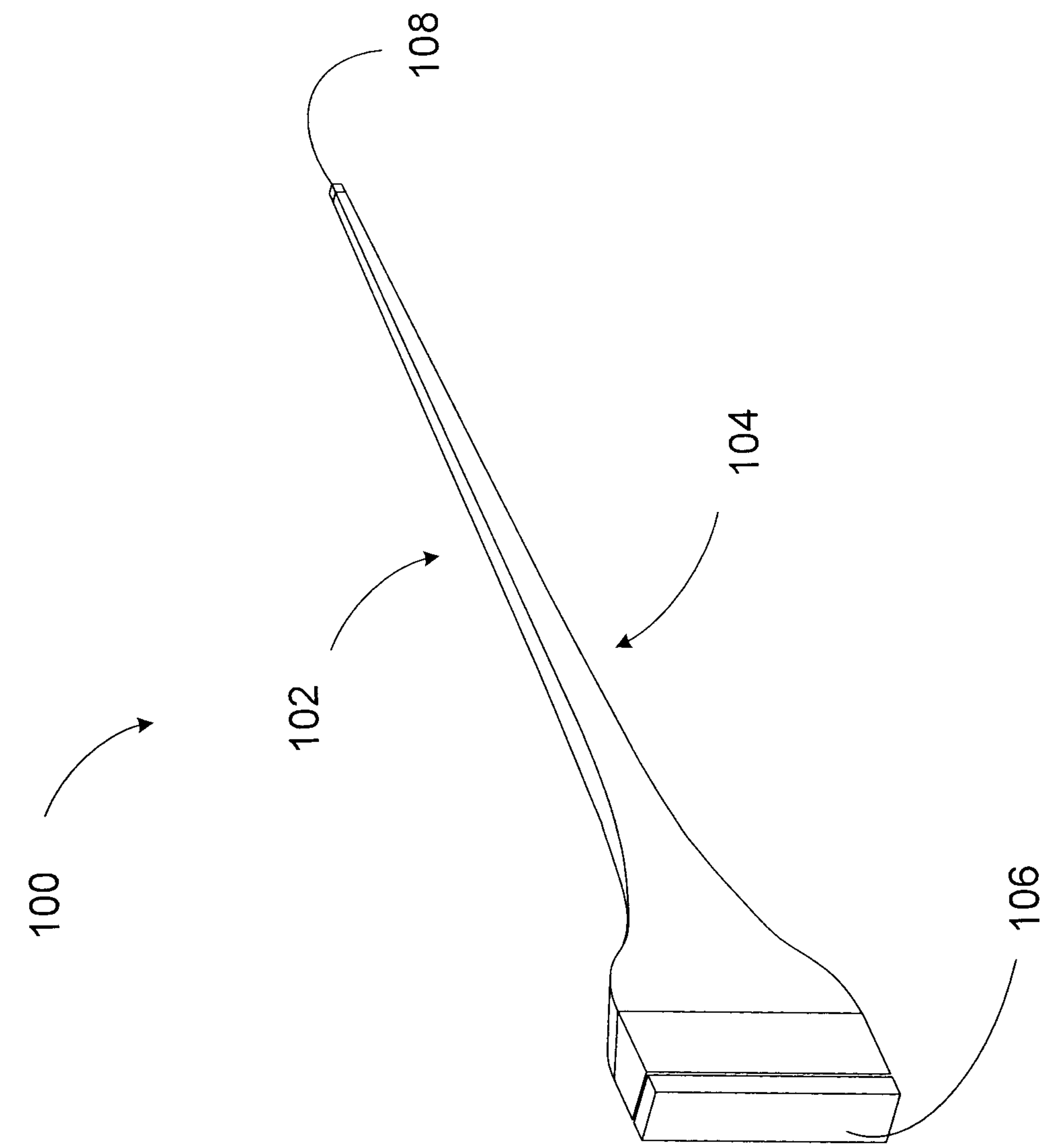


FIG. 1

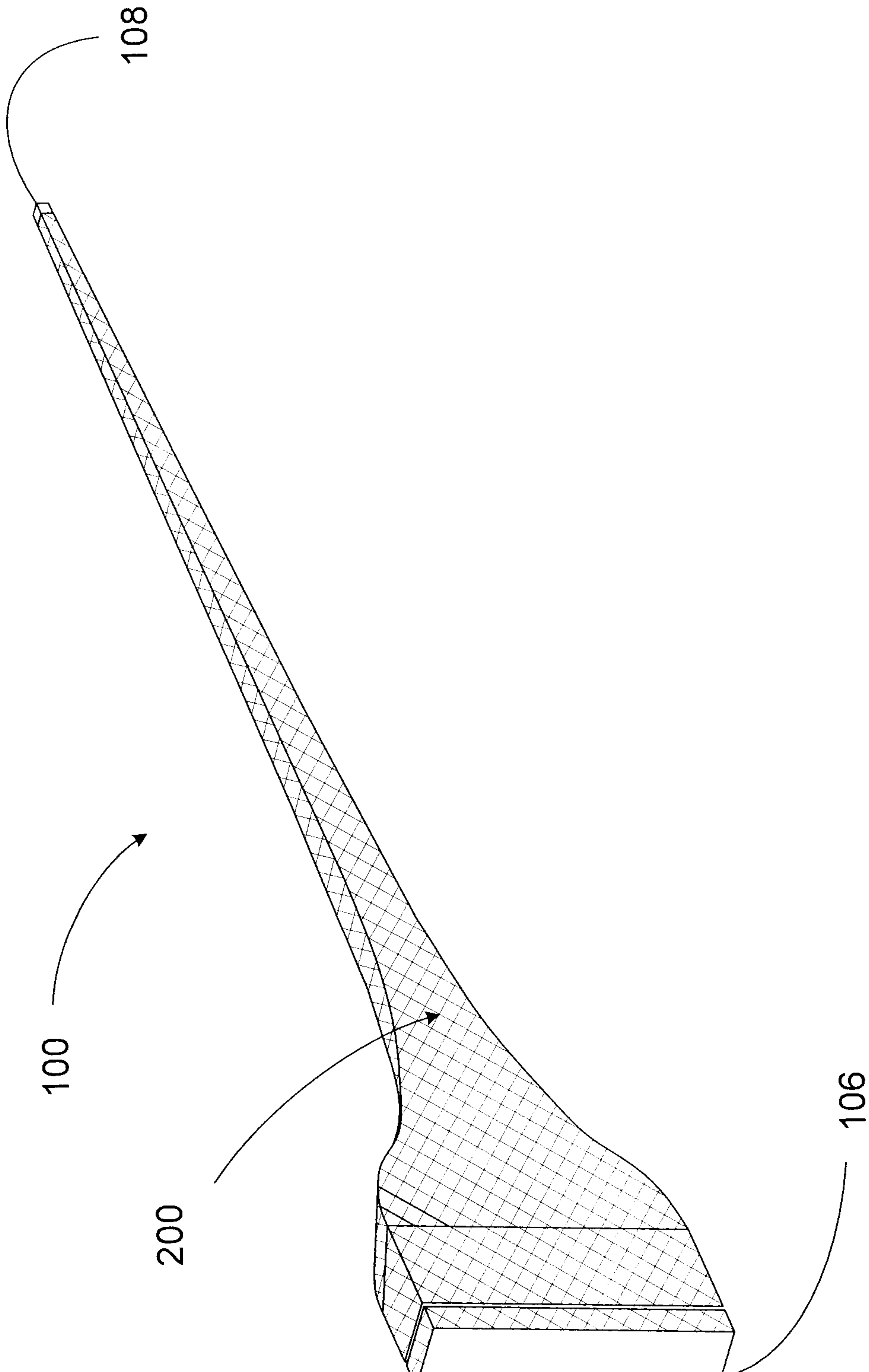


FIG. 2

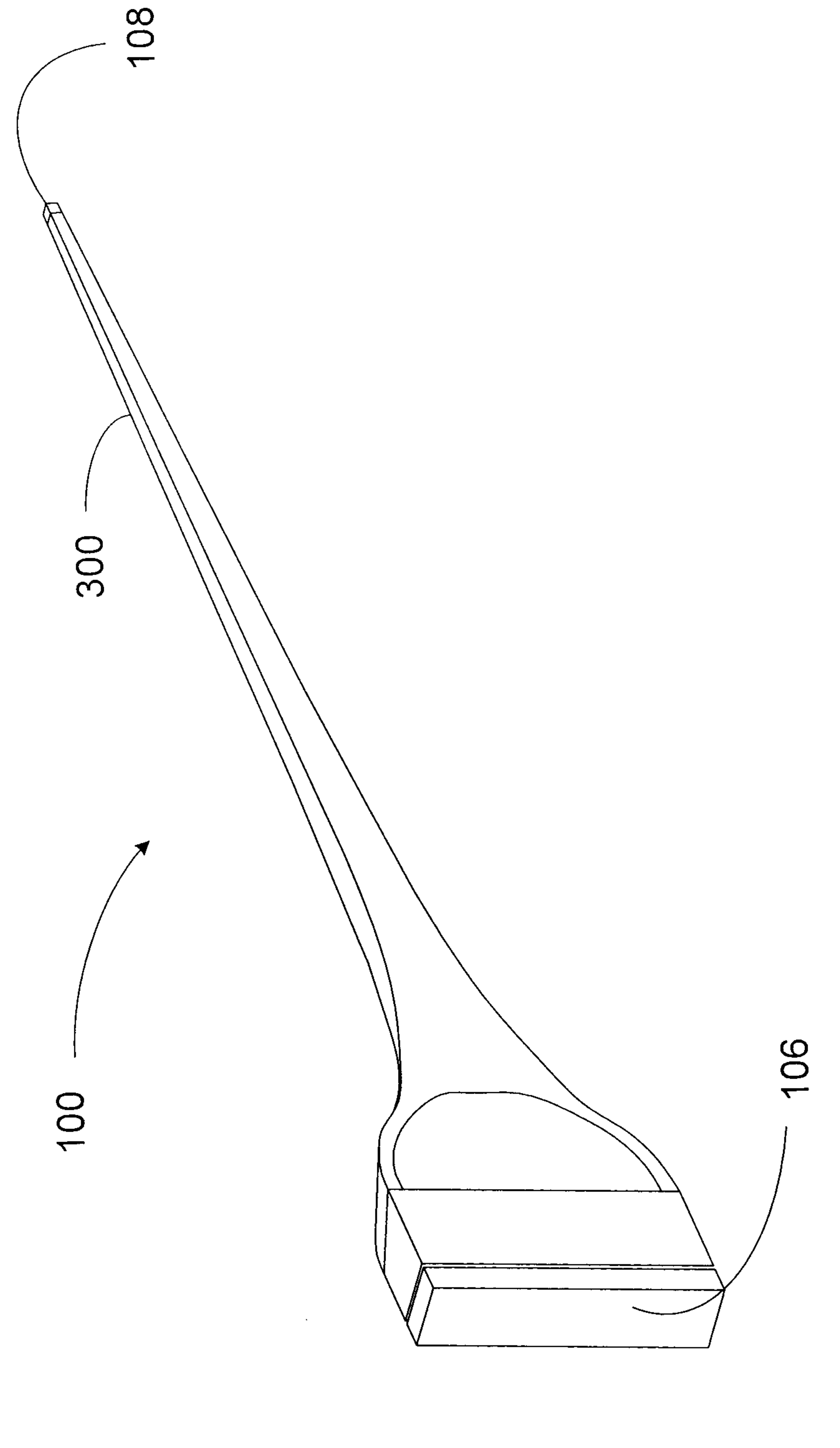


FIG. 3

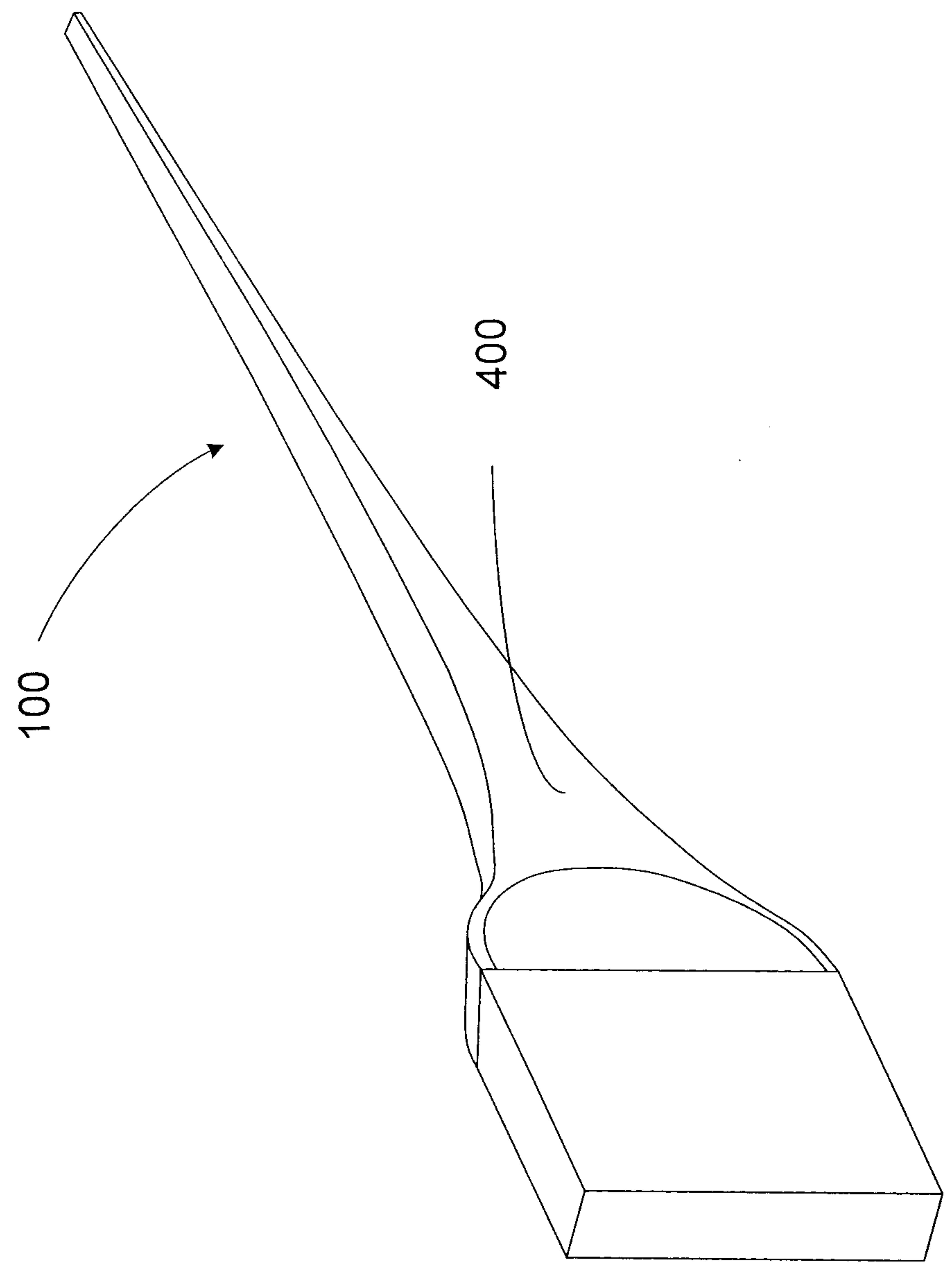


FIG. 4

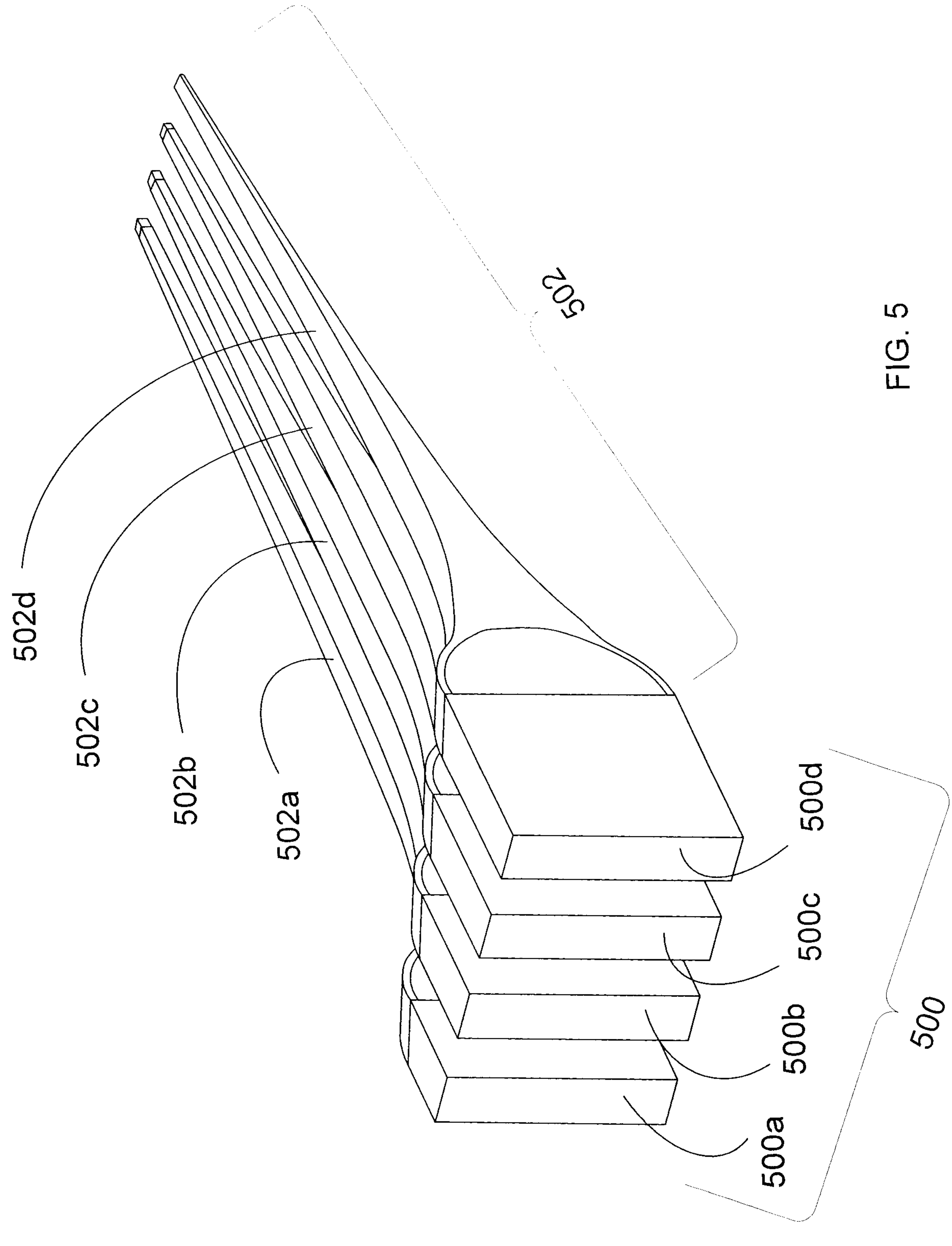


FIG. 5

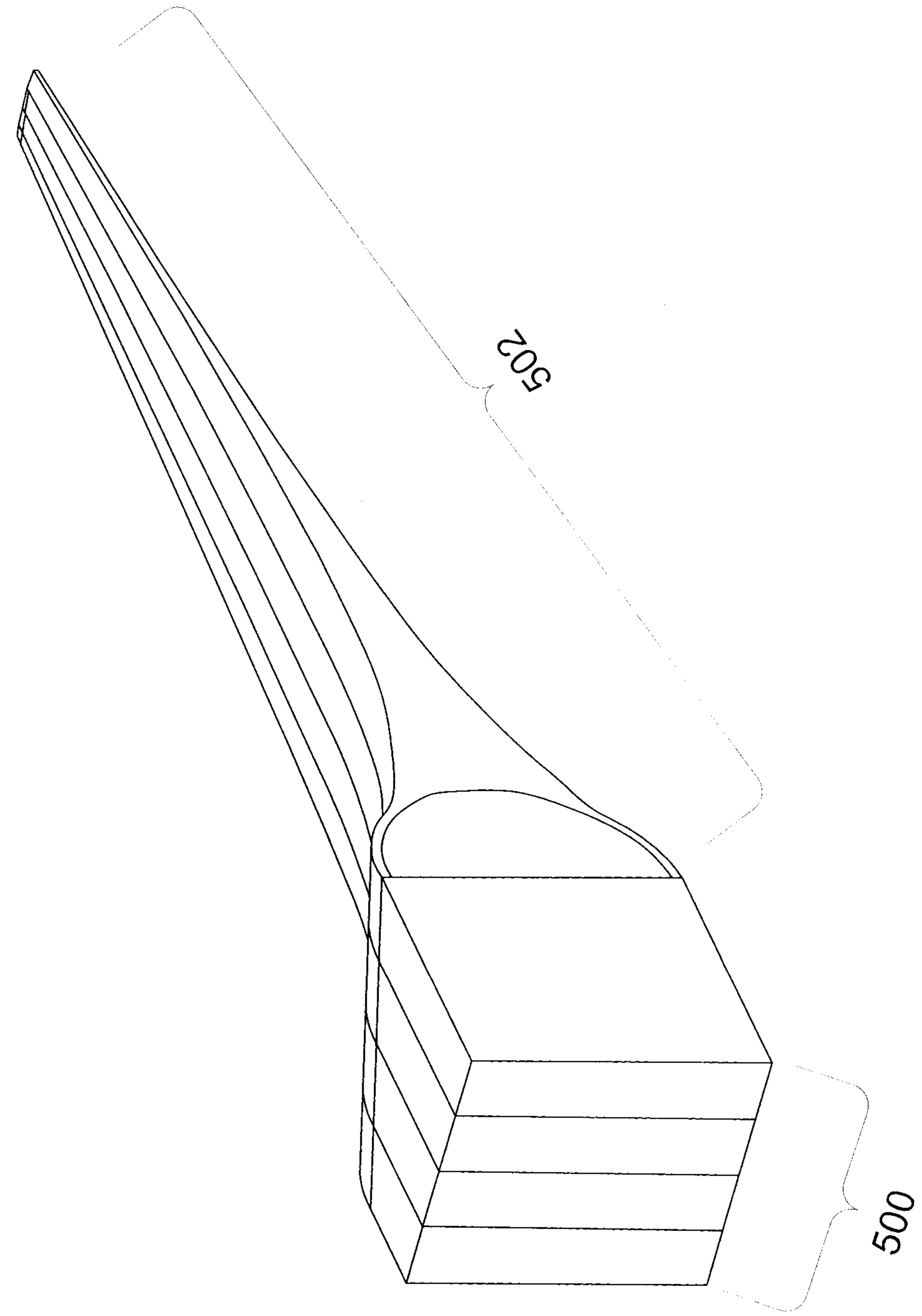


FIG. 6

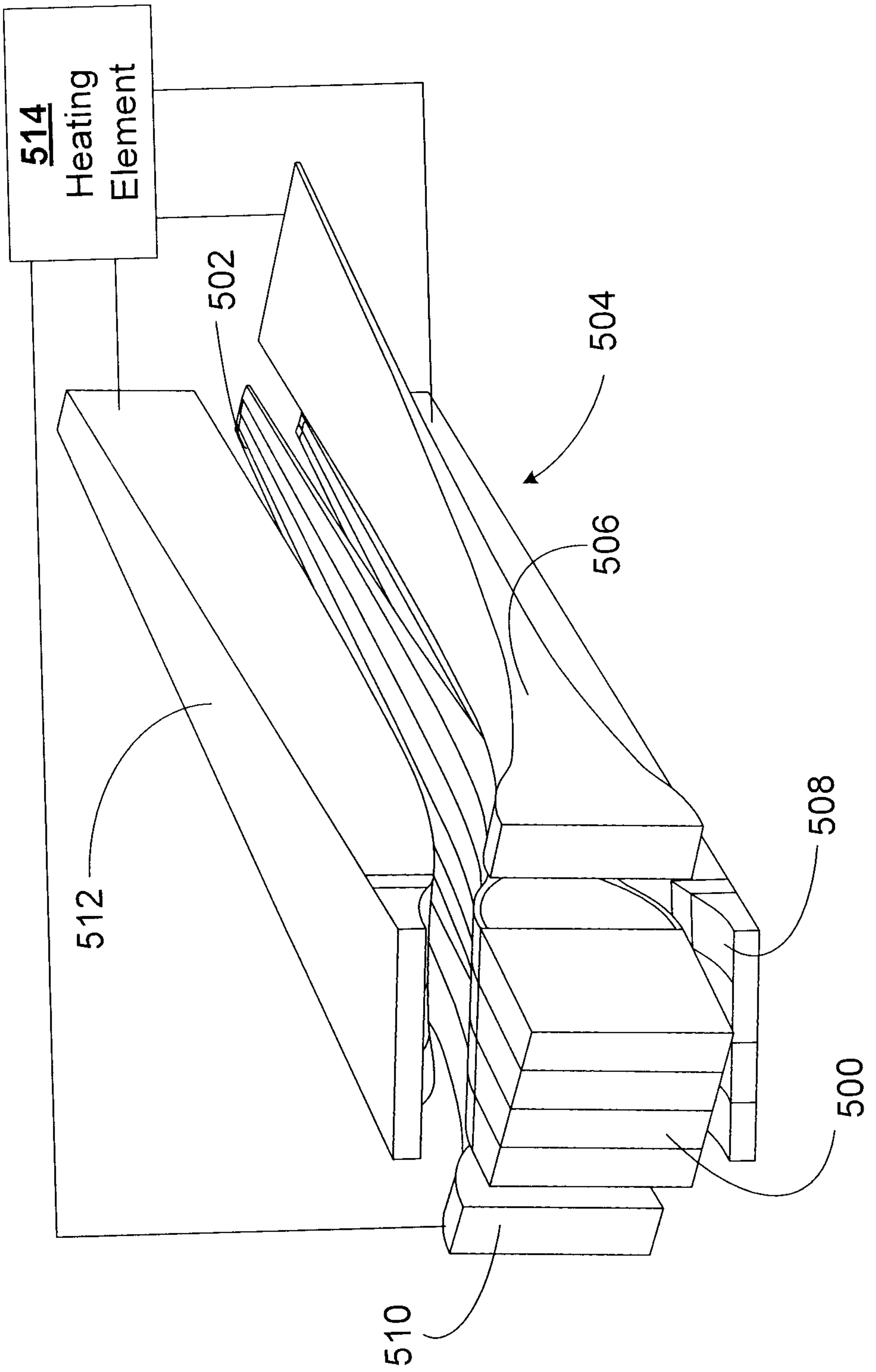


FIG. 7

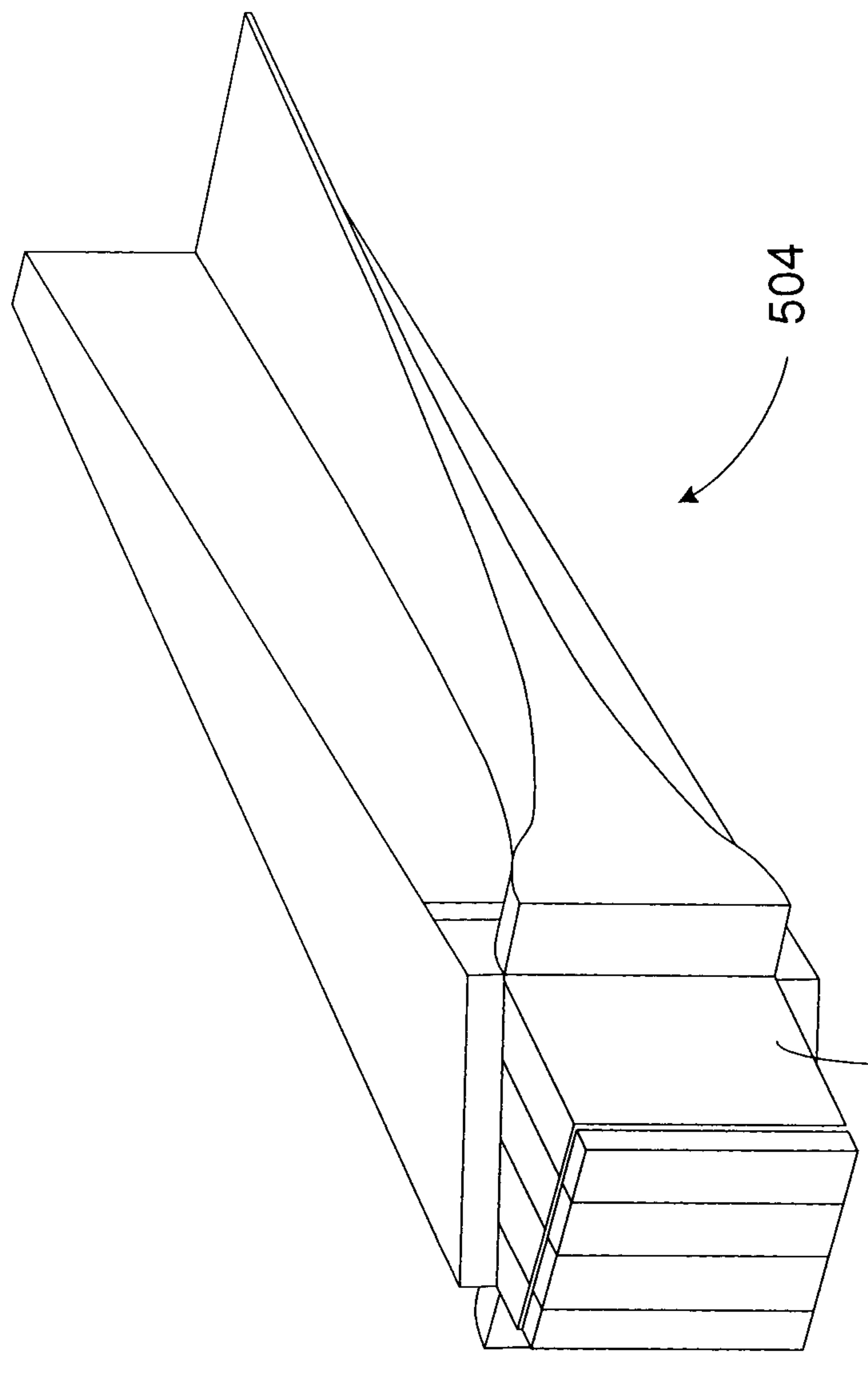


FIG. 8

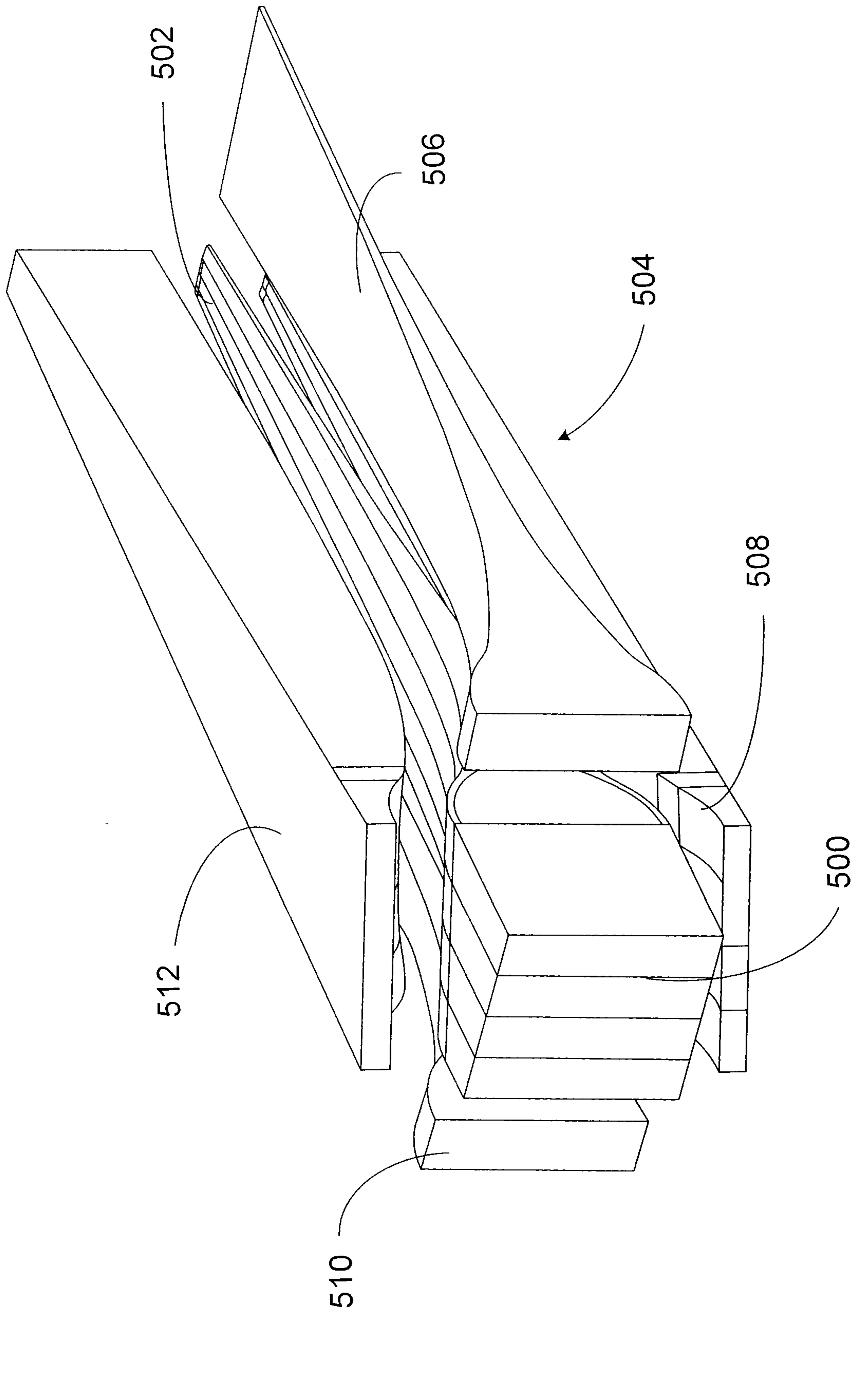


FIG. 9

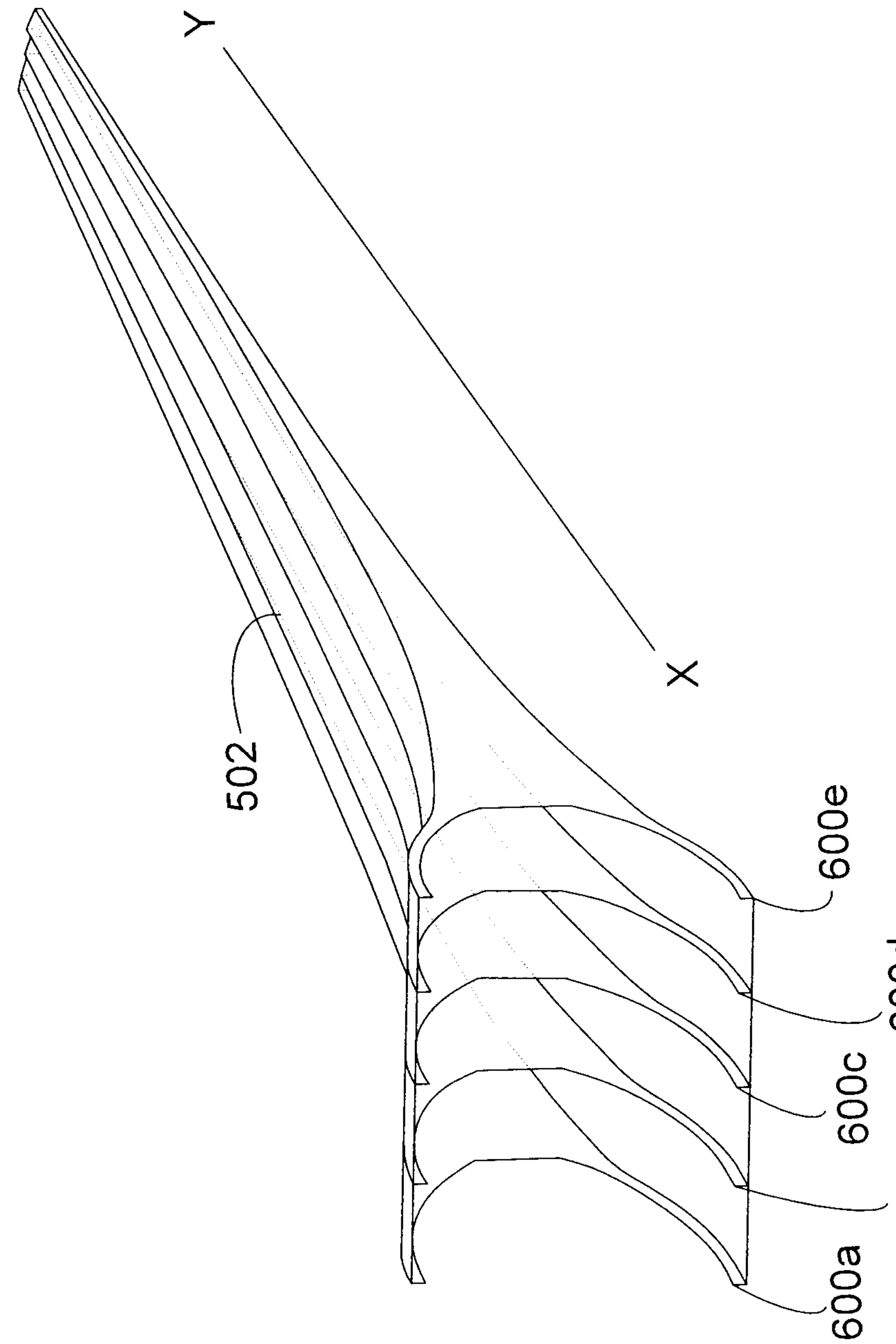


FIG. 10

600e

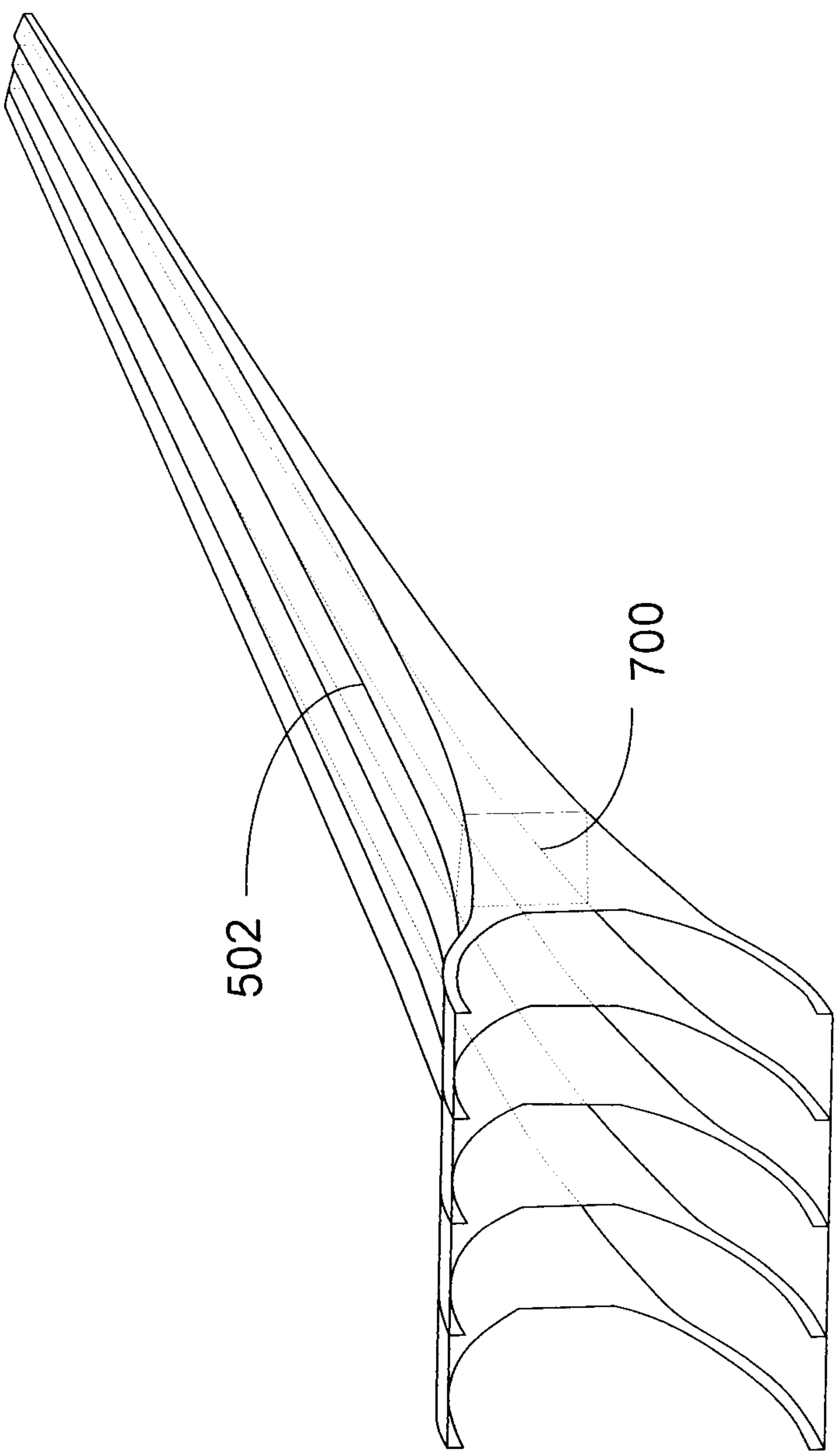


FIG. 11

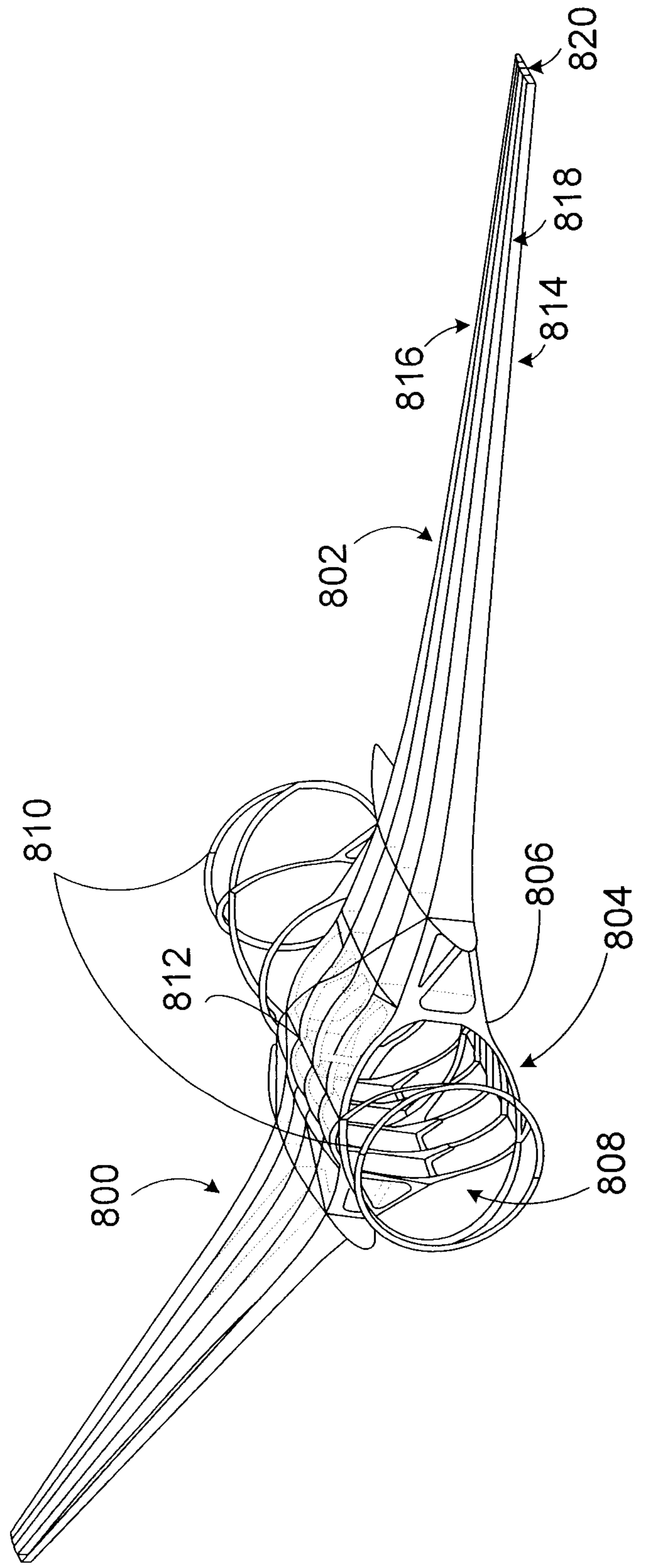


FIG. 12

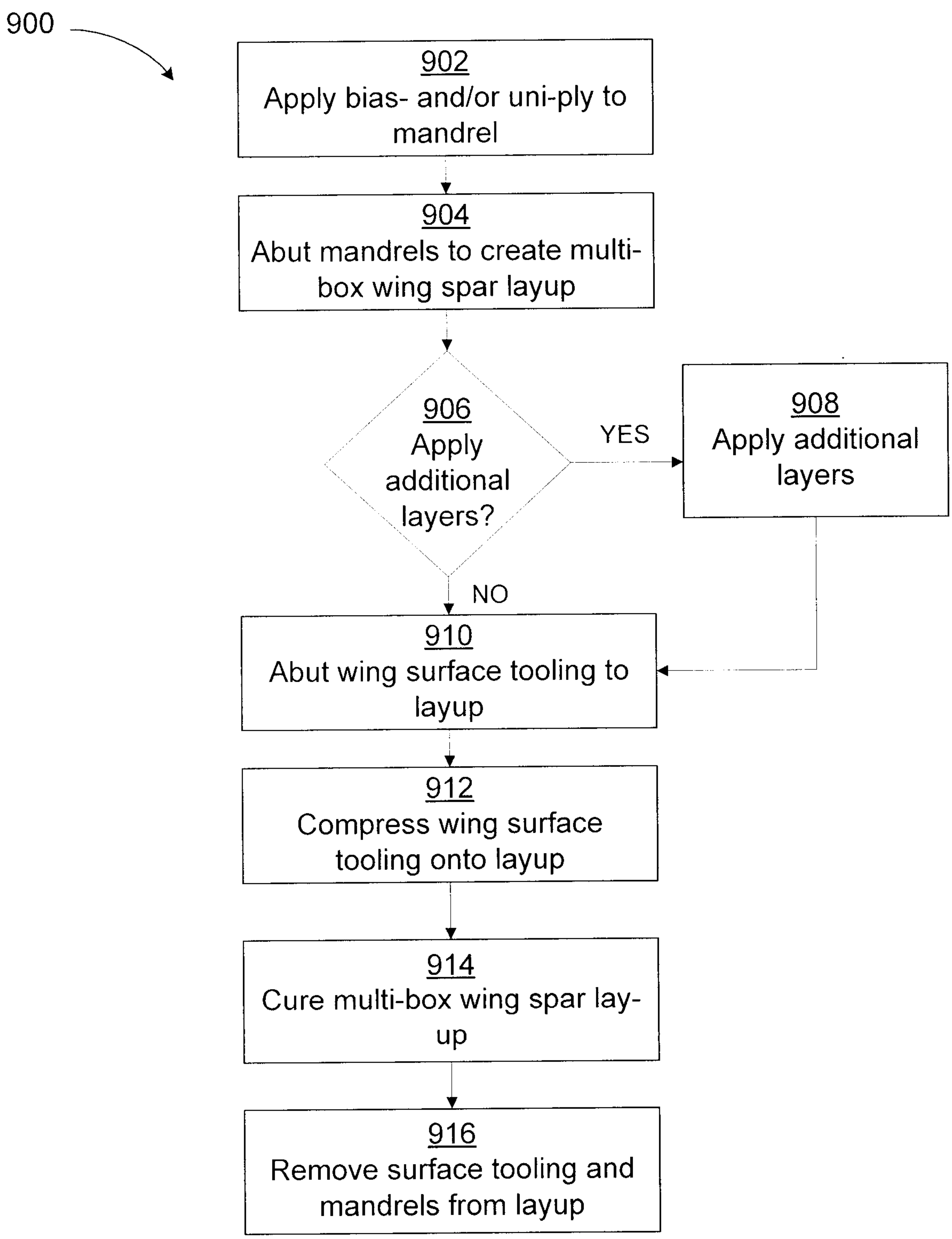
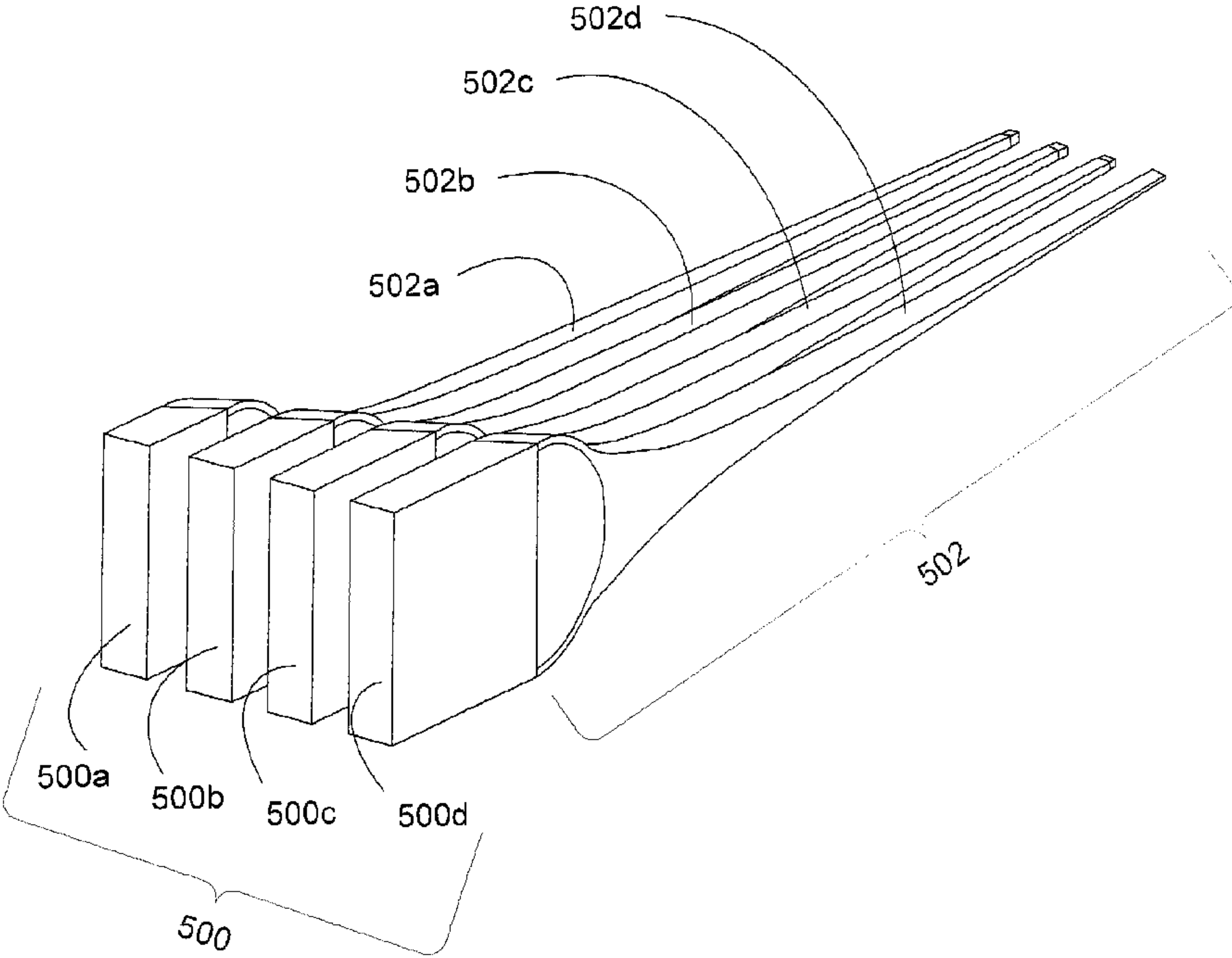

900
902
Apply bias- and/or uni-ply to mandrel
904
Abut mandrels to create multi-box wing spar layup
906
Apply additional layers?
YES
908
Apply additional layers
NO
910
Abut wing surface tooling to layup
912
Compress wing surface tooling onto layup
914
Cure multi-box wing spar lay-up
916
Remove surface tooling and mandrels from layup

FIG. 13



502d
502c
502b
502a
502
500a
500b
500c
500d
500