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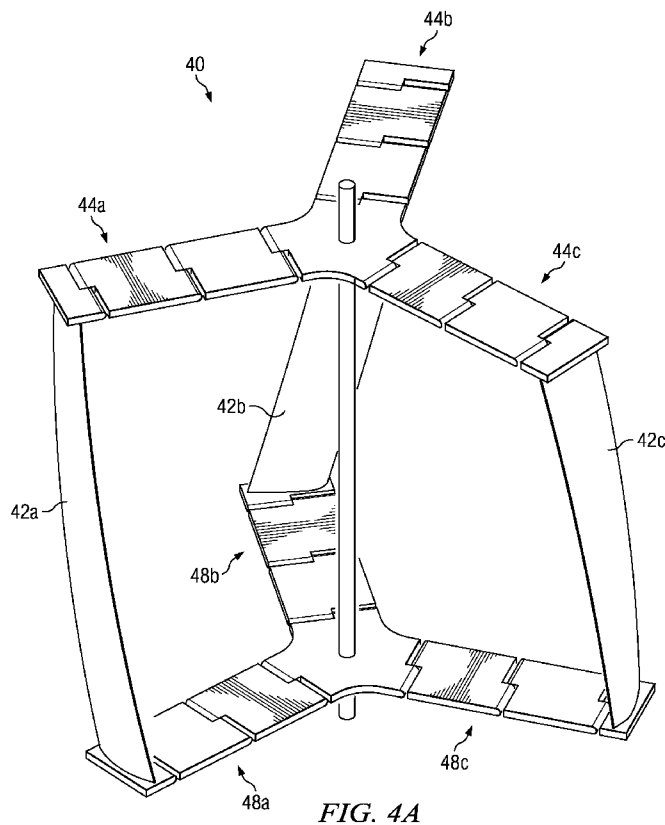
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[Continued on next page]

(54) Title: COLLAPSIBLE REACTION TURBINE



(57) Abstract: A collapsible reaction turbine is disclosed. The turbine includes a rotatable shaft, a plurality of hub portions that are fixedly attached to the rotatable shaft, a plurality of turbine blades, and upper and lower pluralities of spokes. An upper spoke and a lower spoke from each of the spoke pluralities provide a spoke pair to which the upper and lower ends of a corresponding turbine blade are attached. Each upper and lower spoke and each spoke pair is advantageously structured and arranged to be collapsible about at least one joint or hinge.



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a patent (Rule 4.17(ii))*

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— *as to the applicant's entitlement to claim the priority of
the earlier application (Rule 4.17(iii))*

TITLE OF THE INVENTION

COLLAPSIBLE REACTION TURBINE

5 CROSS REFERENCE TO RELATED APPLICATIONS

The present invention claims priority of U.S. Provisional Patent Application 61/187,388 filed on June 16, 2009.

10 STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

N/A

15 BACKGROUND OF THE INVENTION

Machines and turbines that generate electrical power from fluid flow energy, e.g., wind power, hydro-power, and the like, are well known to the art. For example, U.S. Patent Number 20 5,451,137 discloses a Gorlov Helical Turbine (GHT). Referring to FIG. 1A and FIG. 1B, a GHT 10 includes a plurality of air-foil-shaped, helical turbines blades 12 having a leading edge and a trailing edge. The turbine blades 12 are structured and arranged to rotate in from the trailing edge 25 towards the leading edge regardless of the direction of fluid flow. Hence, the GHT is unidirectional, which is to say that, regardless of the direction of fluid flow and the point of attack, the turbine blades 12 will always rotate in one single direction.

Each helical turbine blade 12 has a an upper end 13 and a lower end 15, each of which can be fixedly attached to or integrated with an upper spoke 14 and a lower spoke 18, respectively. Upper spokes 14a-14c are fixedly attached to
5 a hub region 19a having a first opening 17a and lower spokes 18 are fixedly attached to a hub region 19b having a second opening 17b. A rotatable shaft (not shown) is concentric and coaxial with the first 19a and the second openings 19b and is adapted further to rotate about an axis of rotation 11 whenever
10 fluid flow causes the helical turbine blades 12 to rotate.

For illustration purposes, FIG. 2 shows a GHT device 10 being used to harvest mechanical and/or electrical energy in a marine environment. Although the figure shows a vertically-oriented rotatable shaft 21, those skilled in the
15 are can appreciate that the shaft 21 could also be oriented horizontally or skewed at an angle of inclination.

While the boat is moored or anchored, water flow 16 from the current or from tidal activity will cause the helical turbine blades 12 to move, pulling the rotatable shaft 21 and,
20 thereby causing the GHT device 10 to spin around its axis of rotation, to produce mechanical or electrical energy. Advantageously, the electrical energy is renewable and can be used, for example, to charge batteries or to provide power directly to the boat. When the boat is under way, the GHT
25 device 10 could be configured in an appropriate location on deck to harvest wind energy into mechanical and/or electrical power or it could be stored in an appropriate location on board or over the side.

In either event, but especially when it is stored on board, the size of the GHT device 10 takes up valuable space, which is undesirable. To reduce the necessary stowage space for a GHT device 10, the GHT device 10 could be sectionalized, 5 which would require repeated assembly before and disassembly after each use, which is labor and time intensive, may require special tools for doing so, and may become tiresome. Accordingly, it would be desirable to provide a reaction turbine device that is collapsible making it easier to deploy 10 into its working state and just as easy to collapse into its storage state than conventional reaction turbines and that takes up less space than a deployed GHT device 10 would.

SUMMARY OF INVENTION

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A collapsible reaction turbine is disclosed. The turbine includes a rotatable shaft, a plurality of hub portions that are fixedly attached to the rotatable shaft, a plurality of turbine blades, and upper and lower pluralities of spokes. 20 An upper spoke and a lower spoke from each of the spoke pluralities provide a spoke pair to which the upper and lower ends of a corresponding turbine blade are attached. Each upper and lower spoke and each spoke pair is advantageously structured and arranged to be collapsible about at least one 25 joint or hinge.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features, and
5 advantages of the invention will be apparent from the following
more particular description of preferred embodiments of the
invention, as illustrated in the accompanying drawings in
which like reference characters refer to the same parts
throughout the different views. The drawings are not
10 necessarily to scale, emphasis instead being placed upon
illustrating the principles of the invention.

Preferably, the turbine device is collapsible so that the
spoke portions are closer to the rotatable shaft and the
turbine blades are disposed outside of the spoke portions.
15 Alternatively, after removing the turbine blades from the
upper and lower spokes, the removed turbine blades can be
stored closer to the rotatable shaft and the spoke portions
are disposed outside of the turbine blades.

20 BRIEF DESCRIPTION OF THE DRAWINGS

Furthermore, the invention will be more fully understood
by referring to the Detailed Description of the Invention in
conjunction with the Drawings, of which:

25 FIG. 1A is an isometric view of a rigid helical turbine
device in accordance with the prior art;

FIG. 1B is an elevation view of the rigid helical turbine
device shown in FIG. 1A;

FIG. 2 shows an illustration of a rigid helical turbine device in an operational state;

FIG. 3 shows an illustration of a helical turbine device in a storage state in accordance with the invention as claimed;

5 FIGS. 4A to 4H show various diagrammatic views of a multi-hinged, collapsible helical turbine blade device in accordance with the invention as claimed;

10 FIGS. 5A to 5G show various diagrammatic views of a multi-hinged, collapsible non-helical turbine blade device in accordance with the invention as claimed;

FIGS. 6A to 6F show various diagrammatic views of a single-hinged, collapsible non-helical turbine blade device in accordance with the invention as claimed;

15 FIG. 7A shows a diagrammatic cross-sectional view of a slot and rounded cylindrical tip;

FIG. 7B shows a diagrammatic cross-sectional view of a slot and T-shaped tip; and

FIG. 7C shows a diagrammatic detail of the slot and T-shaped tip of FIG. 7B.

20

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 4A to 4H show various diagrammatic views of a collapsible, multi-hinged, helical blade turbine device 40.

25 The collapsible, multi-hinged, helical blade turbine device 40 includes a plurality of helical turbine blades 42 that are operatively attached to upper and lower pluralities of spokes 44 and 48. The upper plurality of spokes 44 is hingedly attached to an upper hub portion 49a while the lower plurality

of spokes 48 is hingedly attached to a lower hub portion 49b. Each of the upper and lower hub portions 49a and 49b is fixedly attached to a rotatable shaft 51 that is supported by at least one bearing (not shown). The at least one bearing is adapted
5 to support the device 40 while allowing the shaft 51 to rotate with minimal interference and frictional loss.

Each upper spoke 44a-44c and each lower spoke 48a-48c include a plurality of spoke portions that make up the whole, which is to say, an inner spoke portion 52 that is hingedly
10 attached to a corresponding hub portion 49a or 49b, an end spoke portion 54 that is integrated into or attached to the helical turbine blade 42, and a number of middle spoke portions 53. Preferably, the number of spoke portions 52-54 is minimized, e.g., three, which is not to say that there cannot be one, two,
15 or more than three. When there are three spoke portions 52-54 as shown illustratively, the middle spoke portion 53 is hingedly attached to each of the inner spoke portion 52 and the end spoke portion 54.

A hinge or joint 47 is disposed between adjacent spoke
20 portions 52-54 and between the hub portion 49 and the inner spoke portion 52. For illustrative purposes only, each of the adjacent portions to be joined at a hinge 47 has either a first female portion 55 or a second female portion 57, each of which has a length that is approximately half the width W of the spoke
25 portion. Female portions 55 and 57 are integrated into the spoke portions and include an opening, e.g., a circular opening that is adapted to provide a tight interference fit with a rod or pin (not shown). The inner diameter of the openings should

be only slightly larger than the outer diameter of the rod or pin.

During manufacture or assembly, to form a hinge 47, adjacent portions -- whether adjacent spoke portions 52-54 or
5 an inner spoke portion 52 adjacent to a hub portion 49 -- are placed next to one another in a radial direction with respect to the axis of rotation, so that the openings in the corresponding first and second female portions 55 and 57 are aligned coaxially, e.g., in a direction that is orthogonal or
10 substantially orthogonal to the radial axis of the adjacent portions. A rigid, e.g., metal, rod or pin having a length equal to or substantially equal to the width W of the adjacent portions can then be inserted through the openings. Because the inner diameter of the openings is only slightly larger than
15 the outer diameter of the rod, there is a tight interference fit between the two. Notwithstanding the tight interference fit, adjacent portions are capable of rotating about the axis of the rod or pin at the hinge 47.

The direction of rotation of the portions at the hinge
20 47 can be unidirectional or bidirectional. Preferably, the hinges 47 on upper and lower spoke pairs 44a and 48a common to the same helical turbine blade 42a are structured and arranged so that the hinge 47 between the inner spoke portion 52 and the middle spoke portion 53 on each spoke 44a and 48a,
25 i.e., the "primary hinge", are movable towards each other rather than away from each other (as shown in the drawings). This makes the length of the collapsible turbine smaller, and, hence, more compact, than if the primary hinges moved away from

each other or were one hinge forced toward and the other hinge forced away from the other hinge.

The upper plurality of spokes 44 is not in registration with the lower plurality of spokes 48 due to the helical arrangement of the turbine blades 42. As a result, the pin or rod at the outermost hinge 47, i.e., between the end portion 54 that is integrated into the helical turbine blade 42 and the middle spoke portion 53 adjacent thereto, can be removed to facilitate storage and to make the whole more compact. Alternatively, the lower end of each helical turbine blade 42 can be hingedly attached to the end spoke portion 54 of a lower spoke 48, e.g., using a rod of pin arrangement previously described, which can be removed. Although the invention has been described such that lower end of each helical turbine blade 42 is hingedly attached to the end spoke portion 54 of a lower spoke 48, the upper end of each helical turbine blade 42 could, instead, be hingedly attached to the end spoke portion 54 of an upper spoke 44.

During operation of the reaction turbine device 10, fluid forces, e.g., from wave action and the like, may have sufficient force to collapse one or more of the hinges 47. Hence, after the pluralities of upper 44 and lower spokes 48 are fully extended, to prevent the hinges from collapsing due to fluid forces and the like, it is necessary to provide a radial brace across each hinge 47. Exemplary radial braces 50 are shown in FIG. 4C.

The radial braces 50 can be provided on the top surface, the bottom surface, or on both the top and bottom surfaces of each spoke portion 52-54. A radial brace 50 includes a first

ring 58a that is disposed on a first spoke portion (or hub portion) and a second ring 58b that is disposed on a second spoke portion adjacent to the first. A rod or pin 59 is insertable into openings through each of the first 58a and
5 second rings 58b. The axis of the rod or pin 59 is parallel or substantially parallel with a radial axis about the axis of rotation.

Diagrammatic views of a collapsible version of a multi-hinged, non-helical (straight) blade turbine device 60 is shown in FIGs. 5A to 5G. Aside from the linearity of the
10 turbine blades 62 with respect to the helical blades 42 described hereinabove, there is little difference between the two with respect to the hinges 47 and rotation of the stroke portions. Due to the linear arrangement of the turbine blades
15 42 and the registration between upper 44 and lower spokes 48, it is not necessary to remove at least one end spoke portion 54 from an adjacent middle spoke portion 53 or to remove an end of each turbine blade 42 from its corresponding end spoke portion 54 as is the case when the turbine blades 42 are
20 helical.

Although not shown in any of FIGs. 5A to 5G, radial braces 50 can be provided on the top surface, the bottom surface, or on both the top and bottom surfaces of each spoke portion 52-54 or each upper and lower spoke. The composition of the radial
25 braces 50 can be similar with that previously described in connection with the helical turbine blade embodiment.

A collapsible version of a single-hinged, non-helical (straight) blade turbine device 70 is shown in FIGs. 6A to 6F. Unlike the two previous embodiments in which the spoke portions

are closer to the rotatable shaft and the turbine blades are outside of collapsed spokes, the single-hinged version 70 has the turbine blades closer to the rotatable shaft and the collapsed spokes are outside of the turbine blades. With a
5 non-helical (straight), single-hinged embodiment 70 there is but a single hinge 47 between upper and lower spoke pairs 44a and 48a and their respective hub portions 49a and 49b. As shown in FIG. 6C, slots 72 and 79 can be provided, respectively, in the upper and lower spoke portions 44a and 48a and in the
10 hub portions 49a and 49b. The slots 72 and 79 can be used to physically slide the turbine blades 42 radially towards the rotatable shaft 51.

Referring to FIG. 7A, rigid, e.g., metal, rubber, plastic, and so forth, rounded cylindrical tips 73 can be
15 provided at both ends of the non-helical turbine blades 42. The dimension of the tips 73 are selected to allow the turbine blades 42 to be moved easily in a radial direction with respect to the rotatable shaft 51 but, more importantly, to retain the turbine blades 42 in the extended position during operation
20 of the device 70. For example, when the device 70 is to be stored, each of the turbine blades 42 can be moved towards the rotatable shaft 51 via the slots 72 and 79. Once a turbine blade 42 reaches the end of the hub portion slot 79, the corresponding upper and lower spoke portions 44a and 48a can
25 be folded towards each other via the hinges 47 (FIG. 6F).

As an alternative to rounded cylindrical tips 73, T-shaped tips 75 can be used. As shown in FIG. 7B and FIG. 7C, the slots 72 and 79 are T-shaped and are structured and arranged to receive T-shaped tips 75. A rigid, e.g., metal,

rubber, plastic, and so forth, stem portion of the tip 75 is fixedly attached to the turbine blade 42b. The T-portion 74 or the tip 75 is disposed in the T-portion of the slots 72 and 79. Collapsing of the device 70 for storage would be the same
5 as previously describe hereinabove.

As an alternative to providing turbine blades 42 that are slidable towards the rotatable shaft 51, each turbine blade 42 can, instead, be attachable to and removable from the corresponding upper and lower spoke pair 44 and 48, e.g., using
10 attaching devices, bolts, and the like. After each turbine blade 42 is removed, they can be stored between the hub portions 49a and 49b. Collapsing the upper 44 and lower spoke portions 48 towards one another can sufficiently confine the respective, stored turbine blades 42.

Although the invention is described through the above-described exemplary embodiments, it will be understood by those of ordinary skill in the art that modifications to, and variations of, the illustrated embodiments can be made without departing from the inventive concepts disclosed
15 herein. Accordingly, the invention should not be viewed as limited, except by the scope and spirit of the appended claims.
20

What I claim is:

1. A reaction turbine capable of unidirectional rotation under reversible flow, the turbine comprising:

- 5 a rotatable shaft, having an axis of rotation;
 a plurality of hub portions that are fixedly attached to the rotatable shaft;
 a plurality of turbine blades; and
 an upper plurality and a lower plurality of spokes, an
10 upper spoke and a lower spoke from each of the spoke pluralities being structured and arranged to provide a spoke pair, the upper spoke and a lower spoke are each fixedly attached at a distal end, respectively, to upper and lower ends of a corresponding turbine blade of the plurality of turbine blades
15 and that are hingedly attached at a proximal end to a corresponding hub portion of the plurality of hub portions,
 each upper and lower spoke and each spoke pair being structured and arranged to be collapsible and rotatable about the proximate end.

20

2. The turbine as recited in claim 1, wherein each of the plurality of turbine blades is a helical turbine blade or a non-helical turbine blade.

- 25 3. The turbine as recited in claim 1, wherein each of the upper and lower spokes and spoke pairs includes at least one hinge.

4. The turbine as recited in claim 1, wherein each of the upper and lower spokes and spoke pairs includes a plurality of hinges.

5 5. The turbine as recited in claim 1, wherein each of the upper and lower spokes and spoke pairs includes an inner spoke portion that is hingedly and rotatably attached to the corresponding hub portion, an end spoke portion, and at least one middle spoke portion that is hingedly and rotatably
10 attached to each of the inner spoke portion and to the end spoke portion.

6. The turbine as recited in claim 5, wherein the at least one middle spoke portion includes an odd number of
15 sub-portions.

7. The turbine as recited in claim 5, wherein the end spoke portion is integrated into one of the upper and lower ends of the corresponding turbine blade.

20

8. The turbine as recited in claim 5, wherein the end spoke portion is removably attached to one of the upper and lower ends of the corresponding turbine blade.

25 9. The turbine as recited in claim 1, wherein a first slot is disposed radially within an outer surface of the upper and lower spokes, and

each of the upper and lower ends of each turbine blade includes a protrusion that is structured and arranged to allow

the respective turbine blade to translate in a radial direction within the first slot.

10. The turbine as recited in claim 9, wherein the protrusion
5 is structured and arranged to retain said respective turbine blade during operation of the turbine.

11. The turbine as recited in claim 9, wherein the protrusion and the first slot are T-shaped.

10

12. The turbine as recited in claim 9, wherein a second slot that is coaxial to the first slot is disposed radially within an outer surface of each of the hub portions, and

the protrusion is structured and arranged to translate
15 within the second slot.

13. A method of collapsing a reaction turbine having a rotatable shaft, a plurality of hub portions that are fixedly attached to the rotatable shaft, and a plurality of turbine
20 blades, to minimize its size, the method comprising:

providing an upper plurality and a lower plurality of spokes, an upper spoke and a lower spoke from each of the spoke pluralities being structured and arranged to provide a spoke pair;

25 attaching the upper spoke and the lower spoke of each spoke pair at a distal end, respectively, to upper and lower ends of a corresponding turbine blade of the plurality of turbine blades;

hingedly attaching the upper spoke and the lower spoke of each spoke pair at a proximal end, respectively, to a corresponding hub portion of the plurality of hub portions; and

5 collapsing each upper and lower spoke and each spoke pair.

14. The method as recited in claim 13, each of the upper and lower spokes and spoke pairs includes an inner spoke portion that is hingedly and rotatably attached to the corresponding
10 hub portion, an end spoke portion, and at least one middle spoke portion that is hingedly and rotatably attached to each of the inner spoke portion and to the end spoke portion.

15. The method as recited in claim 14 further comprising
15 integrating the end spoke portion into one the upper and lower ends of the corresponding turbine blade.

16. The method as recited in claim 14 further comprising
removable attaching the end spoke portion to one of the upper
20 and lower ends of the corresponding turbine blade.

17. The method as recited in claim 13 further comprising:
 providing a first slot radially within an outer surface of the upper and lower spokes;
25 providing a protrusion in each of the upper and lower ends of each turbine blade includes a protrusion, said protrusion is structured and arranged to translate in a radial direction within the first slot.

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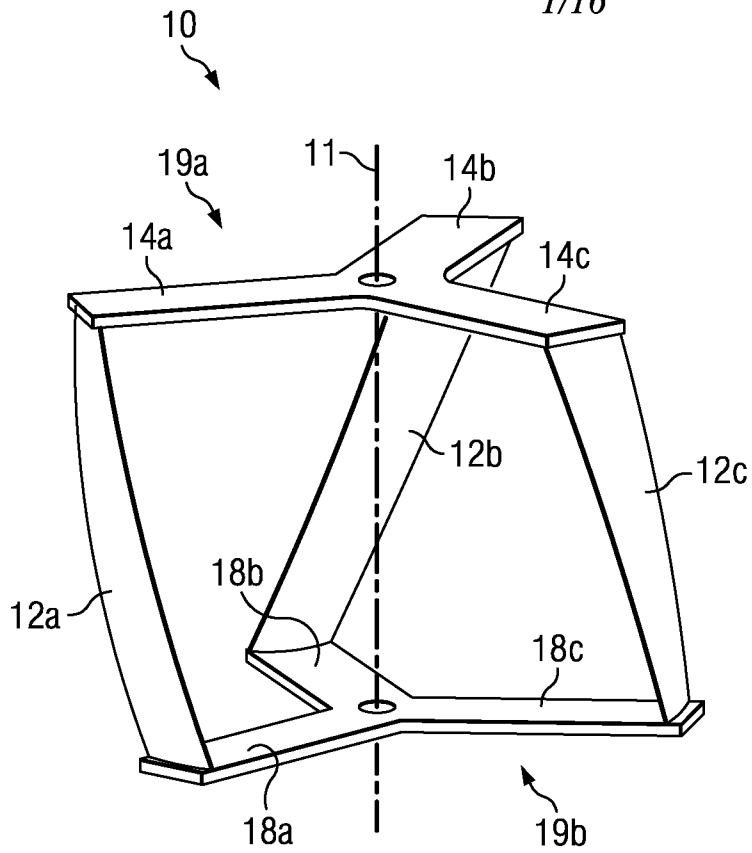


FIG. 1A
(PRIOR ART)

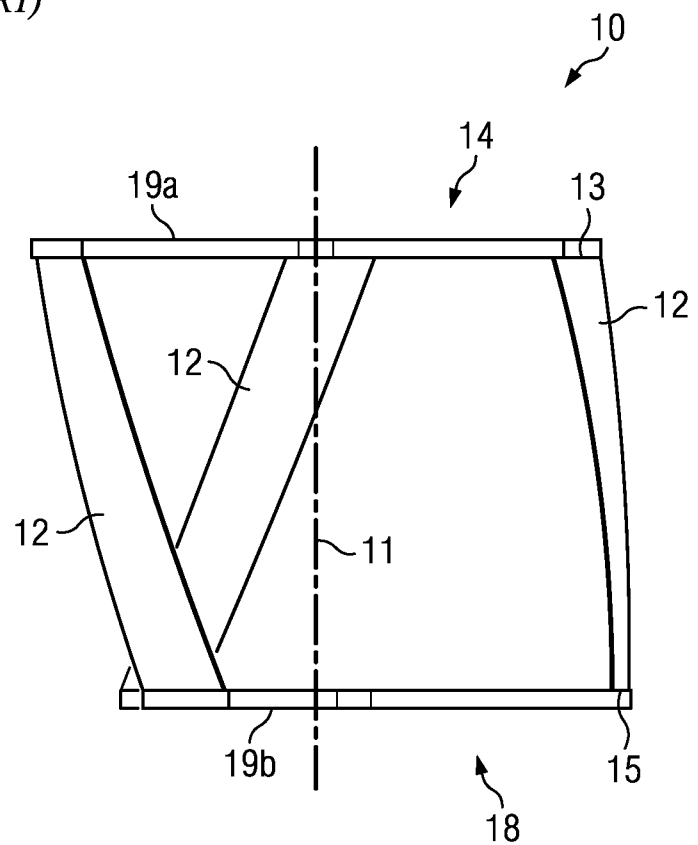


FIG. 1B
(PRIOR ART)

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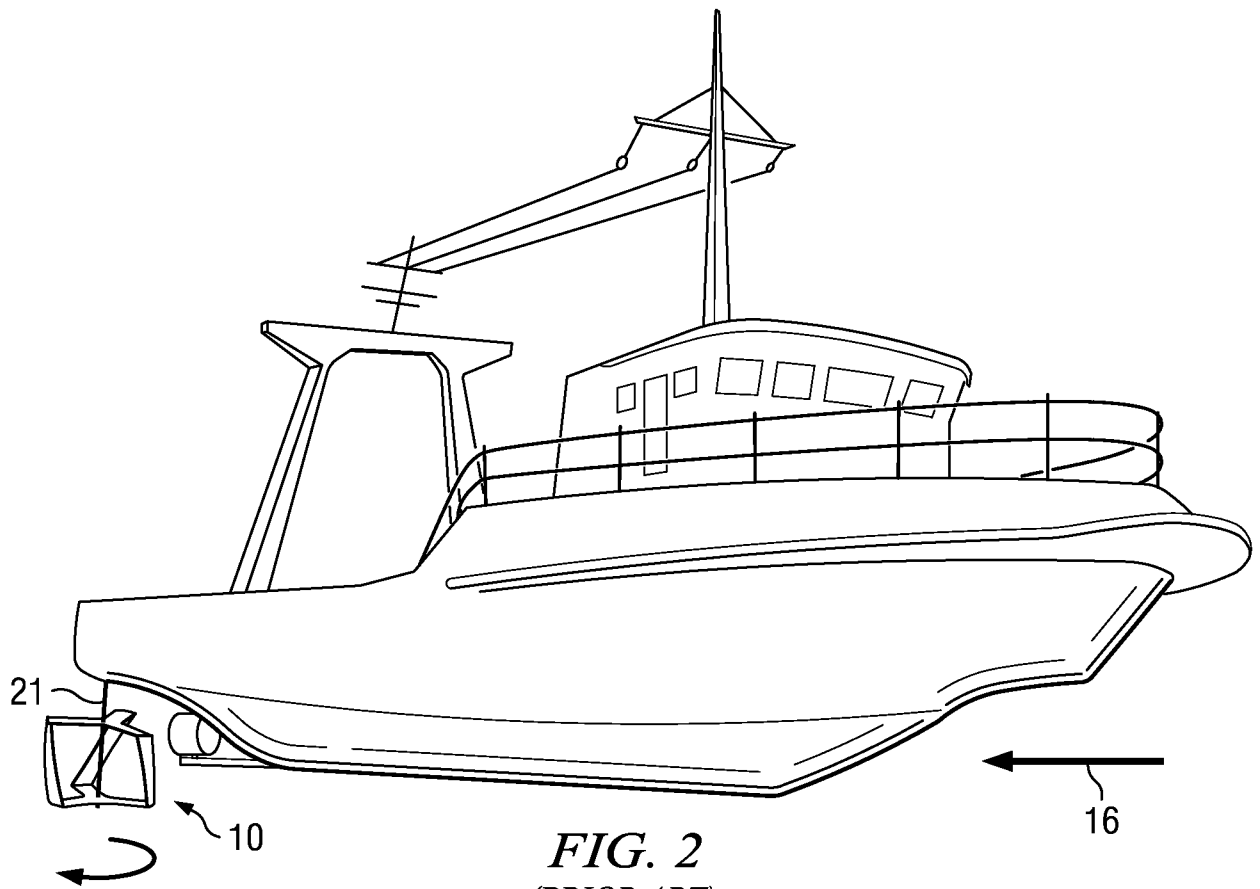


FIG. 2
(PRIOR ART)

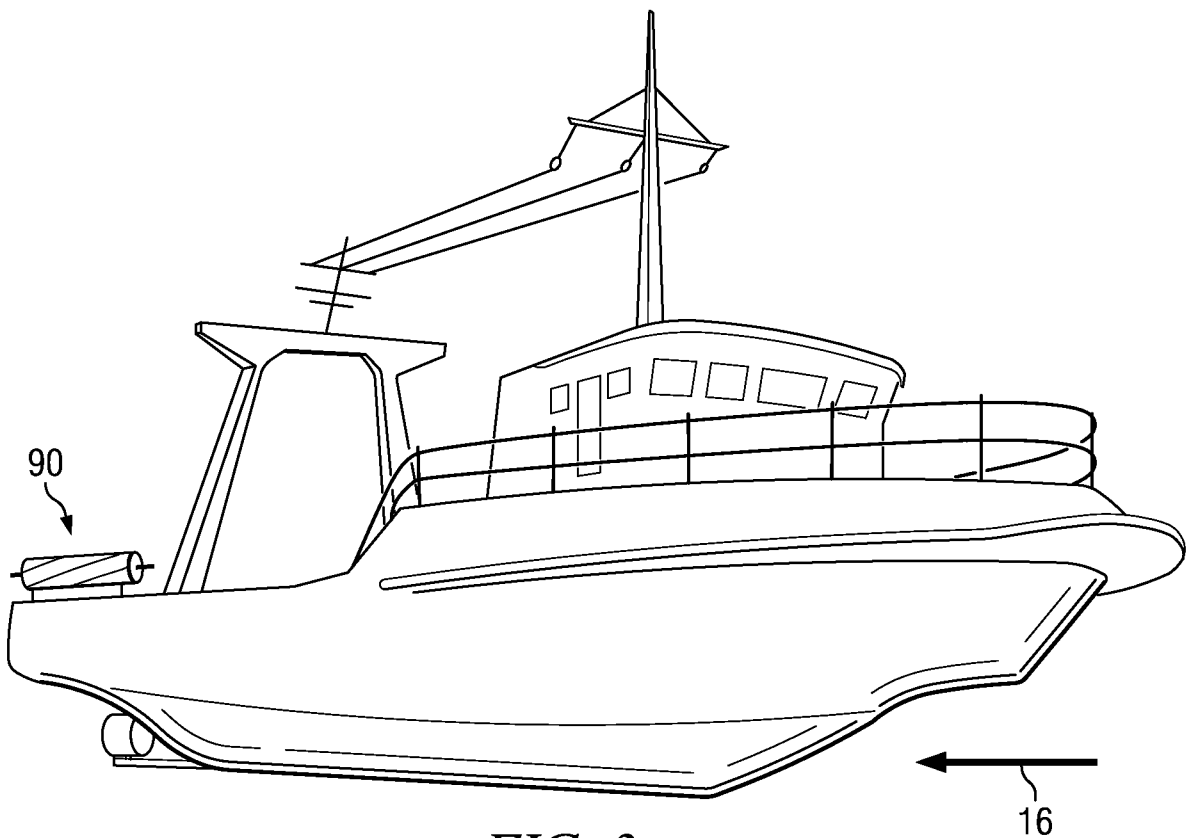
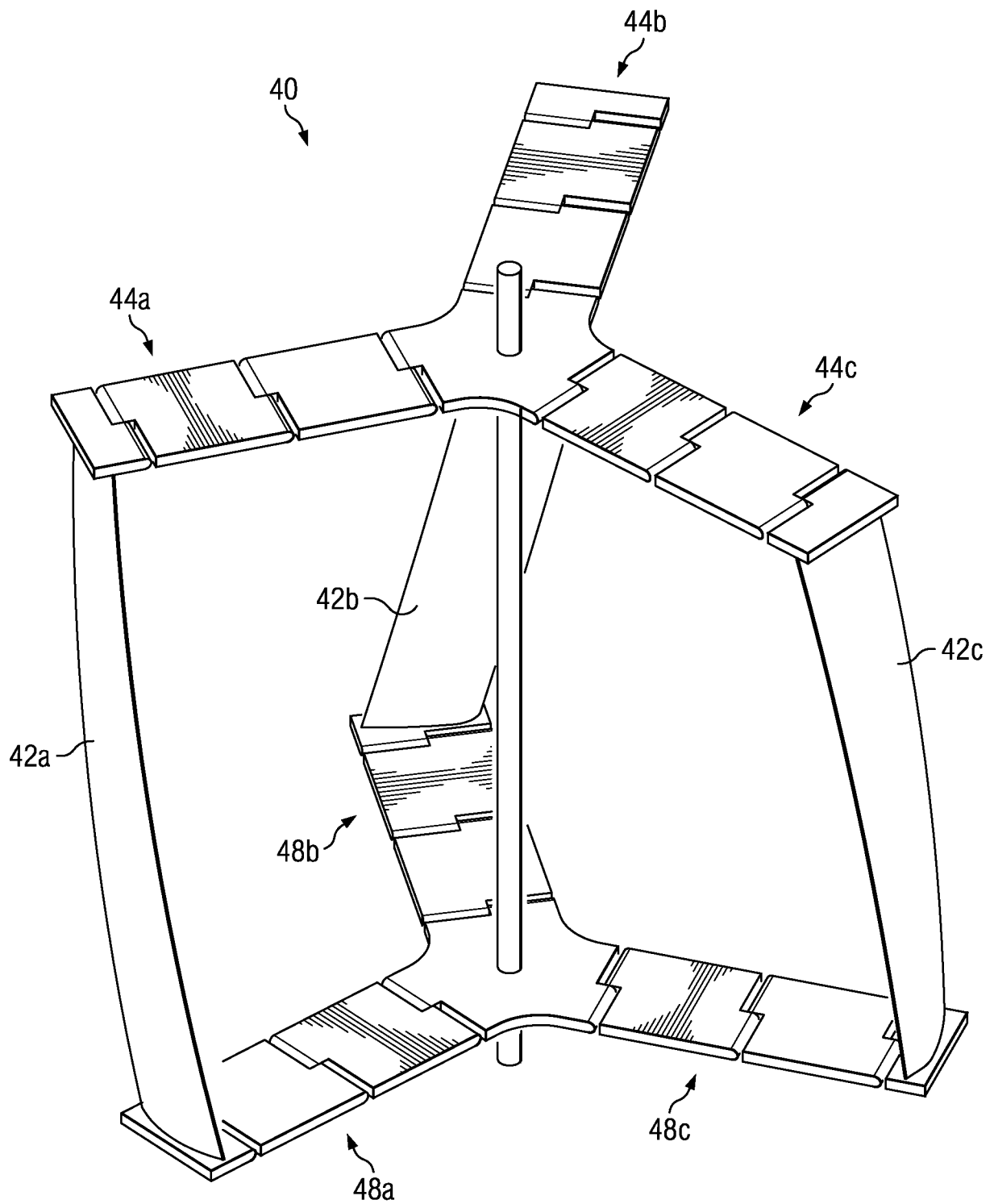


FIG. 3

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*FIG. 4A*

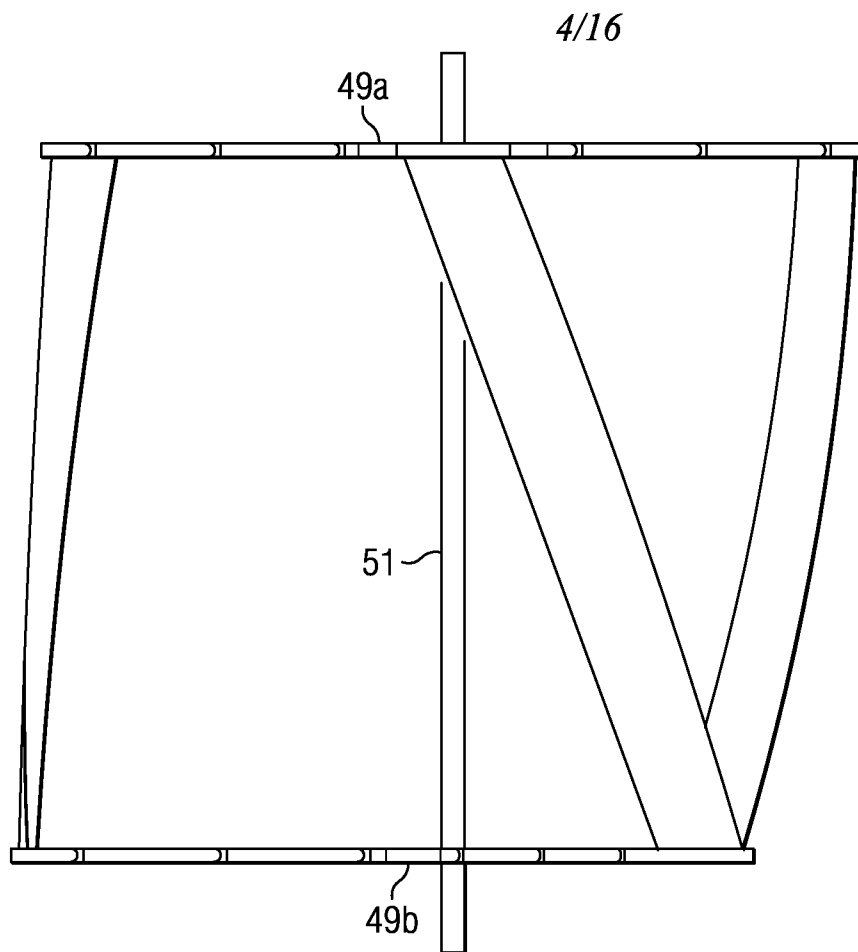


FIG. 4B

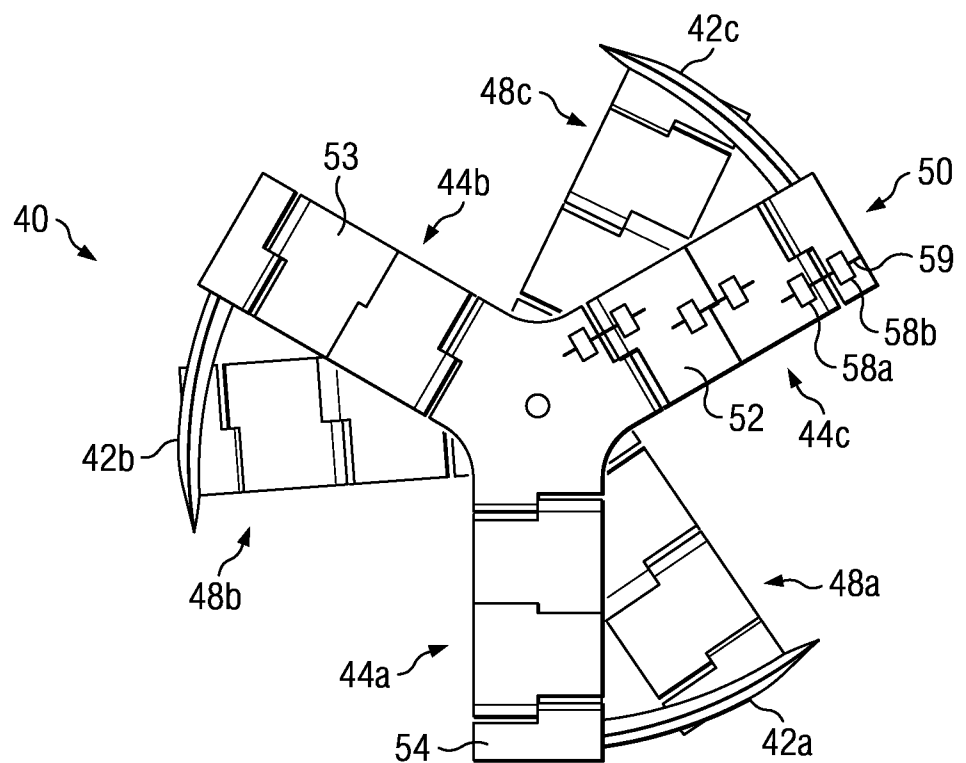


FIG. 4C

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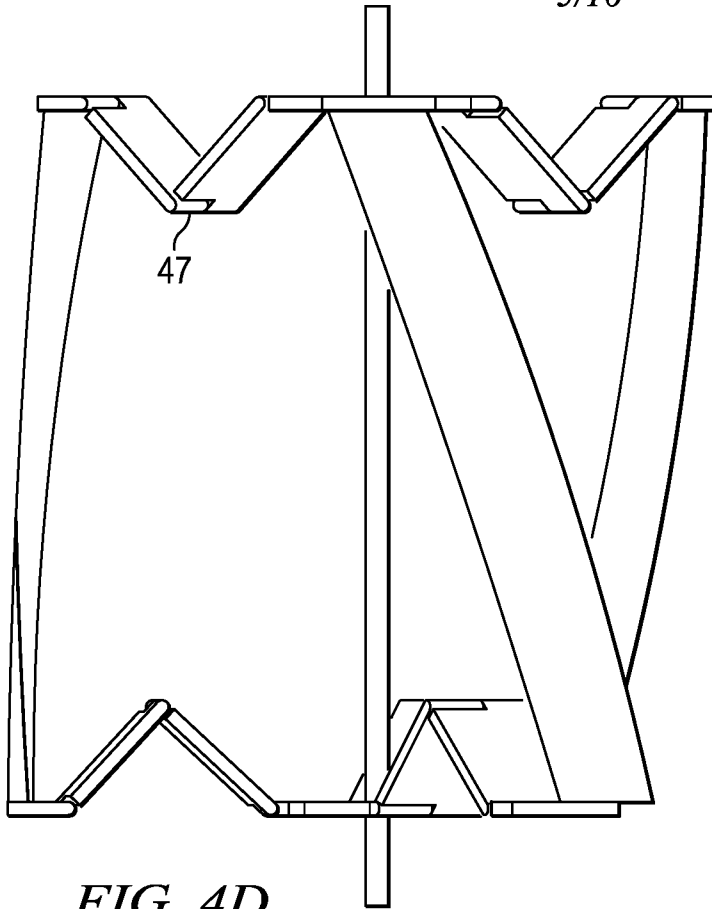


FIG. 4D

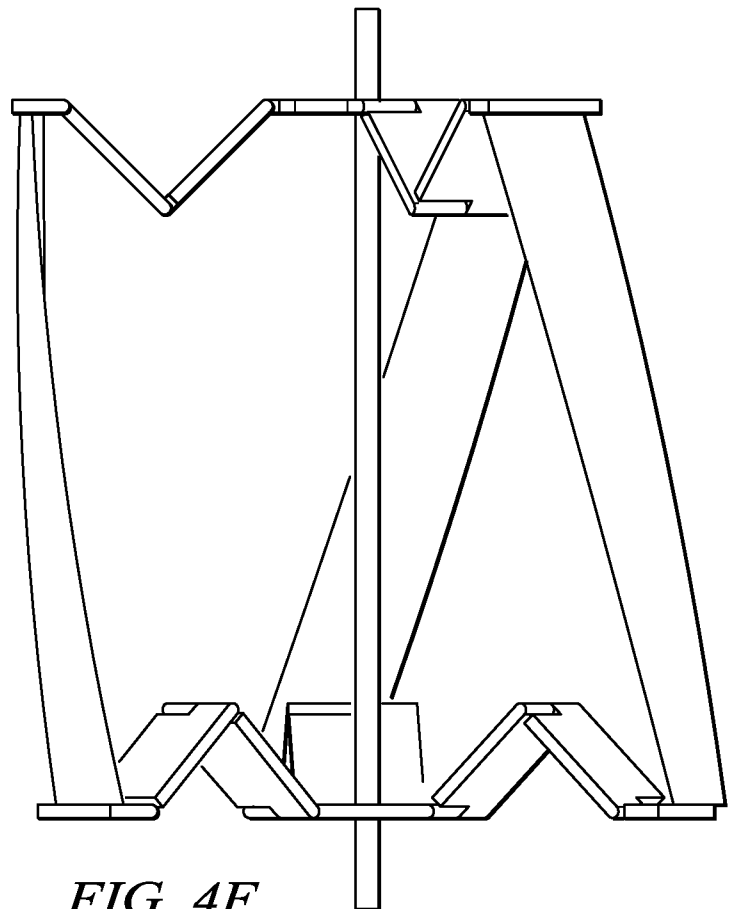


FIG. 4F

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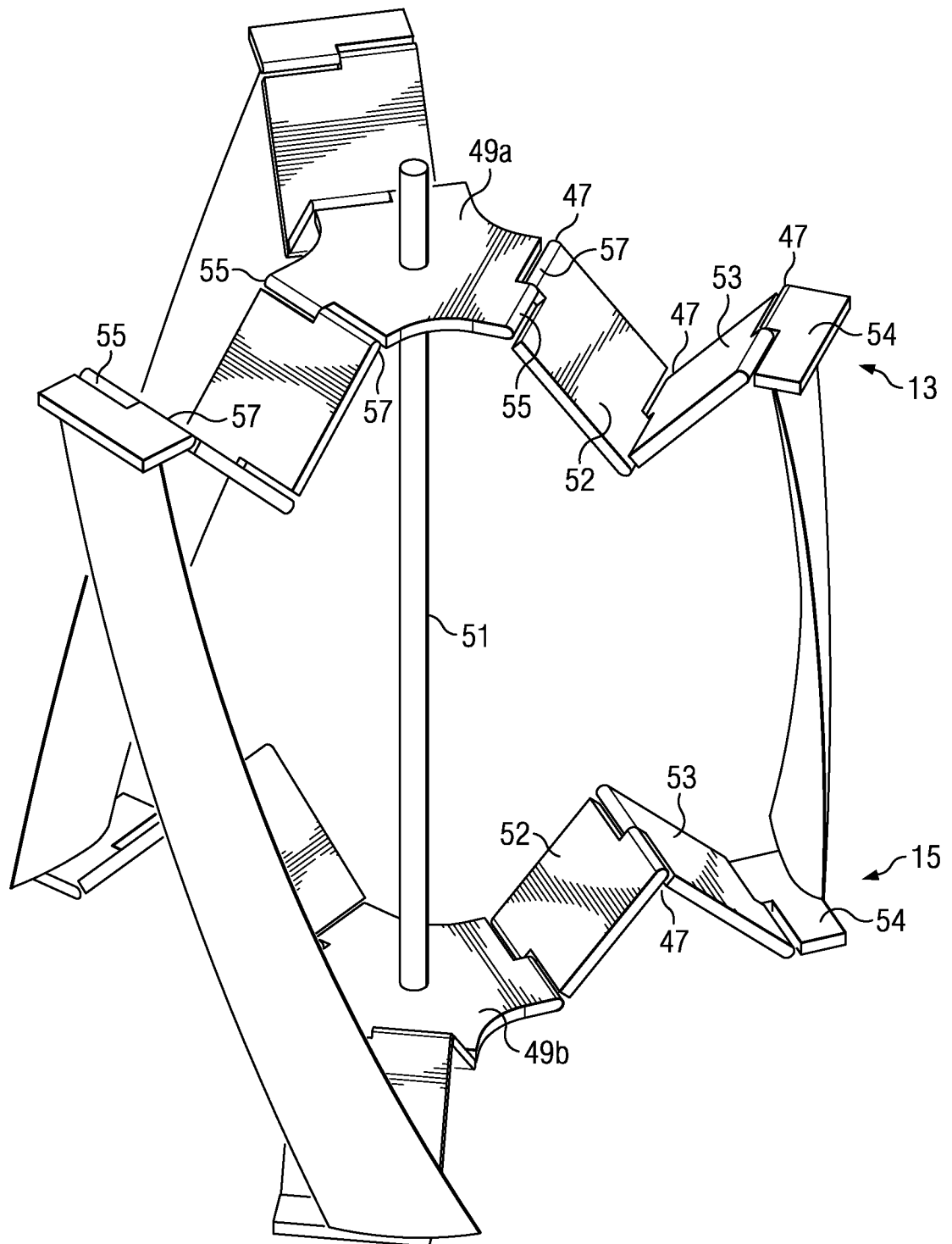


FIG. 4E

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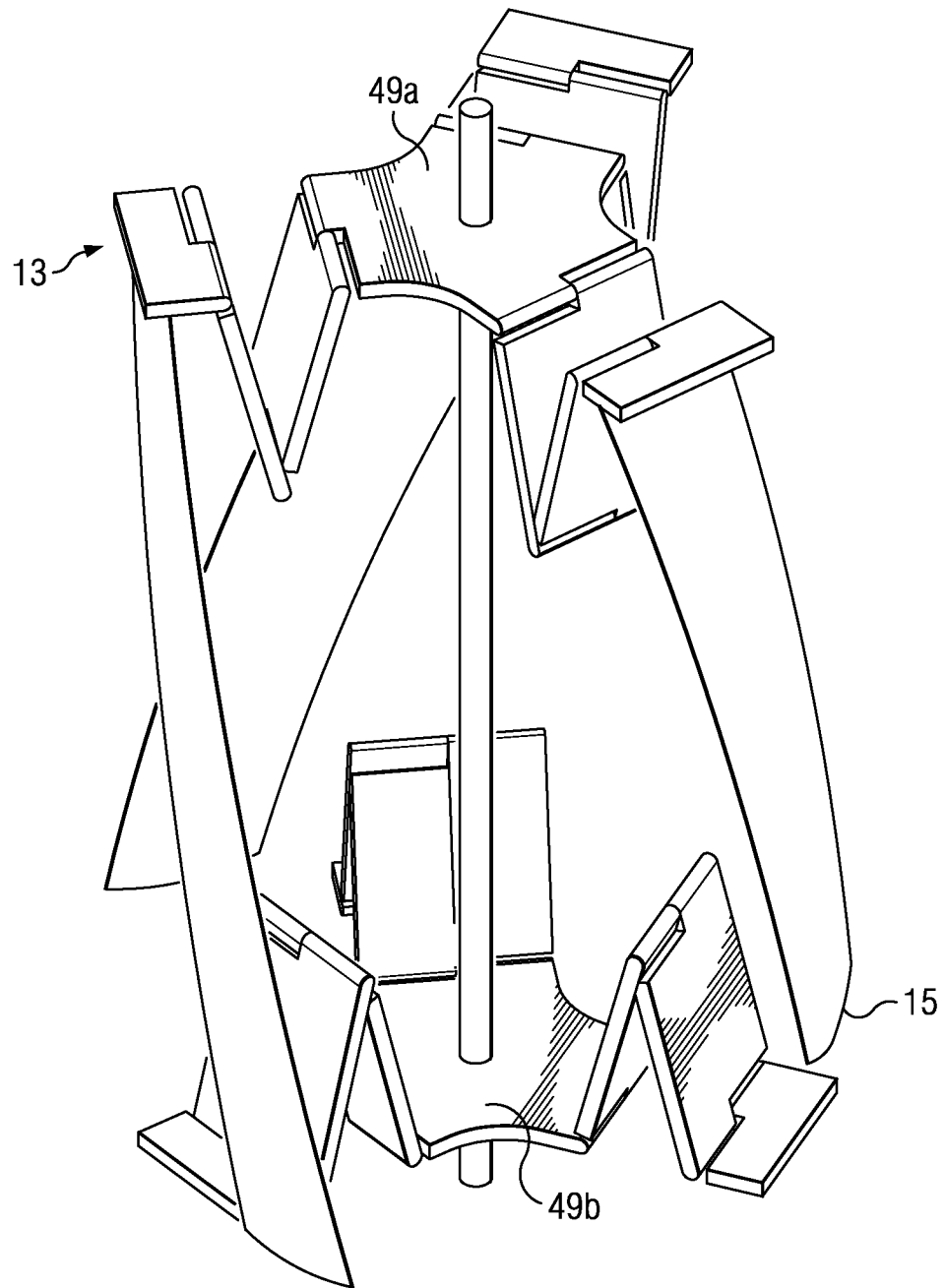


FIG. 4G

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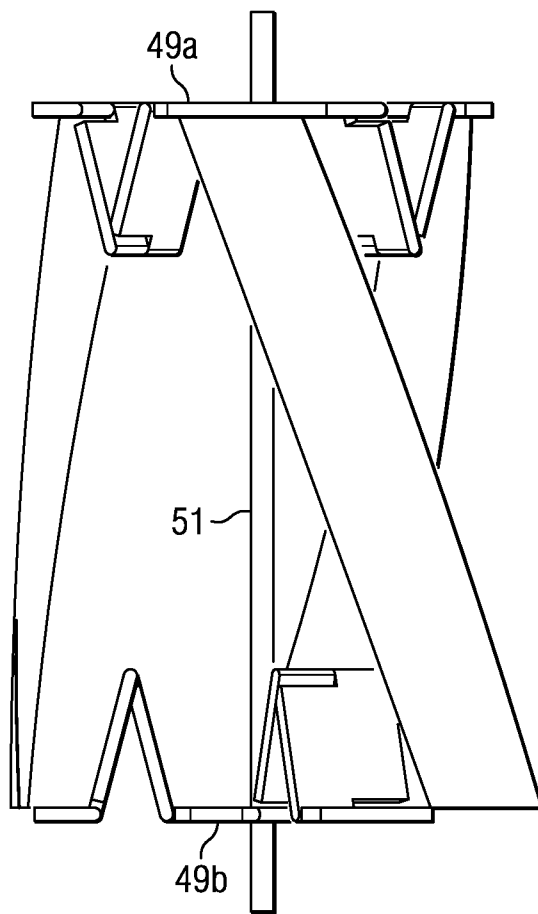


FIG. 4H

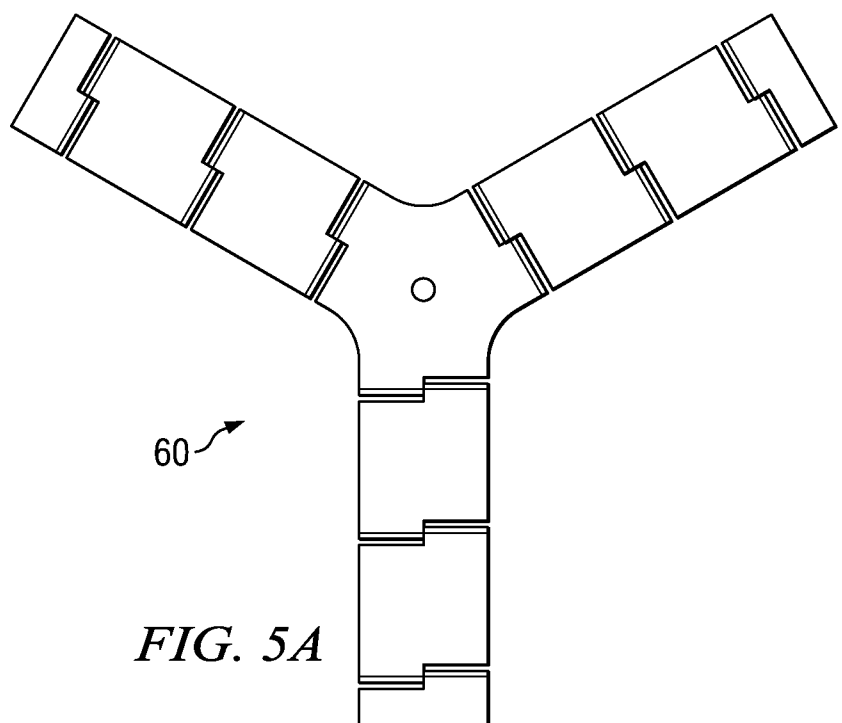


FIG. 5A

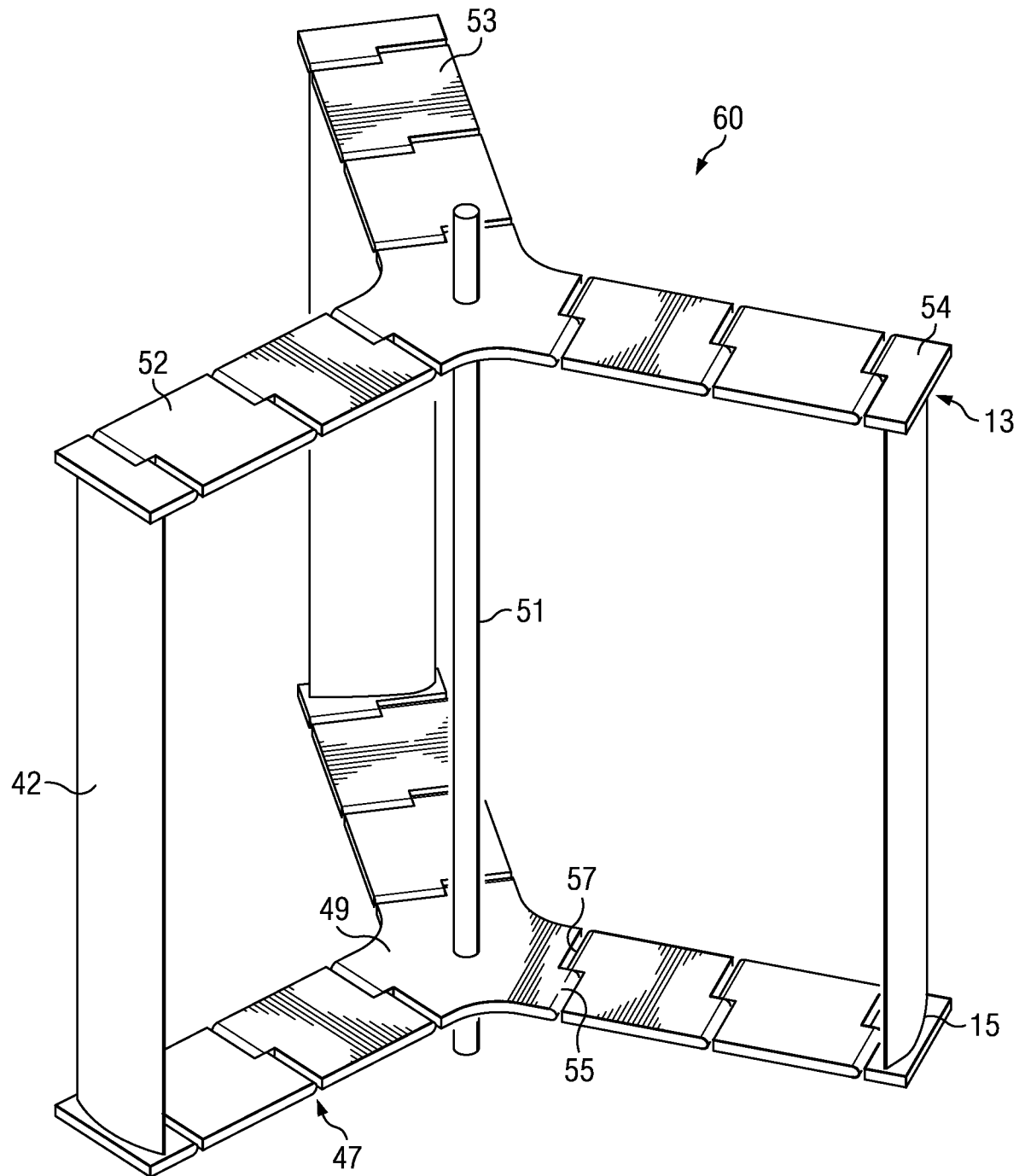
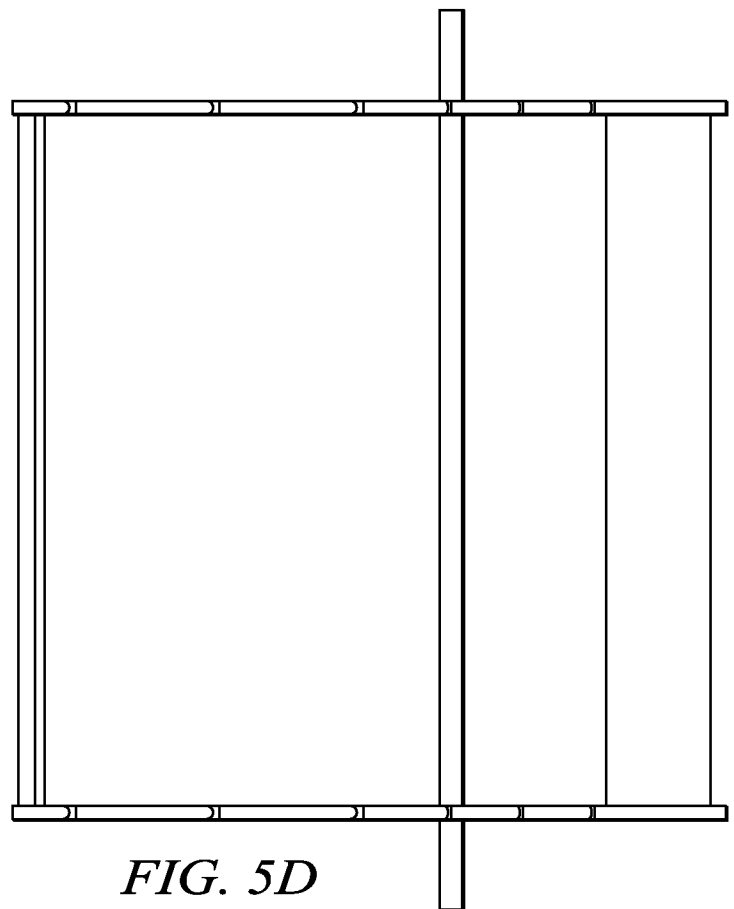
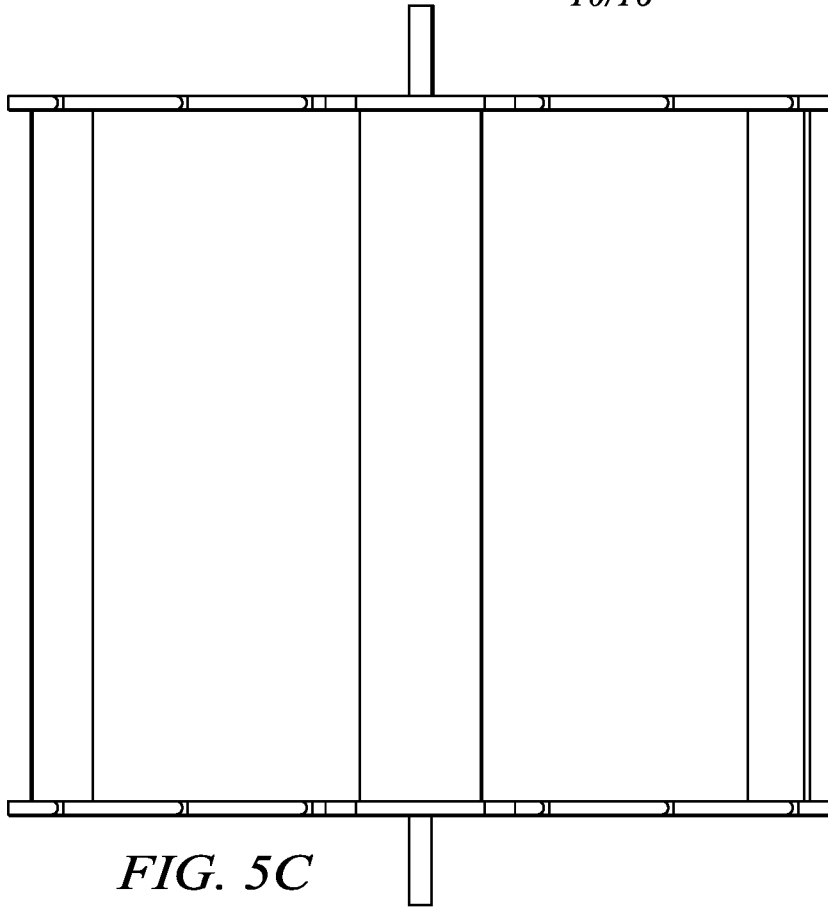


FIG. 5B

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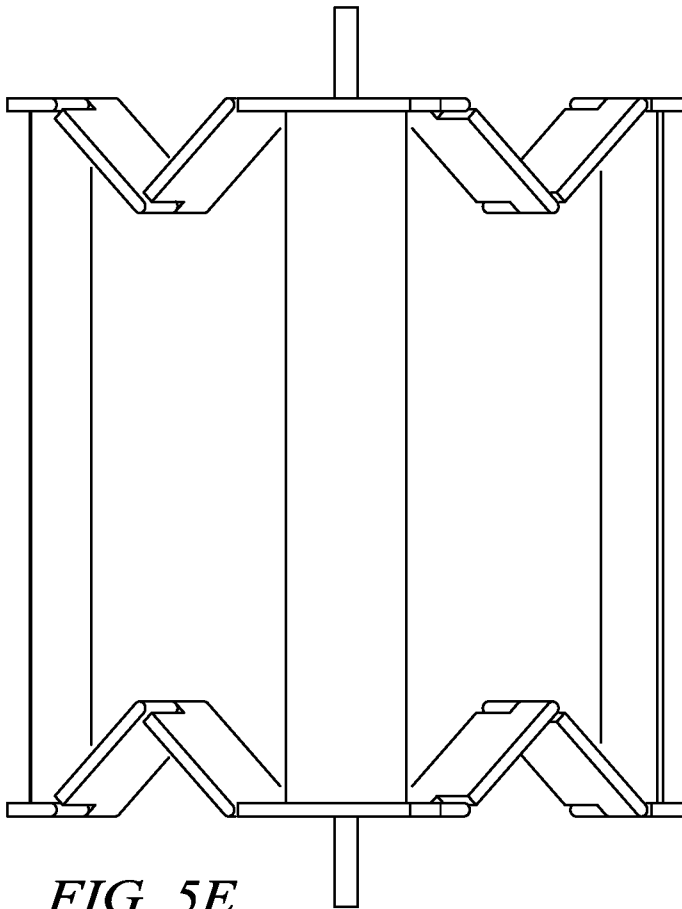


FIG. 5E

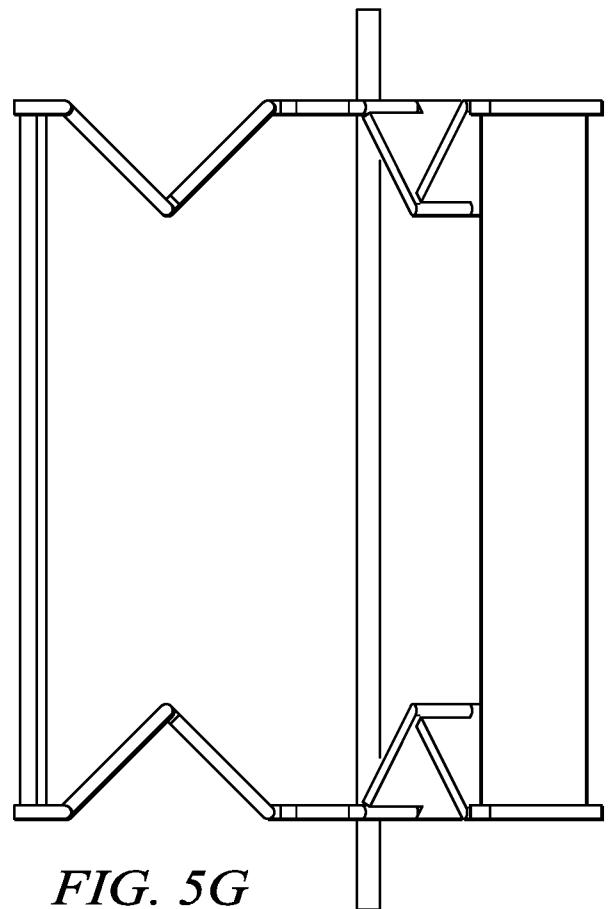


FIG. 5G

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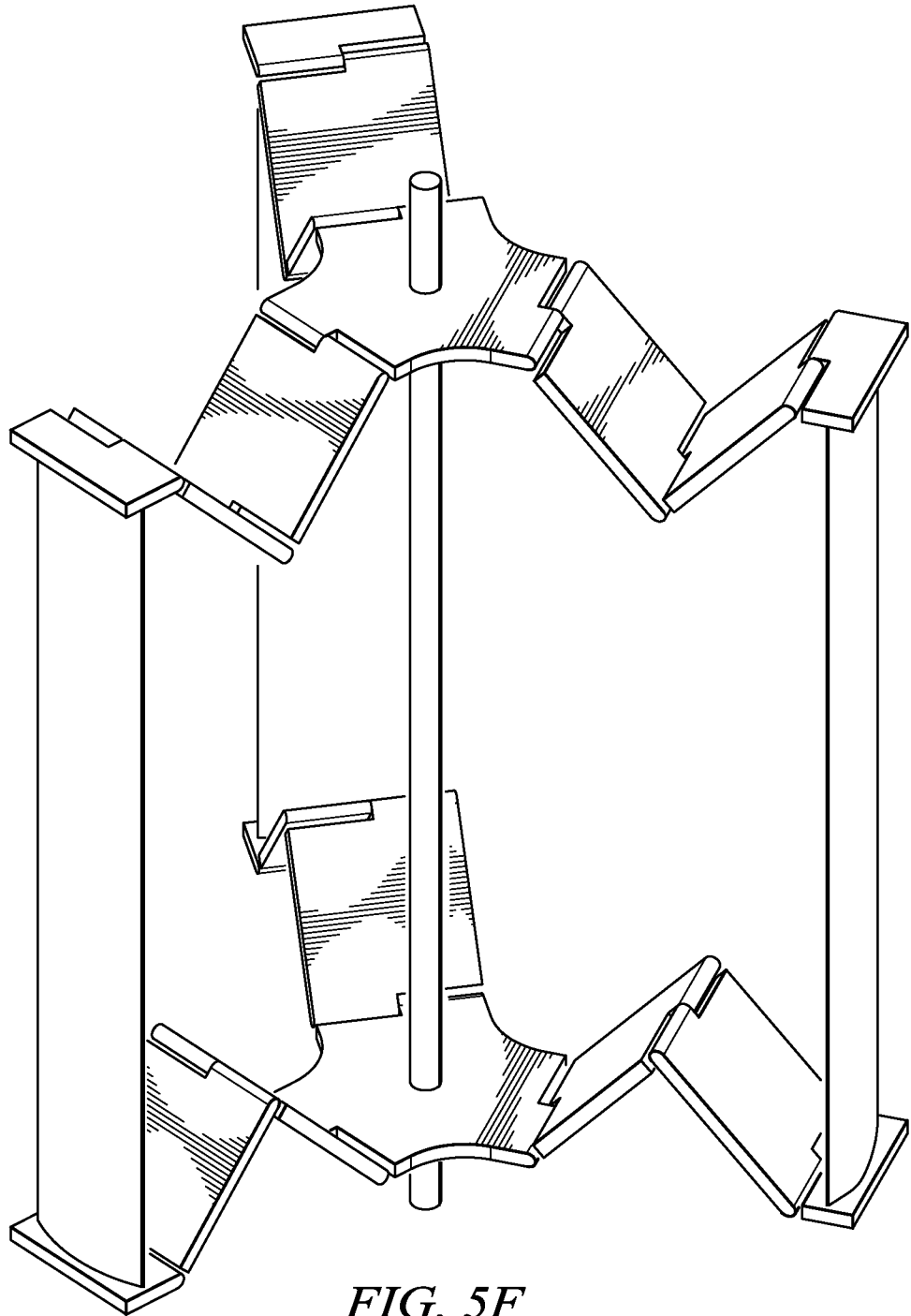


FIG. 5F

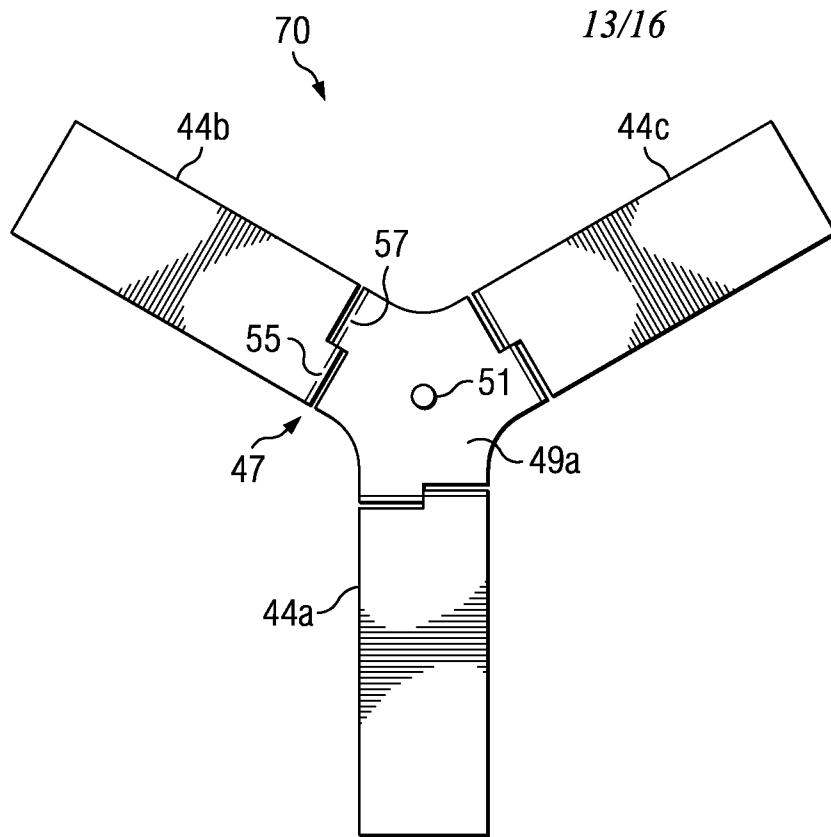


FIG. 6A

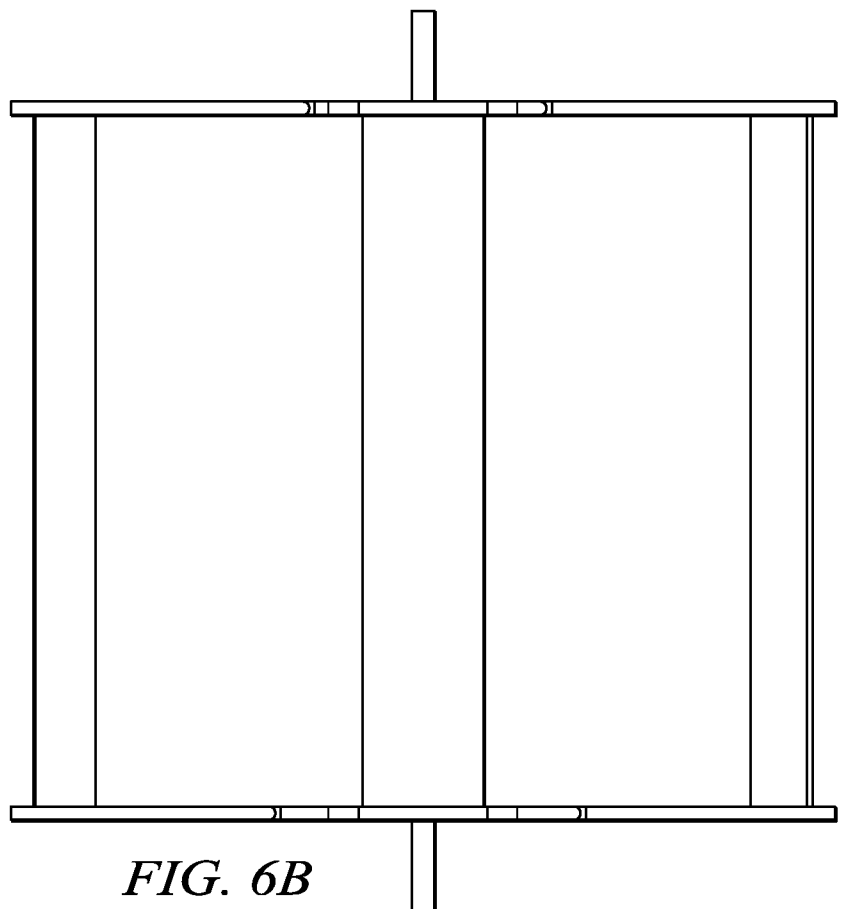


FIG. 6B

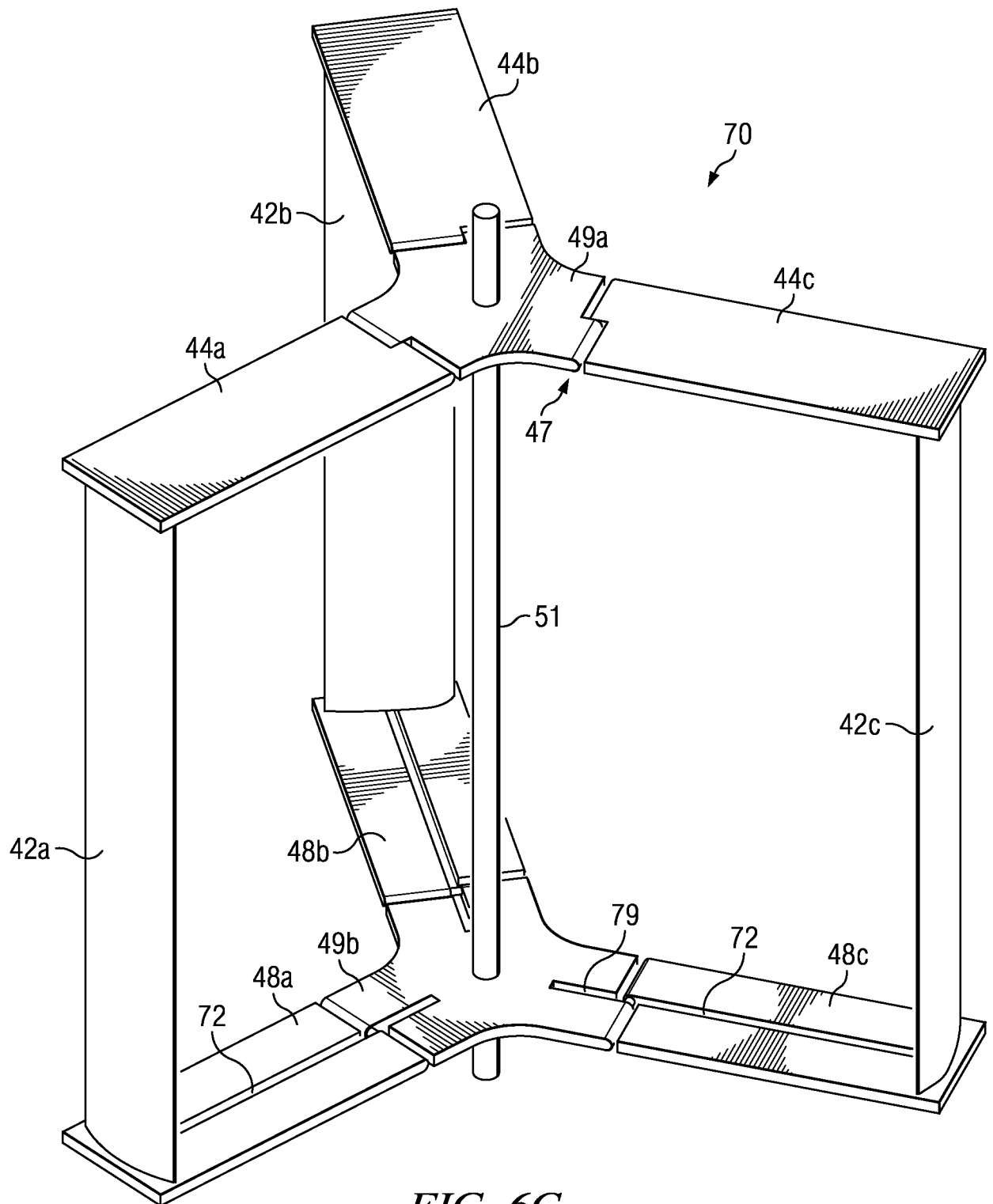


FIG. 6C

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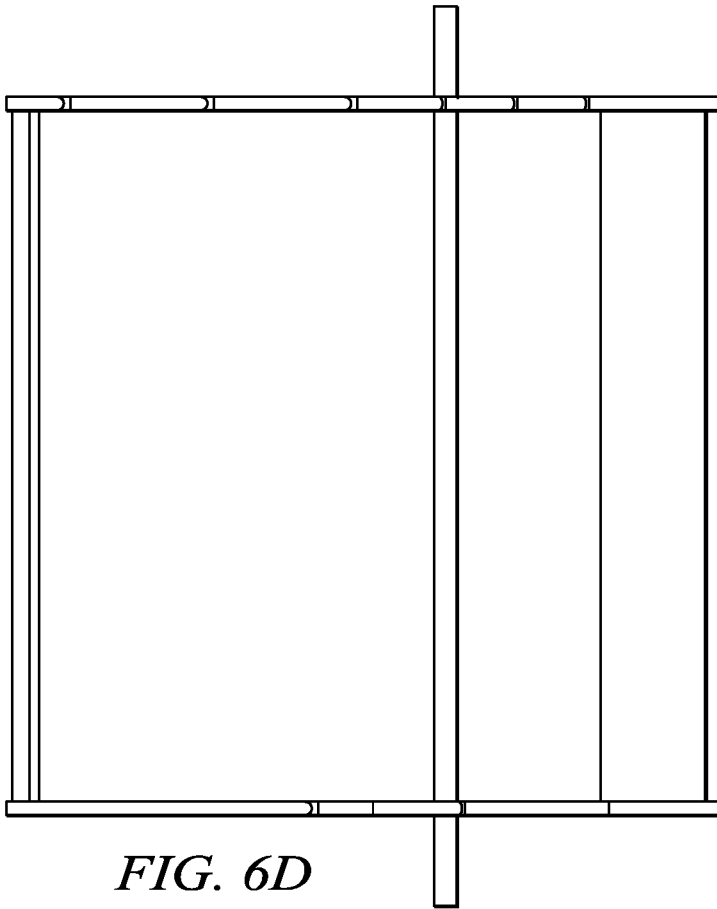


FIG. 6D

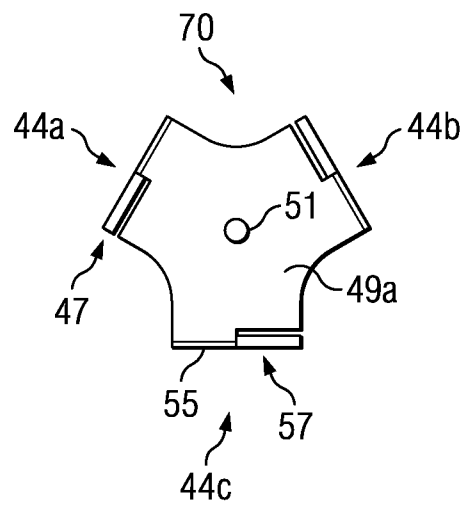


FIG. 6E

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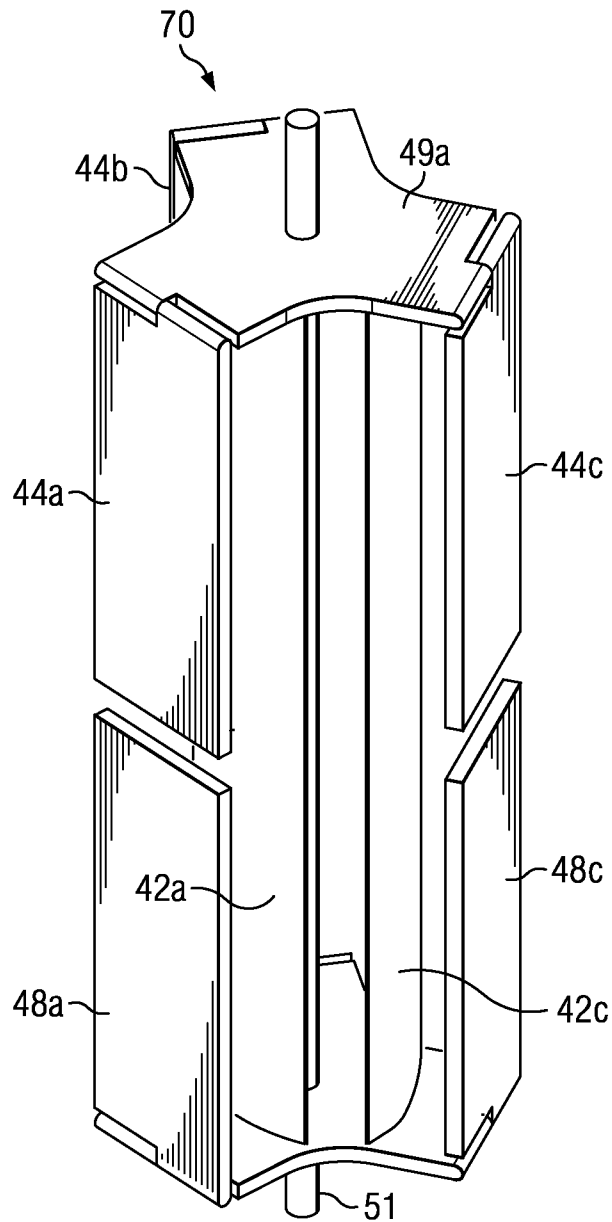


FIG. 6F

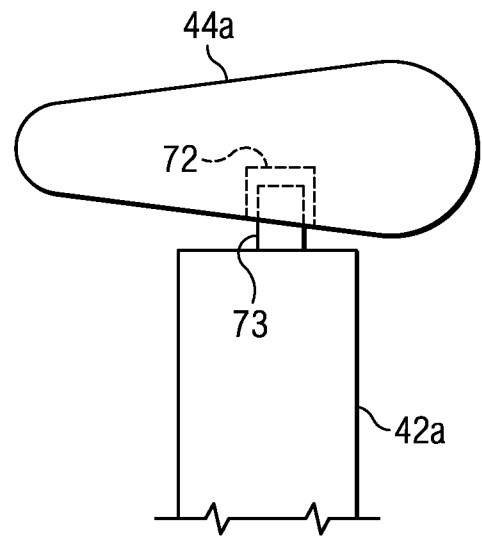


FIG. 7A

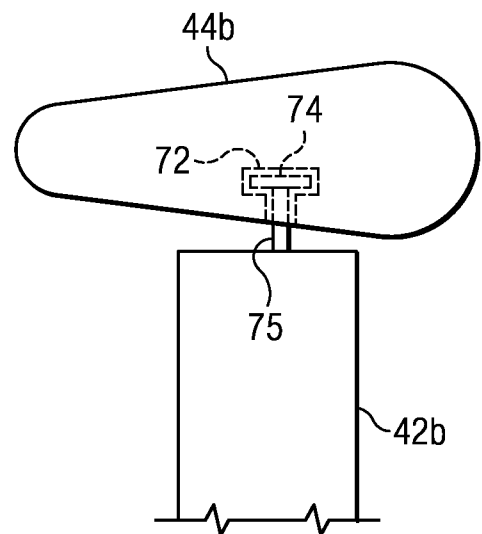


FIG. 7B

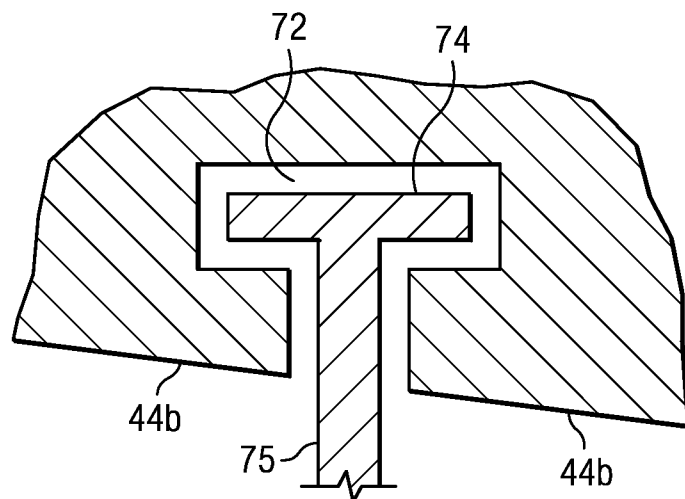


FIG. 7C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2010/038794

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F01D 1/30 (2010.01)

USPC - 415/4.2

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)

IPC(8) - F01D 1/30; F03B 3/04, 15/06; F03D 7/06 (2010.01)

USPC - 290/55; 415/4.2, 7, 53.1; 416/17, 119

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 practicable, search terms used)

PatBase, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7,241,105 B1 (VANDERHYE et al) 10 July 2007 (10.07.2007) entire document	1-2
Y		3-8, 13-16
Y	WO 2008/104060 A1 (VANDER STRAETEN et al) 04 September 2008 (04.09.2008) entire document	3-8, 13-16
A	US 4,452,568 A (ANDERSSON) 05 June 1984 (05.06.1984) entire document	1-17
A	US 7,323,792 B2 (SOHN) 29 January 2008 (29.01.2008) entire document	1-17
A	US 4,764,090 A (DANSON) 16 August 1988 (16.08.1988) entire document	1-17

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

03 August 2010

Date of mailing of the international search report

13 AUG 2010

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