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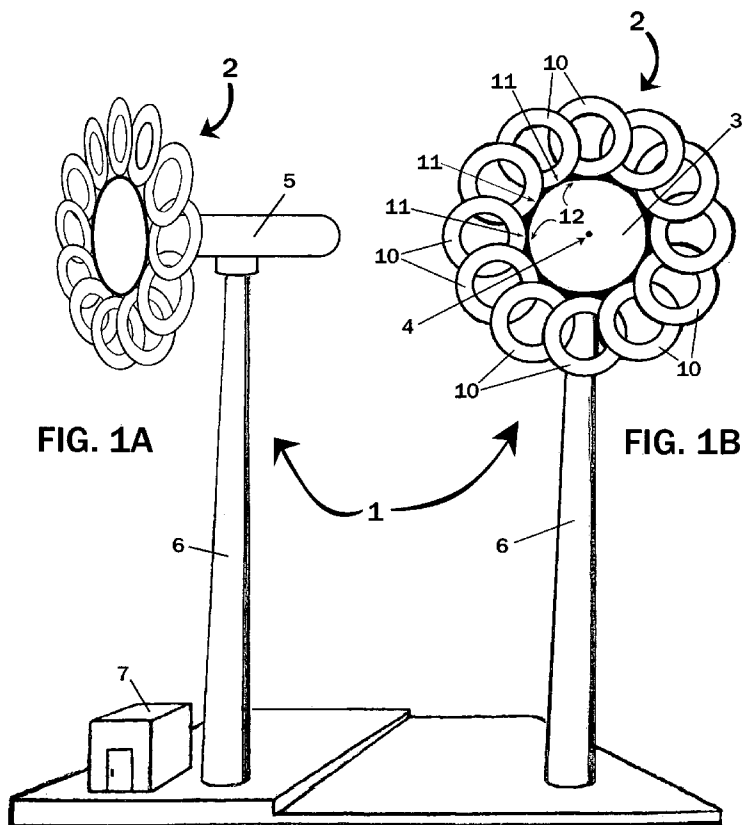
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(54) Title: HORIZONTAL AXIS WIND TURBINE ROTOR ASSEMBLY WITH LIFTING BODY ROTOR BLADES



(57) Abstract: A horizontal axis wind turbine rotor assembly (2) utilizes rotor blades (10) having the aerodynamic characteristics of low aspect ratio lifting bodies. The aerodynamic characteristics of low aspect ratio lifting bodies at typical operating wind velocities permits high energy conversion efficiencies throughout a wide range of wind speeds.

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HORIZONTAL AXIS WIND TURBINE ROTOR ASSEMBLY WITH LIFTING BODY ROTOR BLADES

TECHNICAL FIELD

The present invention relates to a horizontal axis wind turbine rotor assembly with attached rotor blades having the aerodynamic characteristics of a low aspect ratio lifting body rather than a higher aspect ratio wing. Reference is made to provisional patent application number 61/002,087, filed November 5, 2007 by Thomas Stewart Bernatz.

BACKGROUND ART

Wind turbines in the prior art have largely been designed with rotor blades having the aerodynamic characteristics of wings. Wings have been characterized in the prior art according to their aspect ratio. The aspect ratio is discussed in U.S. Pat. No. 6,264,136, issued on July 24, 2001 to Weston. In the prior art, aspect ratios for wings have been defined perhaps somewhat ambiguously as the ratio of the spanwise length of the wing to the mean chordal length of the wing. Aspect ratios for wings are typically greater than 3:1.

Rotor assemblies of wind turbines in the prior art have typically consisted of airfoiled wings with aspect ratios far exceeding 3:1 and approaching 30:1 and even greater. Disadvantages of this type of wind turbine rotor assembly include self-limiting aerodynamic drag characteristics associated with wings, mechanical stress associated with the very long lever arm of the wing blade, high noise level, and high visual impact.

Also in the prior art, there are aerodynamic structures known as low aspect ratio lifting bodies. Low aspect ratio lifting bodies have been distinguished from higher aspect ratio wings in that lifting bodies have an aspect ratio of less than 2:1, whereas wings have aspect ratios greater than 3:1. Additionally, lifting bodies have been distinguished from wings by certain definite advantageous aerodynamic characteristics in certain applications, which include a higher coefficient of lift at high angles of attack, and generally more favorable drag characteristics, discussed in part in U.S. Pat. No. 2,384,893, issued on September 18, 1945 to Crook.

Also in the prior art, there are wind turbines known as horizontal axis type wind turbines. U.S. Pat. No. 6,064,123, issued on May 16, 2000 to Gislason, describes the general features and operation of horizontal axis wind turbines.

DISCLOSURE OF INVENTION

According to the present invention, there is provided a horizontal axis wind turbine rotor assembly whose rotor blades are generally planar in geometry and have the aerodynamic characteristics of low aspect ratio lifting bodies rather than of wings. The central hub of the wind turbine rotor assembly is positioned on an axis of rotation that is generally horizontal and parallel to incident wind streams such that the center point of the central hub is coincident with the axis and such that the central hub may rotate about the axis in a rotational plane perpendicular to the axis. The central hub has a designated upwind side defining the upwind side of the wind turbine rotor assembly which will normally be positioned into incident wind such that the incident wind first contacts the wind turbine rotor assembly on the upwind side.

The lifting body rotor blades are attached at intervals around the perimeter of the central hub. For each lifting body rotor blade, there is a root connection point that is the point at which the lifting body rotor blade is attached to the central hub. The root connection point of the lifting body rotor blade corresponds to, and is attached at, its corresponding attachment point on the central hub. Attachment of the lifting body rotor blade to the central hub is effected such that the manner of attachment minimizes the area of contact between the lifting body rotor blade and the central hub, so as to minimize the extent to which the attachment interrupts or interferes with the shape of the lifting body rotor blade.

For the purpose of explanation, in order to precisely define the planform aspect ratio of a lifting body rotor blade, there is herein defined the term "neutral position." The neutral position is defined as the position of the lifting body rotor blade such that the plane described by the lifting body rotor blade is coplanar with the rotational plane described by the central hub to which the lifting body rotor blade is attached. The operating position of the lifting body rotor blade varies depending on the application and differs from the neutral position.

The axis described by the line between the center point of the central hub and the root connection point of a lifting body rotor blade attached to the central hub in the neutral

position, when extended to the opposite, outermost edge of the lifting body rotor blade, is the root axis of the lifting body rotor blade. The line segment coincident with the root axis of the lifting body rotor blade, extending from the root connection point of the lifting body rotor blade to the outside edge of the lifting body rotor blade, is the span line of the lifting body rotor blade. The length of the span line is the span of the lifting body rotor blade.

A chord line of a lifting body rotor blade is a line intersecting the span line, perpendicular to the span line, and intersecting and terminating at the two opposing outermost edges of the lifting body rotor blade. The length of a chord line is the dimension along the chord line between the opposing outermost edges. The chordal width of a lifting body rotor blade is the length of the longest chord of the lifting body rotor blade thus defined.

Because there is some ambiguity in the prior art regarding the meaning and definition of the aspect ratio, and because the term has been defined somewhat differently in its application to wings and to lifting bodies, there is herein defined the term "planform aspect ratio" for lifting body rotor blades of the present disclosure including those rotor blades that are a hybrid of lifting bodies and wings. The planform aspect ratio of a lifting body rotor blade is the ratio of the span of the lifting body rotor blade to the greatest chordal width of the lifting body rotor blade. The planform aspect ratio for lifting body rotor blades is thus distinguished from the aspect ratio for wings, which is generally understood to be the ratio of the spanwise length of the wing to the mean chordal length of the wing. For purposes of this invention rotor blades of a hybrid nature of lifting bodies and wings having a planform aspect ratio between 3:1 and 2:1, are considered a subset type of lifting body rotor blade.

According to the present invention, lifting body rotor blades attached to the central hub of a wind turbine rotor assembly shall have a planform aspect ratio less than 2:1.

Also according to the present invention, hybrid lifting body rotor blades may be utilized which have a planform aspect ratio of less than 3:1 and greater than 2:1.

Each lifting body rotor blade attached to a central hub is oriented so that during operation it is angled away from the planar face of the upwind side of the central hub, and thus angled away from the neutral position. The angle established by rotating the lifting body rotor blade about its root axis is the angle of incidence of the rotor blade relative to the rotational plane described by the central hub. The angle of incidence of the lifting body rotor blade relative to the rotational plane described by the central hub defines the angle of attack of the lifting body rotor blade relative to an incident wind stream.

Each lifting body rotor blade is geometrically substantially planar in form with two opposite-facing surfaces with one surface being an upwind surface and the other surface being a downwind surface. Each surface may independently be flat or curved with constant or varying curvature with the overall surface and sections of the surface having the general characteristics of airfoils similar in airfoil profile to modern aircraft wing airfoil profiles. The optimum design(s) of lifting body rotor blades and hybrid lifting body rotor blades is to be determined. It is believed that optimum design features may include ring-shaped forms, or more generally, lifting body rotor blades and hybrid lifting body rotor blades may include apertures. Different sizes and shapes of lifting body rotor blades may be utilized within the same horizontal axis wind turbine rotor assembly. Lifting body rotor blades may have differing sizes and shapes of apertures even within the same horizontal axis wind turbine rotor assembly.

A preferred embodiment of a lifting body rotor assembly has been constructed, this prototype utilizing twelve ring-shaped overlapping lifting body rotor blades. Alternate embodiments of rotor assemblies may have differing numbers and combinations of lifting body rotor blades and hybrid lifting body rotor blades. Alternate embodiments of rotor assemblies may have blades which do not overlap.

It is believed that wind turbines employing this invention will achieve higher energy conversion efficiencies than existing wind turbine designs employing wing-type rotor blades due in part to advantageous lift-to-drag characteristics of lifting bodies depending on their particular shape and the velocity of incident wind. It is believed that anticipated higher energy conversion efficiencies will be due in part to reduced tip vortices.

It is anticipated that particular combinations of features of central hub and lifting body rotor blade design including the size of lifting body rotor blades, the relative size of lifting body rotor blades with respect to the central hub, the relative size and shape of apertures with respect to lifting body rotor blade geometry, the lifting body rotor blade count, the orientation of lifting body rotor blades, and the particular surface geometry of central hubs and lifting body rotor blades will exhibit particular advantages.

Preferred embodiments of the present invention present a large reactive surface area to incident wind compared to rotor assemblies of comparable swept area employing wing-type rotor blades. It is anticipated that this factor will contribute further advantages to wind turbines employing lifting body rotor assemblies. It is also anticipated that the present

invention will exhibit increased structural reliability due to use of relatively smaller rotor blades and larger hubs.

Low aspect ratio lifting bodies can exhibit advantageous lift-to-drag characteristics at high relative wind velocities and high angles of attack compared to higher aspect ratio wings. It is anticipated that wind turbine rotor assemblies employing lifting body rotor blades rather than wing-type rotor blades will allow the possibility of faster rotation at comparable wind speeds, thus potentially generating more power over a wider range of wind speeds.

While wind speeds generally increase at greater heights, improved performance of lifting body rotor blades may reduce the necessary height at which a wind turbine employing the current invention must be elevated for efficient operation. Owing to the reduced diameter of the lifting body rotor assembly, and the possibly reduced requirements for tower height, this invention may permit the use of wind turbines in areas where it is important to minimize the visual impact created by a wind turbine. For similar reasons, this invention permits installation of a greater number of wind turbines on a given land mass.

It is believed that this invention can be used in both upwind and downwind applications.

It has been observed and it is anticipated that wind turbines employing the current invention will operate more quietly than wind turbines employing wing-type rotor assemblies.

BRIEF DESCRIPTION OF DRAWINGS

The invention may take physical form in certain parts and arrangement of parts, preferred embodiments and alternate embodiments of the invention which are described in detail in the specification and illustrated in the accompanying drawings which form a part hereof, and wherein:

FIGS. 1A and 1B are perspective and elevation views of a utility-scale wind turbine employing a rotor assembly with twelve overlapping lifting body rotor blades;

FIG. 2 is an exploded perspective view of a rotor assembly with two blades depicting a method for attaching the rotor assembly to an energy conversion device;

FIG. 3 is a perspective view of a hub section with two attached lifting body rotor blades depicting the root connection attachments of the two lifting body rotor blades;

FIGS. 4A-4F and 5A-5F are planform views of variously shaped lifting body rotor blades, some with and some without apertures, some having concentric apertures and others having non-concentric apertures, and some with apertures of different geometric shape than that of the outer perimeter of the lifting body rotor blade;

FIG. 6A is a cross section view of a solid lifting body rotor blade;

FIG. 6B is a cross section view of a lifting body rotor blade with an aperture;

FIGS. 6C-6F are views of possible alternate airfoil profiles exhibiting various curvatures of upwind and downwind surfaces applicable to solid lifting body rotor blades, lifting body rotor blades with apertures, and sections of lifting body rotor blades with apertures;

FIG. 7A is a perspective cutaway view of a ring-shaped lifting body rotor blade;

FIG. 7B is a side view of the ring-shaped lifting body rotor blade;

FIG. 7C is a sectional side view of the ring-shaped lifting body rotor blade;

FIGS. 8A-8F are planform views of alternate embodiments of rotor assemblies exhibiting differing ratios of central hub size to lifting body rotor blade size, differing numbers of lifting body rotor blades, and wherein blades overlap adjacent blades to differing extents;

FIGS. 9A-9B are perspective views looking at the downwind and upwind sides of a preferred embodiment of a wind turbine rotor assembly with lifting body rotor blades illustrating geometric and dimensional relationships among the components;

FIG. 10A is a diagrammatic planform view of a lifting body exhibiting a 1:1 planform aspect ratio;

FIG. 10B is a diagrammatic planform view of a hybrid lifting body exhibiting a 2:1 planform aspect ratio;

FIG. 10C is a diagrammatic planform view of a wing exhibiting a 3:1 planform aspect ratio characteristic of the minimum wing aspect ratio; and,

FIG. 11 is a planform view of a preferred embodiment of a wind turbine rotor assembly with six non-overlapping lifting body rotor blades.

MODES FOR CARRYING OUT THE INVENTION

Referring now more specifically to the drawings, wherein the showings are for the purpose of illustrating the preferred embodiments of the invention only and not for purposes of limiting the same, there is shown in FIGS. 1A and 1B a preferred embodiment of a horizontal axis wind turbine 1. The horizontal axis wind turbine rotor assembly 2 has a central hub 3, rotatable about center point 4, attached to an energy conversion device 5, which may be an electrical generator. The energy conversion device 5 is elevated on tower 6 in such a manner as to allow the energy conversion device 5 to pivot into an oncoming wind stream and thereby orient the upwind side of the rotor assembly 2 into contact with the oncoming wind stream, consequently allowing the rotor assembly 2 to rotate about its axis of rotation in response to the incident wind. The height of tower 6 is variable according to local considerations including prevailing wind conditions and visual impact. The utility shed 7 is depicted to demonstrate possible relative scale of a preferred embodiment of the invention.

FIG. 2 shows an exploded view of a preferred method of attachment of a preferred embodiment of a wind turbine rotor assembly 2 to an energy conversion device 5, wherein the rotatable central hub 3 attaches at center point 4 of the downwind side of rotatable central hub 3 to mounting flange 8 of drive shaft 9 of energy conversion device 5.

FIG. 3 shows a preferred embodiment of a means for attaching lifting body rotor blades 10 to a section of a rotatable central hub 3 wherein mounting straps are affixed to the rotatable central hub 3, thereby defining and constituting attachment points at the perimeter 12 of the hub 3, to which attachment points are attached lifting body rotor blades 10 such that the root connection points 11 of blades 10 correspond with the attachment points.

Lifting body rotor blades 10 utilized in a single embodiment of a wind turbine rotor assembly 2 may be of consistent shapes and sizes. Alternate embodiments of a wind turbine rotor assembly 2 may have lifting body rotor blades 10 of varying shapes and sizes, yet still possessing the characteristics of lifting body rotor blades. Possible alternate shapes of lifting body rotor blades 10 are depicted in FIGS. 4A-4F and 5A-5F. Alternate embodiments of lifting body rotor blades 10 may include apertures of different geometric shape than that of the outer perimeter of the lifting body rotor blade. Apertures may vary in size and location relative to the blades in which they are included.

Alternate embodiments utilizing lifting body rotor blades 10 having planform aspect ratio of up to 2:1 may, as well, utilize hybrid lifting body rotor blades 10 having planform aspect ratio between 3:1 and 2:1.

Possible alternate curvatures of upwind surfaces **13** and downwind surfaces **14** of lifting body rotor blades **10** are depicted in FIGS. 6A-6F. FIG. 6A shows the airfoil profile of a central cross section of a lifting body rotor blade **10** lacking an aperture. FIG. 6B shows the airfoil profile of a central cross section of a lifting body rotor blade **10** that includes an aperture. The cross section shown in FIG. 6B depicts the airfoil profile of the entire lifting body rotor blade **10** defined by surfaces **13** and **14** and reveals the independent airfoil profiles of opposing sections of the rotor blade defined by the outermost portions of surfaces **13** and **14** and the innermost portions of surfaces **13** and **14** converging at the aperture. FIGS. 6C-6F depict possible alternate airfoil profiles of entire lifting body rotor blades. The airfoil profiles of FIGS. 6C-6F may alternately define the shapes of sections of lifting body rotor blades with apertures.

FIG. 7A depicts a preferred embodiment of a lifting body rotor blade **10**, which is ring-shaped with a flattish upwind surface **13**, and a curved downwind surface **14**. FIG. 7B is an elevation view of the lifting body rotor blade **10** of FIG. 7A. FIG. 7C is a cross sectional view of the lifting body rotor blade **10** of FIG. 7A showing the airfoil profiles of opposing sections of the lifting body rotor blade **10**.

The number of lifting body rotor blades **10** attached around the perimeter of a rotatable central hub **3** may vary, as shown in FIGS. 8A-8F. It is anticipated that experimentation will demonstrate the optimum shapes of rotor blades **10**, the optimum sizes of rotor blades **10** relative to a rotatable central hub **3**, the optimum number of lifting body rotor blades **10** attached around the perimeter of a rotatable central hub **3**, and the optimum intervals between attachment points around the perimeter of a central hub **3**.

FIGS. 9A and 9B show perspective views of the downwind and upwind sides of a preferred embodiment of a rotor assembly **2** with lifting body rotor blades **10**, wherein the rotor blades are shown in their operating positions with equal angles of incidence, and wherein the lifting body rotor blades **10** are uniform in shape and size and include apertures. FIG. 9A shows a view from the downwind side of rotor assembly **2** wherein are depicted the center point **4** of rotatable central hub **3**, the curved downwind surfaces **14** of lifting body rotor blades **10**, the plane **17** of one individual lifting body rotor blade **10**, and the rotational plane **18** of the rotor assembly **2**. FIG. 9B shows a view from the upwind side of rotor assembly **2** wherein are depicted the center point **4** of rotatable central hub **3**, the flattish upwind surfaces **13** of lifting body rotor blades **10**, the plane **17** of one individual lifting body

rotor blade **10**, and the rotational plane **18** of the rotor assembly **2**. FIG. 9B shows the individual lifting body rotor blade **10**, attached at its root connection point **11** to the rotatable central hub **3**. A segment of the root axis **15** of the individual lifting body rotor blade **10** extends from the blade's attachment point on the perimeter of central hub **3** past the outermost edge of the rotor blade **10**. The plane **17** of the individual lifting body rotor blade **10** intersects the rotational plane **18** of the central hub **3** along the root axis **15**. In the depicted embodiment the angle of incidence **16** of the plane **17** of the individual lifting body rotor blade, relative to the rotational plane **18** of the rotor assembly **2**, is established by rotating the rotor blade **10** about its root axis **15**. This angle of incidence **16** is variable and may also be adjustable. It is anticipated that experimentation will demonstrate optimum angle(s) of incidence **16** and optimum adjustment ranges.

Referring to FIG. 10A, the planform view of a lifting body rotor blade **10** has a circular shape with a planform aspect ratio of approximately 1:1. Shown in FIG. 10B, a lifting body rotor blade **10** has an elongated shape with a planform aspect ratio of approximately 2:1. Shown in FIG. 10C, a rotor blade **10** has a further elongated shape with a planform aspect ratio of approximately 3:1, and consequently may correspond with the smallest aspect ratio wing or with the largest aspect ratio hybrid lifting body depending on the actual size of the physical embodiment constructed according to the shape.

Referring to FIG. 11, there is shown an embodiment of a horizontal axis wind turbine rotor blade assembly **2** with non-overlapping lifting body rotor blades **10** attached at their root connection points **11** to rotatable central hub **3**. FIG. 11 shows the root axis **15** of one individual lifting body rotor blade **10**, extending from center point **4** of rotatable central hub **3**, through root connection point **11** of the lifting body rotor blade **10**, to the outermost edge of the lifting body rotor blade **10**. The segment of root axis **15**, from root connection point **11** of the lifting body rotor blade to the outermost edge of the lifting body rotor blade, defines the span line of the lifting body rotor blade.

What is claimed is:

1. A horizontal axis wind turbine lifting body rotor assembly comprising:
a hub mounted so as to permit said hub to rotate about its center when positioned within an incident wind stream and mounted in such a manner as to permit the rotational mechanical energy thus produced to transfer to a device for purposes of energy conversion;
a plurality of lifting body rotor blades attached to said hub at intervals around the perimeter of said hub wherein the point of attachment for each lifting body rotor blade forms a root connection for that lifting body rotor blade, each said lifting body rotor blade having a planform aspect ratio of less than 2:1, and wherein the configuration of lifting body rotor blades mounted on the hub is such that each individual lifting body rotor blade is positioned at an angle of incidence relative to the upwind-facing surface of the hub, wherein said angle of incidence may be adjustable, and wherein said angle of incidence may vary among the diverse lifting body rotor blades connected to said hub, and wherein the opposite-facing surfaces of each of the lifting body rotor blades may be contoured differently from one another, and wherein the lifting body rotor blades may contain apertures of various dimension and positioning.
2. The wind turbine lifting body rotor assembly of Claim 1 wherein the lifting body rotor blades are of uniform shape and geometry relative to the other lifting body rotor blades.
3. The wind turbine lifting body rotor assembly of Claim 1 wherein the lifting body rotor blades are of non-uniform shape and geometry relative to the other lifting body rotor blades.
4. A horizontal axis wind turbine lifting body rotor assembly comprising:
a hub mounted so as to permit said hub to rotate about its center when positioned within an incident wind stream and mounted in such a manner as to permit the rotational mechanical energy thus produced to transfer to a device for purposes of energy conversion;

a plurality of lifting body rotor blades attached to said hub at intervals around the perimeter of said hub wherein the point of attachment for each lifting body rotor blade forms a root connection for that lifting body rotor blade, each said lifting body rotor blade having a planform aspect ratio of less than 2:1, and wherein the configuration of lifting body rotor blades mounted on the hub is such that each individual lifting body rotor blade is positioned at an angle of incidence relative to the upwind-facing surface of the hub, wherein said angle of incidence may be adjustable, and wherein said angle of incidence may vary among the diverse lifting body rotor blades connected to said hub, and wherein the opposite-facing surfaces of each of the lifting body rotor blades may be contoured differently from one another, and wherein the lifting body rotor blades have solid geometric shape without apertures.

5. The wind turbine lifting body rotor assembly of Claim 4 wherein the lifting body rotor blades are of uniform shape and geometry relative to the other lifting body rotor blades.

6. The wind turbine lifting body rotor assembly of Claim 4 wherein the lifting body rotor blades are of non-uniform shape and geometry relative to the other lifting body rotor blades.

7. A horizontal axis wind turbine lifting body rotor assembly comprising:
a hub mounted so as to permit said hub to rotate about its center when positioned within an incident wind stream and mounted in such a manner as to permit the rotational mechanical energy thus produced to transfer to a device for purposes of energy conversion;

a plurality of lifting body rotor blades attached to said hub at intervals around the perimeter of said hub wherein the point of attachment for each lifting body rotor blade forms a root connection for that lifting body rotor blade, each said lifting body rotor blade having a planform aspect ratio of less than 3:1, and wherein the configuration of lifting body rotor blades mounted on the hub is such that each individual lifting body rotor blade is positioned at an angle of incidence relative to the upwind-facing surface of the hub, wherein said angle

of incidence may be adjustable, and wherein said angle of incidence may vary among the diverse lifting body rotor blades connected to said hub, and wherein the opposite-facing surfaces of each of the lifting body rotor blades may be contoured differently from one another, and wherein the lifting body rotor blades may contain apertures of various dimension and positioning.

8. The wind turbine lifting body rotor assembly of Claim 7 wherein the lifting body rotor blades are of uniform shape and geometry relative to the other lifting body rotor blades.

9. The wind turbine lifting body rotor assembly of Claim 7 wherein the lifting body rotor blades are of non-uniform shape and geometry relative to the other lifting body rotor blades.

10. A horizontal axis wind turbine lifting body rotor assembly comprising:
a hub mounted so as to permit said hub to rotate about its center when positioned within an incident wind stream and mounted in such a manner as to permit the rotational mechanical energy thus produced to transfer to a device for purposes of energy conversion;
a plurality of lifting body rotor blades attached to said hub at intervals around the perimeter of said hub wherein the center point of attachment for each lifting body rotor blade forms a root connection for that lifting body rotor blade, each said lifting body rotor blade having a planform aspect ratio of less than 3:1, and wherein the configuration of lifting body rotor blades mounted on the hub is such that each individual lifting body rotor blade is positioned at an angle of incidence relative to the upwind-facing surface of the hub, wherein said angle of incidence may be adjustable, and wherein said angle of incidence may vary among the diverse lifting body rotor blades connected to said hub, and wherein the opposite-facing surfaces of each of the lifting body rotor blades may be contoured differently from one another, and wherein the lifting body rotor blades have solid geometric shape without apertures.

11. The wind turbine lifting body rotor assembly of Claim 10 wherein the lifting body rotor blades are of uniform shape and geometry relative to the other lifting body rotor blades.

12. The wind turbine lifting body rotor assembly of Claim 10 wherein the lifting body rotor blades are of non-uniform shape and geometry relative to the other lifting body rotor blades.

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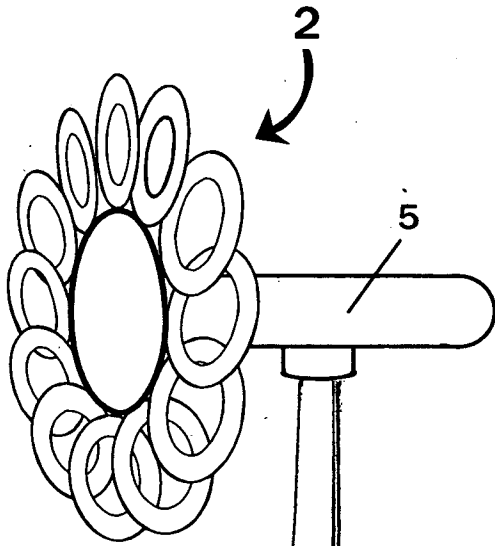


FIG. 1A

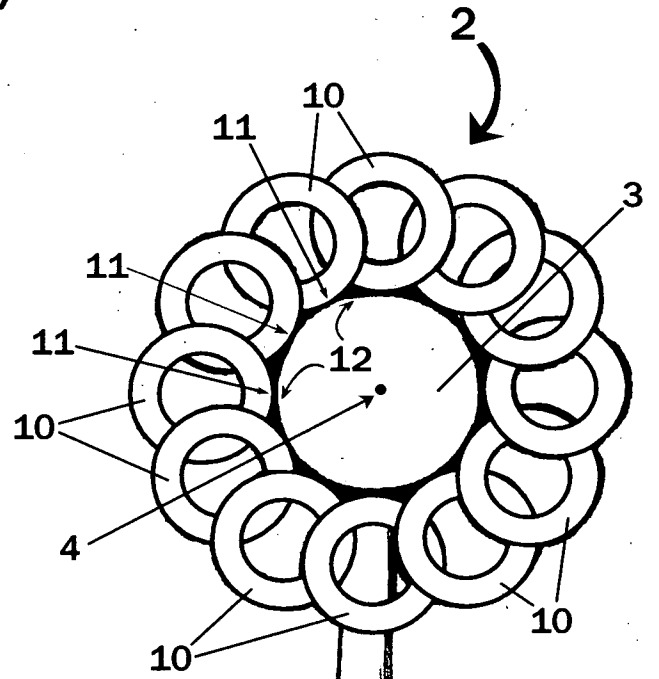
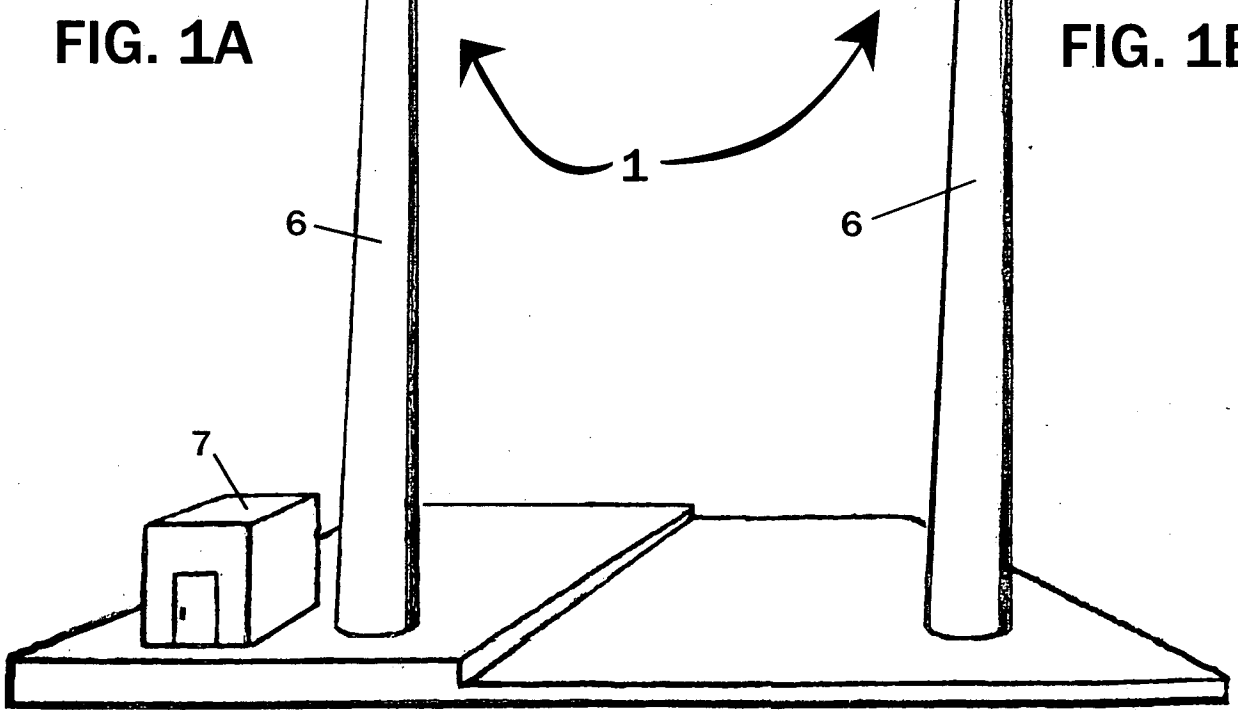
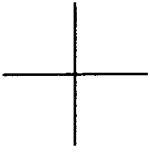


FIG. 1B





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FIG. 2

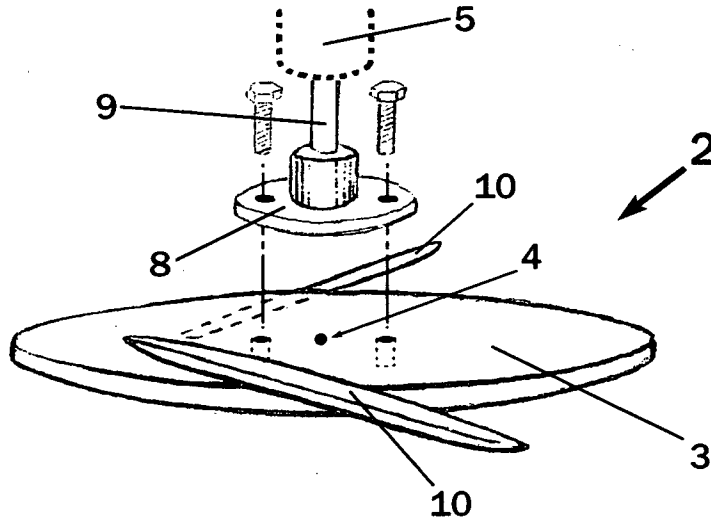
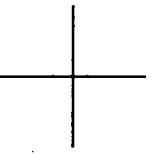
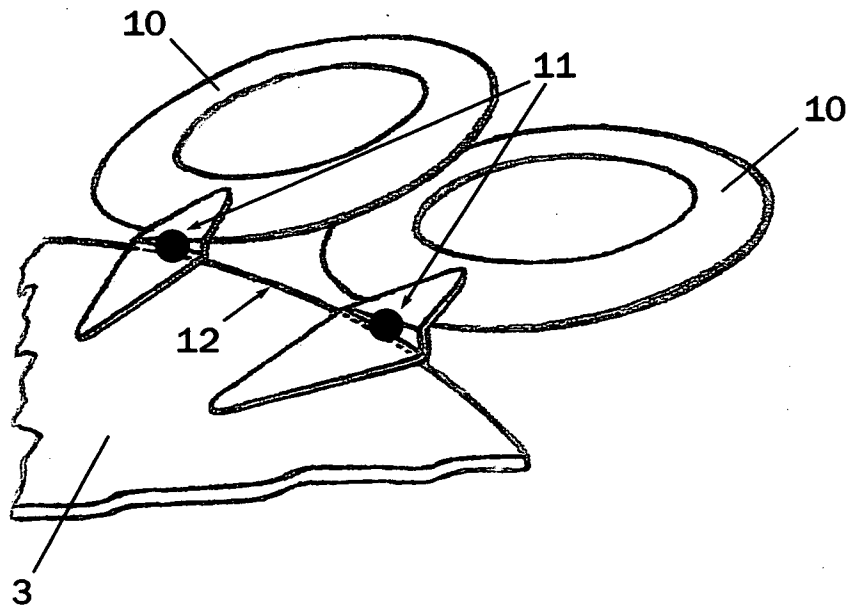


FIG. 3



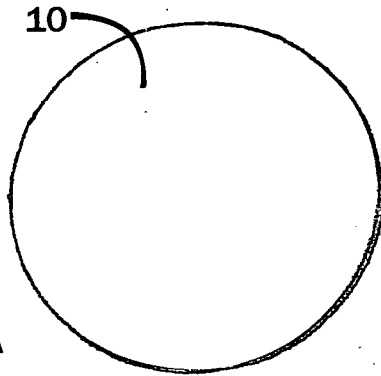
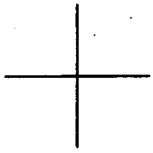


FIG. 4A

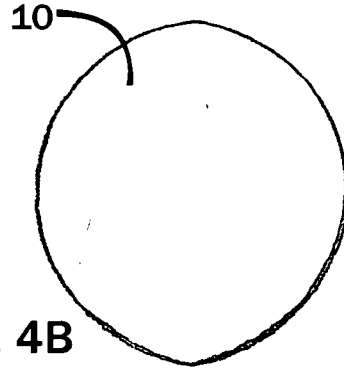


FIG. 4B

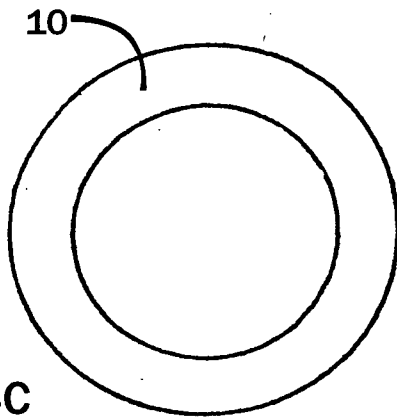


FIG. 4C

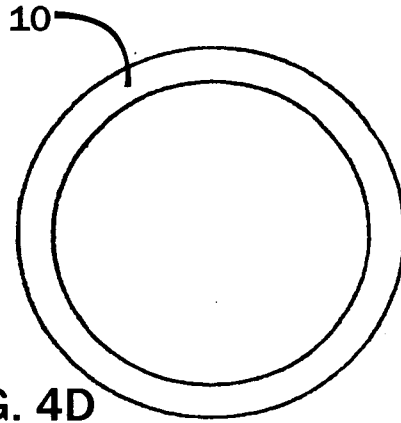


FIG. 4D

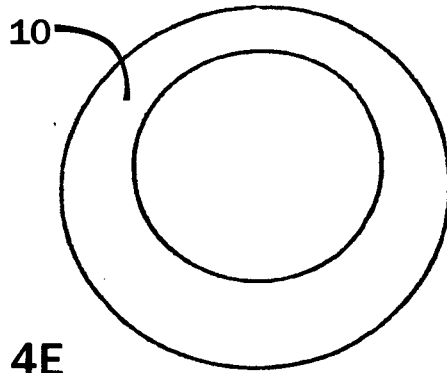


FIG. 4E

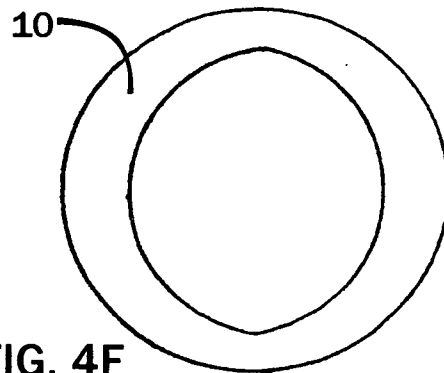
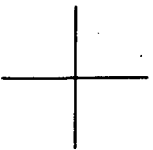


FIG. 4F



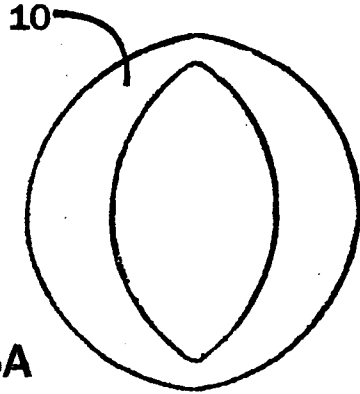
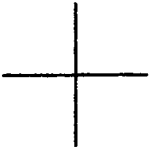


FIG. 5A

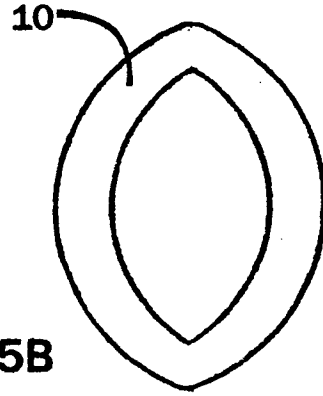


FIG. 5B

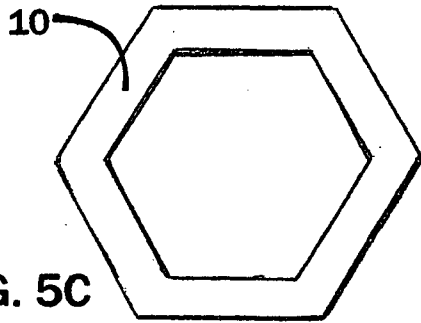


FIG. 5C

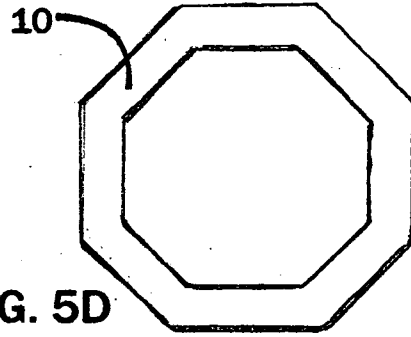


FIG. 5D

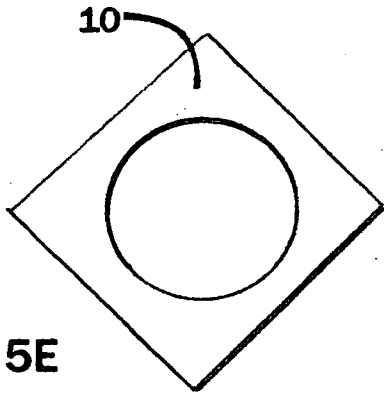


FIG. 5E

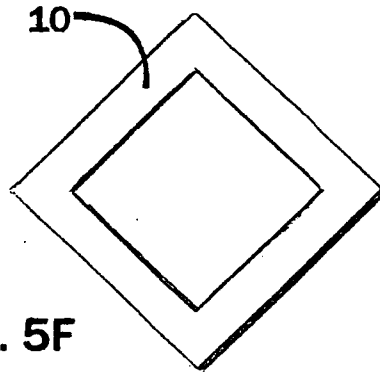
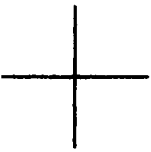
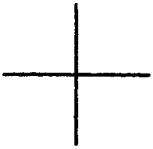
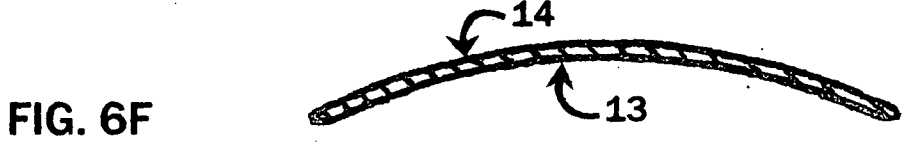
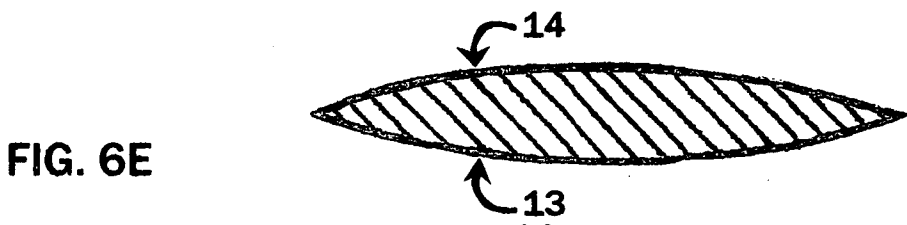
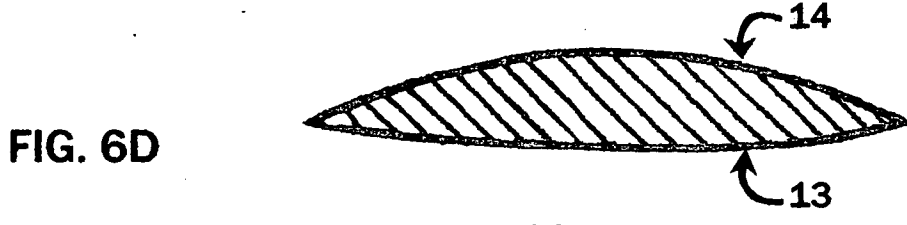
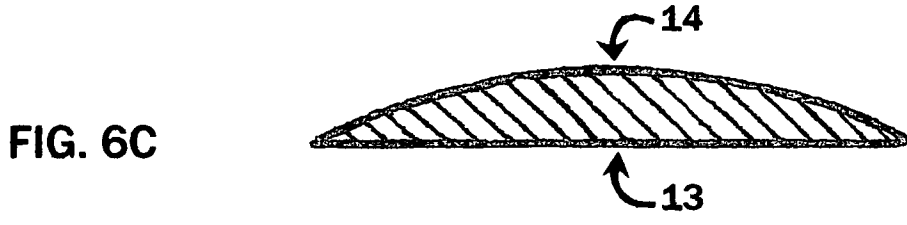
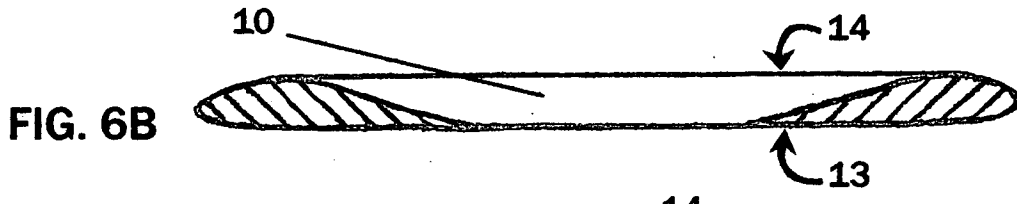
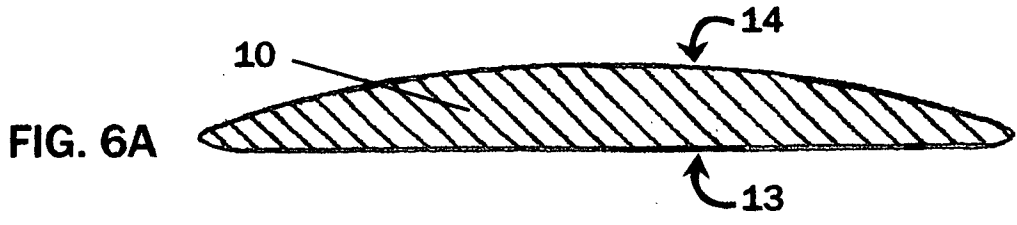
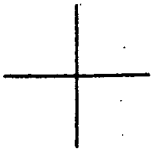
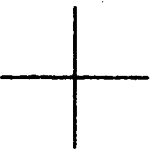
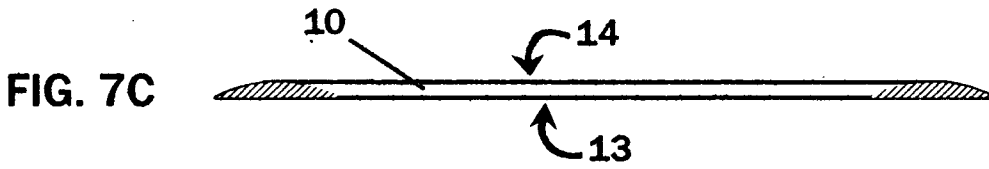
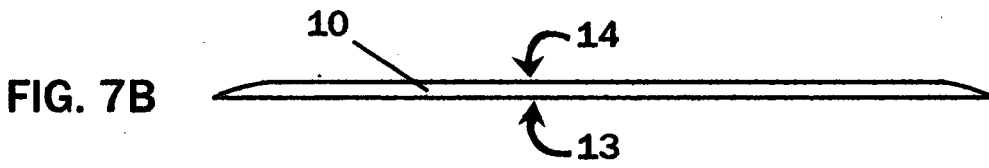
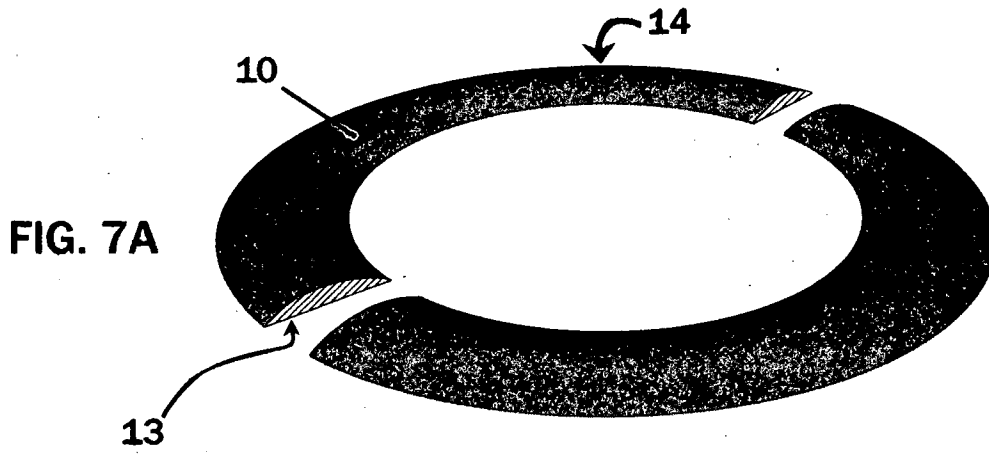
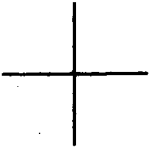


FIG. 5F







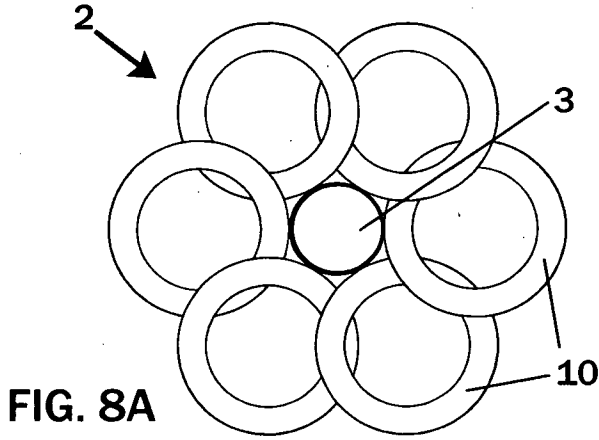
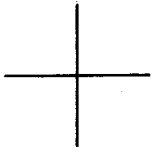


FIG. 8A

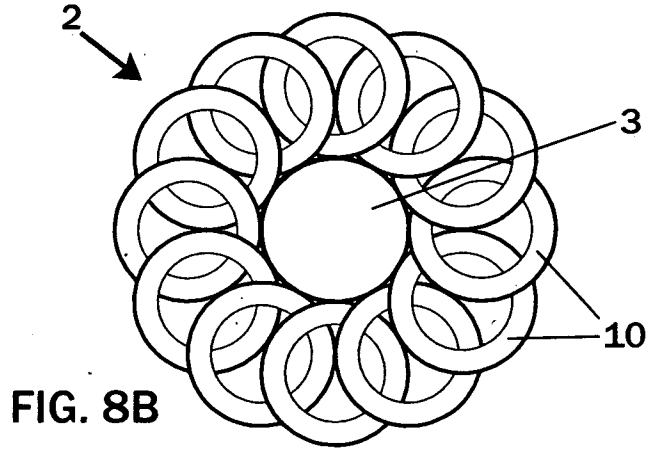


FIG. 8B

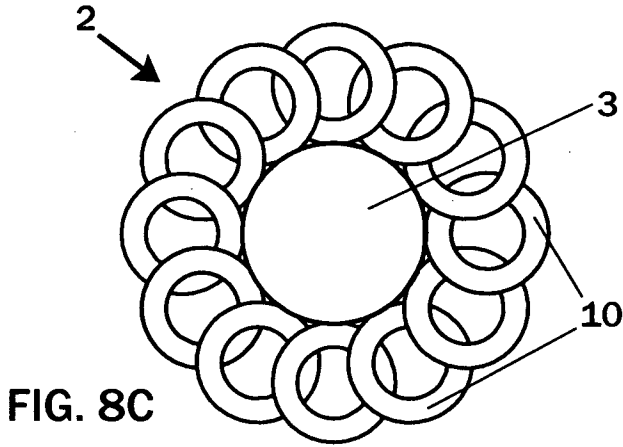


FIG. 8C

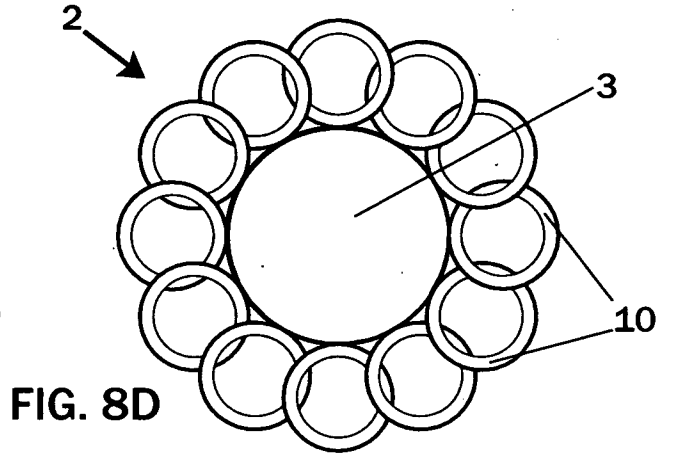


FIG. 8D

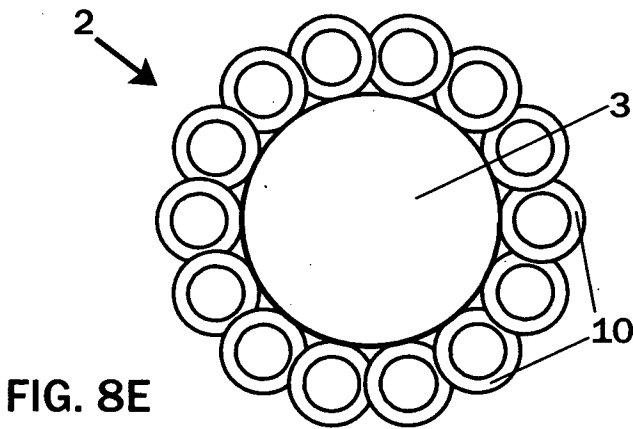


FIG. 8E

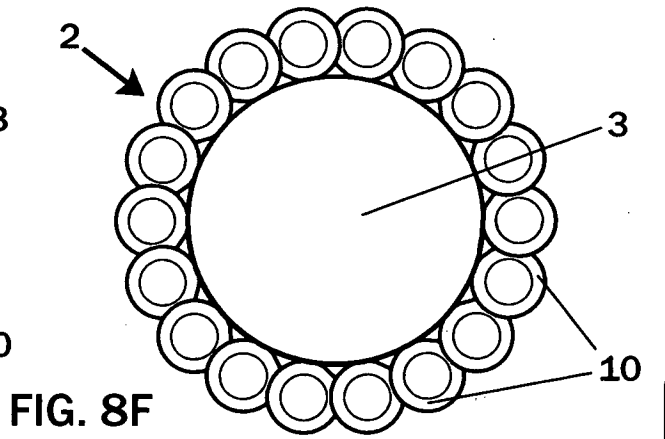
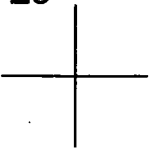
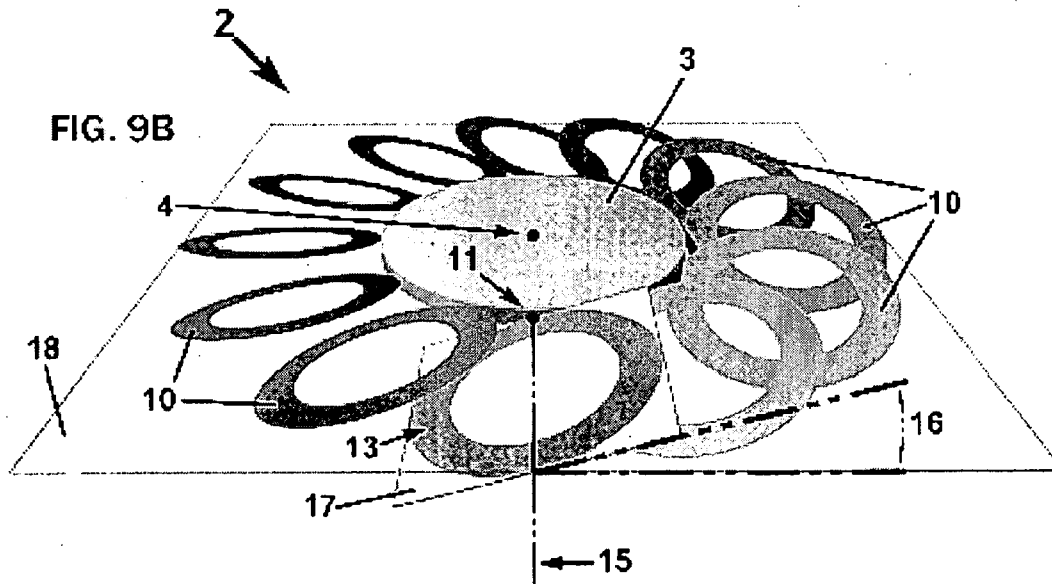
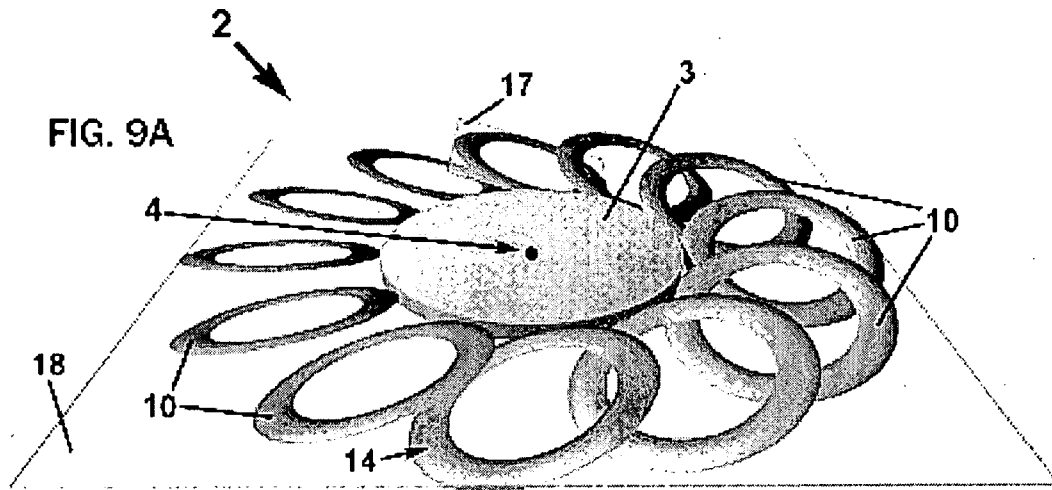
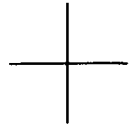
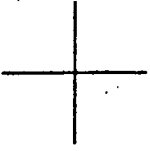


FIG. 8F



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FIG. 10A

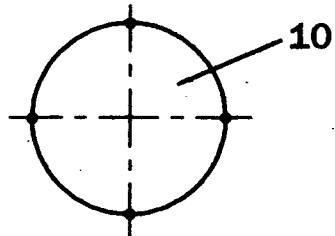


FIG. 10B

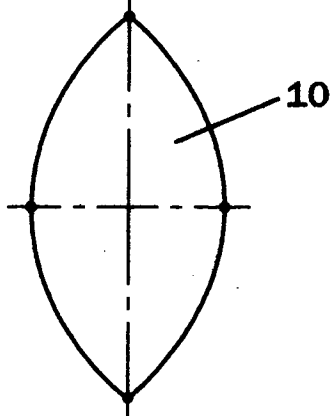
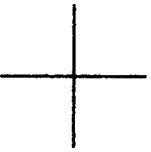
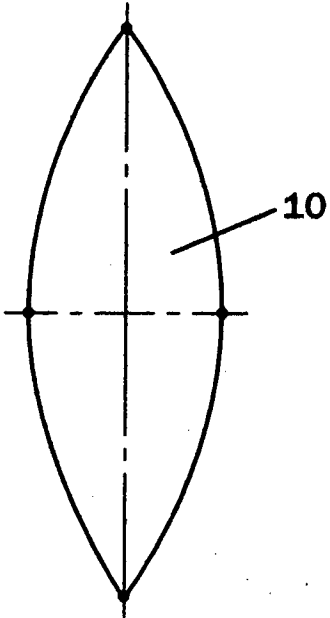
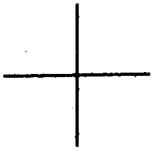
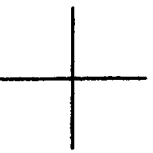
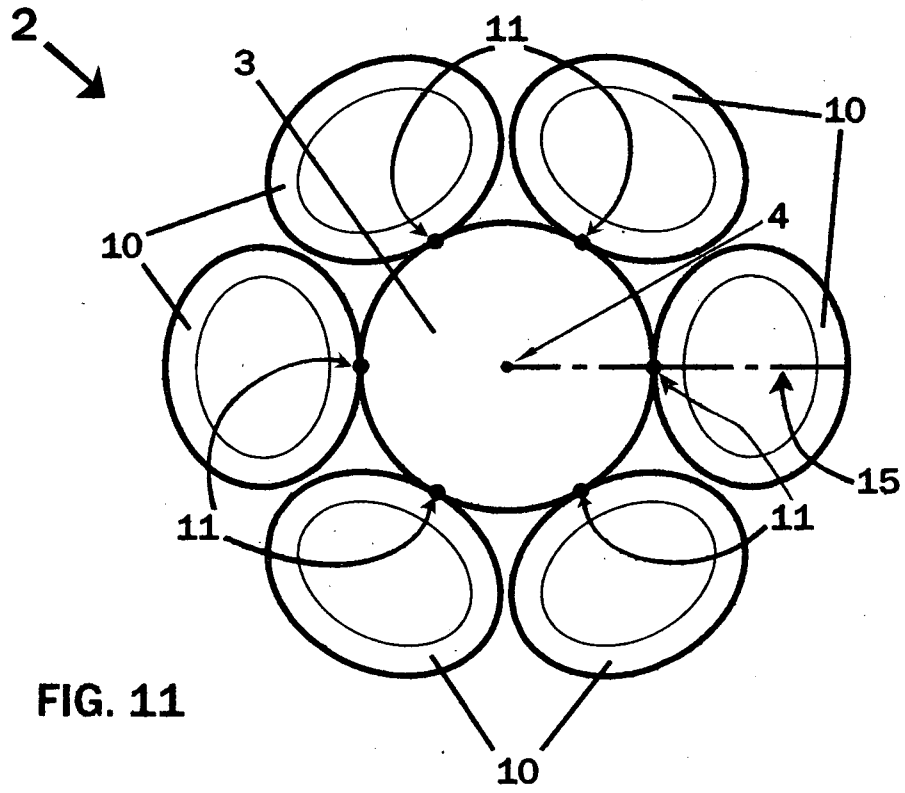


FIG. 10C





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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/12472

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - H02P 9/04 ; F03D 9/00 (2009.01) USPC - 290/44 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) USPC: 290/44 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched USPC: 416/23,223R,235,46,155; 290/44,55 -- term limited -- see search terms below -- Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PubWEST (PGPB, USPT, EPAB, JPAB); Google Search Terms Used: horizontal axis wind turbine, aspect ratio, angle, adjust\$4, aperture, hole, opening, var\$5, contour\$3, blade, etc.										
C. DOCUMENTS CONSIDERED TO BE RELEVANT										
<table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X ---- Y</td> <td>US 2006/0093483 A1 (Brueckner) 04 May 2006 (04.05.2006) Figs. 1, 2, 5, 6, 7, 21 and 22; para [0005], [0006], [0022], [0075], [0102]; claim 2</td> <td>4-6 and 10-12 ---- 1-3 and 7-9</td> </tr> <tr> <td>Y</td> <td>US 2007/0253819 A1 (Doorenspleet et al.) 01 November 2007 (01.11.2007) Figs. 1, 4 and 6; para [0024], [0027] and [0030]</td> <td>1-3 and 7-9</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X ---- Y	US 2006/0093483 A1 (Brueckner) 04 May 2006 (04.05.2006) Figs. 1, 2, 5, 6, 7, 21 and 22; para [0005], [0006], [0022], [0075], [0102]; claim 2	4-6 and 10-12 ---- 1-3 and 7-9	Y	US 2007/0253819 A1 (Doorenspleet et al.) 01 November 2007 (01.11.2007) Figs. 1, 4 and 6; para [0024], [0027] and [0030]	1-3 and 7-9	
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X ---- Y	US 2006/0093483 A1 (Brueckner) 04 May 2006 (04.05.2006) Figs. 1, 2, 5, 6, 7, 21 and 22; para [0005], [0006], [0022], [0075], [0102]; claim 2	4-6 and 10-12 ---- 1-3 and 7-9								
Y	US 2007/0253819 A1 (Doorenspleet et al.) 01 November 2007 (01.11.2007) Figs. 1, 4 and 6; para [0024], [0027] and [0030]	1-3 and 7-9								
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/>										
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Date of the actual completion of the international search 16 March 2009 (16.03.2009)	Date of mailing of the international search report 23 MAR 2009									
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774									