(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 September 2006 (08.09.2006)

PCT

(10) International Publication Number
WO 2006/093790 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/US2006/006432

(22) International Filing Date: 24 February 2006 (24.02.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/656,787	25 February 2005 (25.02.2005)	US
60/660,880	10 March 2005 (10.03.2005)	US
60/678,717	6 May 2005 (06.05.2005)	US
60/736,489	14 November 2005 (14.11.2005)	US

(71) Applicant: **MORRIS, David, C.** [US/US]; 455 W. 23rd #14f, New York, New York 10011 (US).

(74) Agent: **HUNTER, Robert, M.**; Robert M. Hunter PLLC, P.O. Box 2709, Kamuela, HI 96743 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

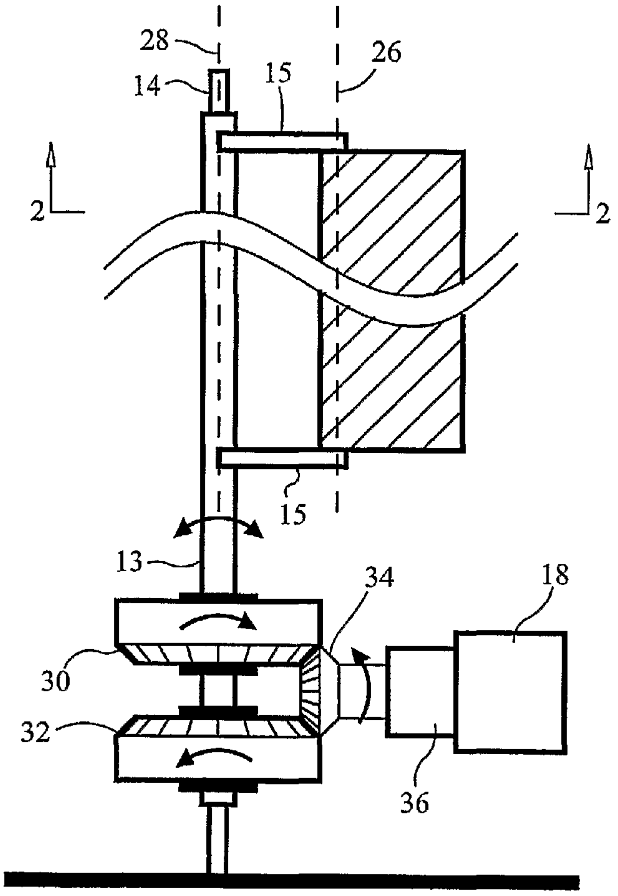
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

[Continued on next page]

(54) Title: WIND FIN: ARTICULATED, OSCILLATING WIND POWER GENERATOR



(57) Abstract: A system and method for harvesting the kinetic energy of a fluid flow for power generation with an articulated airfoil shape capable of form inversion. Pivoted about a mast, the mechanism moves in an oscillatory manner and harvests the maximum aerodynamic lift forces available for a given oscillation cycle. Unlike other oscillating devices, this device presents a preferred shape to a fluid flow, and depends neither upon mechanical trimming devices for optimum control nor upon aeroelastic flutter. In an elongated form, such as a vertical fin, the system harvests an amount of energy comparable to a turbine of the same overall height, yet can be grouped in more compact clusters, and is less evident in the landscape.

WO 2006/093790 A2

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

TITLE OF THE INVENTION

WIND FIN: ARTICULATED, OSCILLATING WIND POWER GENERATOR

David C. Morris

CROSS-REFERENCE TO RELATED APPLICATIONS

This international patent application claims priority in U.S. Provisional Patent Application Nos. 60/656,787, filed February 25, 2005, pending; 60/660,880, filed March 10, 2005, pending; 60/678,717, filed May 6, 2005, pending; and 60/736,489, filed November 14, 2005, pending, the disclosures of which patent applications are incorporated by reference as is fully set forth herein.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not Applicable

BACKGROUND OF THE INVENTION

This invention relates to a method and system for wind power generation. In particular, the invention relates to a method and system for wind power generation by means of articulated, oscillating wind power generator.

In an age of fossil fuel depletion and high energy prices, wind power is a preferred choice for those wishing to power society in a sustainable manner and in a manner which does not cause harm to our environment. Unfortunately, wind power itself is not free from controversy as some react with alarm to the prospect of unsightly large windmills dotting the landscape. Furthermore, turbines can injure or kill birds and bats and interfere with radio frequency (RF) transmissions.

The background art is characterized by U.S. Patents Nos. 252,947; 3,442,493; 3,647,315; 3,743,848; 3,785,213; 3,995,972; 4,024,409; 4,251,040; 4,298,313; 4,346,305; 4,387,318; 4,486,145; 4,525,122; 4,536,674; 4,582,013; 4,684,817; 5,009,571; 5,193,978; 5,324,169; 5,844,323; 6,153,944; 6,273,680; 6,320,273; 6,652,232; 6,700,218; 6,731,018; 6,734,576; 6,853,096; and 6,926,491; and U.S. Patent Application Nos. 2002/0079705, 2003/0123983; and 2005/0141994; the disclosures of which documents are incorporated by reference as if fully set forth herein. The background art is also characterized by the disclosures of the following patent documents: GB 2073327; EP 683316 and EP 490830.

State-of-the-art wind turbines (as well as older wind turbines) have a number of major technical drawbacks that make them expensive to manufacture as well as maintain: (1) they require designs that must overcome great forces at the blade root, including bending in two axes and large torsional loads; they must also resist very large centrifugal forces at the blade root as well as loading fluctuations caused by wind shadowing from the tower or local ground effect; (2) the towers that support wind turbines must resist high overturning moments at their base due to the very high forces concentrated at the center of the rotor; because of the large rotor blade size in larger systems, towers cannot be guyed; this requires the towers to be constructed of very strong and expensive materials, contributing substantially to the overall system cost; (3) the high-rotation tip speeds of smaller and older large-scale turbines presents a lethal threat to birds and bats; much of the public objection to wind turbines is based on the perception that they contribute to a high death rate for these animals; in addition, many wind turbines are perceived to be noisy; (4) high-lift-capable service equipment is often required for maintenance of the motor/generators that are necessarily located at the top of the wind-turbine towers in horizontal-axis wind turbine systems; (5) in order to withstand very high winds, turbine blades in modern conventional horizontal-axis wind turbine systems must be allowed to feather by rotating the blades approximately 90 degrees along their longitudinal axes, which requires complex and expensive gearing; in Darrieus-type vertical-axis wind turbine systems, the blades cannot be feathered and powerful mechanical brakes or other speed control devices must be employed, increasing the expense of manufacture; (6) Darrieus-type systems are not self-starting and require motors to get the blades rotating at a functional speed; and (7) turbines must be fairly widely spaced to minimize side-by-side and tandem interference with neighboring installations. In conclusion, relatively expensive materials and sophisticated, costly manufacturing techniques are required for wind turbine components, including blades, gearboxes, bearings, and towers. In addition, many systems, especially older, utility-scale systems, require costly maintenance.

BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of invention have the potential to harvest wind energy much more cost-effectively than wind turbines, lower the purchase cost of wind-energy systems, and increase the technical and economic viability of wind-power generation. In addition, some embodiments have the potential to eliminate lethality to birds and bats caused by wind-power systems, overcome public objections to the aesthetics of wind-power structures, and improve public acceptance of wind-power generation. In short, it has outstanding potential to significantly expand wind power's contribution to the national energy supply.

Preferred embodiments of the invention exploit the kinetic energy of an aerodynamic, oscillating apparatus, rather than relying on a rotating wind turbine. The invention was initially developed as a visually pleasing alternative to wind turbines. In preferred embodiments, the system allows for designs that are more compatible with existing architectural forms as well as able to blend more readily into the natural landscape. Initial testing, however, indicates that this new technology also is much more affordable and cost-effective than wind turbines.

Preliminary wind-chamber tests and computer modeling of preferred embodiments of the invention have shown that it is comparable if not superior in performance to current state-of-the-art wind turbines of similar size—at approximately half the system cost. This research suggests that the Wind Fin technology will be technically and economically feasible for use at many different scales—from small-scale distributed wind systems up to large, utility-scale systems. Initial research also suggests that preferred embodiments of the invention can operate more cost-effectively in lower-speed wind areas than wind turbines. This would facilitate the expansion of wind generation to more prevalent lower-wind sites than are currently being harnessed.

In preferred embodiments, the invention comprises three major components: (1) a mast, which both anchors the structure and also serves as a pivot axis for the vertical, hinged wind fin; the mast can be guyed for stability or can be free standing; (2) a vertical, hinged fin, attached to the mast by a sleeve, which allows the fin to swing freely about the mast; these aerodynamic wing elements automatically orient downwind and respond readily to wind with an oscillating motion; the fin's oscillating action is self-sustaining in the wind and needs no mechanical assist and is self-starting; fins can be constructed in several different ways; for example, they can be built-up like an aircraft wing with a skin made of fiberglass or other durable membrane that conforms to symmetrical wing ribs, or constructed of a rigid material within a frame; because these fins are not subject to the enormous, alternating, bending stresses of wind turbine blades, they can be less complex and much less costly to manufacture; fins also can easily be designed in many different color schemes and patterns, making them more visually appealing than wind turbines and able to fit less obtrusively into both built and natural environments; and (3) a power-extraction system that is attached to the mast so that it is not affected by the wind direction; the reciprocating motion of the hinged fin drives a concentric shaft that turns two stacked, opposing, overrunning clutches; these clutches convert oscillating motion to continuous motion and, in turn, drive a bevel gear that turns a generator, producing electricity.

The operation of preferred embodiments of the Wind Fin system is conceptually straightforward. When the wind blows, the hinged fin oscillates, and this oscillating motion generates electricity. The greater the wind speed, the faster the fin oscillates, and the greater the electrical output. The applicant believes that the principle behind the fin's oscillating motion is as follows (but his claims are not bound by this principle): In a no-wind condition, a single fin or the two or more elements that constitute the aerodynamic form will never be in a perfectly aligned orientation downwind because of a slight, built-in, off-axis bias. For this reason, the system is self-starting. Once activated by wind, the system forms a convex shape that produces aerodynamic lift. This lift force causes the system to continue swinging to the side. At a certain point, the aerodynamic form cannot swing further due to the force of the oncoming wind. However, the outer, trailing half continues to swing due to its momentum. This creates a shape inversion which has the opposite overall lift characteristic. The system is now positioned to reverse course: it reverses its swing, and repeats and perpetuates the oscillation.

One object of preferred embodiments of the invention is to avoid the tremendous stresses that wind turbine blades need to withstand. Therefore, the wind fins in accordance with these embodiments of the invention can be constructed of lower-cost, less complex, lighter-weight (but highly durable) materials, making power generation with this new technology significantly more affordable and cost-effective. Another object of preferred embodiments of the invention is to function effectively at lower wind speeds. The large wind surface of the wind fins in accordance with this embodiment of the invention, compared to the much smaller wind surface areas of wind turbine blades, creates greater responsiveness to wind force, allowing the new system to function effectively at lower wind speeds than existing wind turbines. Yet another objective of preferred embodiments of the invention is to reduce maintenance requirements. Maintenance is greatly simplified and less costly, because the Wind Fin is a much simpler system than both (1) conventional horizontal-axis wind turbines (HAWTs), where the fan-like rotor is located at the top of a tower, and (2) vertical-axis wind turbines (VAWTs), where the rotor blades revolve around a vertically aligned axle. In addition, the Wind Fin's power-extraction system is located at ground level, where it is readily accessible for maintenance. By contrast, the power-extraction system (including generator and gearbox) in HAWT designs is located high above the ground, increasing the logistical difficulties and expense of maintenance; in VAWT systems, it is often located inside the rotating vertical tube, where it is relatively inaccessible for maintenance. A further object of preferred embodiments of the invention is to decrease lethality to birds and bats. The downwind orientation of the oscillating wind fins—combined with their relatively short range of movement and lower speeds than wind turbine blades—prevents this new technology from being lethal to birds and bats. In addition, some embodiments of the oscillating wind fins are expected be far less noisy than wind turbines. Both of these factors should help overcome specific public objections to current wind-turbine technology. Another object of preferred embodiments of the invention is to be more aesthetically pleasing than wind turbines. Its upright, vertical, finned form is more compatible with existing architectural structures than are wind turbines. In addition, wind fins can easily be designed in different color schemes and patterns. Therefore, this new system can blend more readily into both built and natural landscapes. The visual advantages of this new technology will allow it to overcome public objections to wind power on aesthetic grounds.

In a preferred embodiment, the flapping wind power generator is a structure, comprising an aerodynamic member adapted to respond to wind by a reciprocating motion (flapping). Preferably, the structure further comprises an electricity generator operatively connected to said aerodynamic member so that the reciprocating motion is harvested to generate electricity.

The optimization of forces that produce lift is carried out with a shape over which fluid flows smoothly. Laminar flow preferably prevails for the duration of a traverse of the shape by the fluid in order that turbulence and drag be minimized. For a shape which undergoes an inversion, there are a range of lift forces generated, and it is preferred that the shape offer the most efficient form for lift generation at each point of its half-cycle. This generates the most powerful stroke during the first half-cycle to drive a power extraction mechanism.

In a preferred embodiment, maximum lift is achieved when the system is highly flexed, or highly cambered. In this embodiment, this configuration predominates during most of the half-cycle. It then inverts, and during the inversion process, the device continues to generate lift at reduced, but positive efficiency.

In a preferred embodiment, the invention is an apparatus for extracting power from a moving fluid stream, said apparatus comprising: a mast; a sleeve that pivots about said mast; a wing structure selected from the group consisting of: (1) at least two stand-off arms, each of which stand-off arms having two ends, a first end that is fixed to said sleeve and a second end upon which a hinge is mounted, and a symmetrical airfoil having a forward edge that is attached each said hinge, and (2) a first airfoil portion having two ends, a first end that is fixed to said sleeve and a second end upon which a pivot is mounted, and a second airfoil portion having a forward edge that is attached each said pivot, wherein said airfoil portions are configured to, as a combination, present airfoil surfaces to the moving fluid stream that generate lift first in one direction that is transverse the direction of movement of the moving stream and then in another direction that is opposite said one direction during an oscillation of said airfoil portions in the moving fluid stream; and a power take-off mechanism that comprises a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box; wherein said wing structure is configured to flutter back and forth in the moving fluid stream which is operative to cause said sleeve to pivot back and forth; and wherein said pivoting movement of said sleeve is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches.

In another preferred embodiment, the invention is an apparatus for extracting power from a moving fluid stream, said apparatus comprising: a mast; a sleeve that pivots about said mast; at least two stand-off arms, each of which stand-off arms having two ends, a first end that is fixed to said sleeve and a second end upon which a hinge is mounted; a symmetrical airfoil having a forward edge that is attached each said hinge; and a power take-off mechanism that comprises a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box; wherein said plurality of stand-off arms and said symmetrical airfoil are configured to flutter back and forth in the moving fluid stream which is operative to cause said sleeve to pivot back and forth; and wherein said pivoting movement of said sleeve is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches. Preferably, the apparatus further comprises a trim bias element that is attached to said symmetrical airfoil. Preferably, said symmetrical airfoil is selected from the group consisting of: a framed sheet airfoil; a ribbed airfoil; and an inflated sail airfoil comprising a laminate sail comprising fibers that are laid up between sheets of mylar in a grid pattern.

In another preferred embodiment, the invention is an apparatus for extracting power from a moving fluid stream, said apparatus comprising: a mast; a sleeve that pivots about said mast; a leading element having two ends, a first end that is fixed to said sleeve and a second end upon which a hinge is mounted; a trailing element having a forward edge that is attached each said hinge and a following edge; and a power take-off mechanism that comprises a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box; wherein said leading element and said trailing element are configured to flutter back and forth in the moving fluid stream which is operative to cause said sleeve to pivot back and forth; and wherein said pivoting movement of said sleeve is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches. Preferably, the apparatus further comprises a trim bias element that is attached to said following edge. Preferably, leading element is a symmetrical airfoil and said trailing element further comprises a second symmetrical airfoil that is pivotably attached to said following edge.

In yet another embodiment, the invention is an apparatus for extracting power from a moving fluid stream, said moving stream having a direction of movement, said apparatus comprising: a mast; a sleeve that pivots about said mast; a first airfoil portion (e.g., a first portion of an airfoil) having two ends, a first end that is fixed to said sleeve and a second end upon which a first hinge is mounted; a second airfoil portion (e.g., a second portion of an airfoil) having a forward edge that is attached each said first hinge and a rear edge; and a power take-off mechanism that comprises a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box; wherein said airfoil portions (which in combination at certain angular orientations relative to one another comprise an airfoil) are configured to, in combination, present airfoil surfaces to the moving fluid stream that generate lift first in one direction that is transverse the direction of movement of the moving stream and then in another direction that is opposite said one direction during an oscillation of said airfoil portions in the moving fluid stream, which oscillation is operative to cause said sleeve to pivot back and forth; and wherein said pivoting movement of said sleeve is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches. Preferably, a second hinge is mounted on said rear edge and said apparatus further comprises: a third airfoil portion that is attached to said second hinge. Preferably, the apparatus further comprises: a gear mechanism that links said first airfoil portion to said third airfoil portion. Preferably, the apparatus of further comprises: a linkwork mechanism that links said first airfoil portion to said third airfoil portion. Preferably, each of said airfoil portions comprises a framed sheet; or a ribbed airfoil. Preferably, said second airfoil portion is tapered along its height. Preferably, each of said airfoil portions comprises a plurality of stacked elements.

In a further preferred embodiment, the invention is an apparatus for extracting power from a moving fluid stream, said apparatus comprising: a mast; a first airfoil portion (e.g., a leading element) that is connected to said mast; a second airfoil portion (e.g., a trailing element) that is pivotably attached to said first airfoil portion by a hinge; and a power take-off mechanism that is driven either directly by a pivoting movement of said mast and said first airfoil portion or by a pivoting movement of said first airfoil portion with said mast remaining stationary; wherein said airfoil portions are configured to, as a combination, present airfoil surfaces to the moving fluid stream that generate lift first in one direction that is transverse the direction of movement of the moving stream and then in another direction that is opposite said one direction during an oscillation of said airfoil portions in the moving fluid stream; thereby maximizing the aerodynamic lift of said combination in the moving stream, which in turn maximizes the conversion of the energy of the moving stream into useful power. Preferably, said second airfoil portion comprises a weight.

In another preferred embodiment, the invention is an apparatus for extracting power from a moving fluid stream, said apparatus comprising: a mast assembly; a leading airfoil portion (e.g., leading form) having a leading edge that is connected to said mast assembly and a following edge; a plurality of following airfoil portions (e.g., following forms), each of which has a front edge and a rear edge, the front edge of a first of said following airfoil portions being pivotably attached to the following edge of said leading airfoil portion, and the front edge of each other following airfoil portion being pivotably attached to the rear end of another following airfoil portion; and a power take-off mechanism that is driven either directly by a pivoting movement of said mast and said first airfoil portion or by a pivoting movement of said first airfoil portion with said mast remaining stationary; wherein said airfoil portions are configured to, in combination, present airfoil surfaces to the moving fluid stream that generate lift first in one direction that is transverse the direction of movement of the moving stream and then in another direction that is opposite said one direction during an oscillation of said airfoil portions in the moving fluid stream. Preferably, the apparatus of further comprises: a gear arrangement or a linkwork arrangement that links said leading airfoil portion and a third following airfoil portion. Preferably, the apparatus further comprises: a gear arrangement or a linkwork arrangement that links said second following airfoil portion and a fourth following airfoil portion. Preferably, the apparatus further comprises: a first link arm having that is fixed to said leading airfoil portion, said first link arm having a first end; a second link arm that is fixed to said third following airfoil portion, said second link arm having a second end; and a lever arm that links said first end to said second end. Preferably, the apparatus further comprises: a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box; wherein said moving fluid stream is operative to cause said mast to pivot back and forth; and wherein said pivoting movement of said mast is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches. Preferably, the apparatus further comprises: a crank arm that is connected to said first airfoil portion and to said power take-off mechanism; wherein pivoting movement of said first airfoil portion is converted into longitudinal back and forth movement of said crank arm.

In another preferred embodiment, the invention is a method of generating power comprising: placing an apparatus disclosed herein in a location that experiences a sustained wind; initiating the fluttering of said leading element and said trailing element which causes said sleeve to move back and forth; converting the back and forth movement into rotation of said drive shaft to produce motive power; and providing said motive power to a generator.

In yet another preferred embodiment, the invention is a method of generating power comprising: the step of placing an apparatus disclosed herein in a location that experiences a wind; the step of allowing the combination of said stand-off arms and said symmetrical airfoil to flutter in said wind, causing said sleeve to pivot back and forth; the step of converting the back and forth movement into the rotation of said drive shaft; and the step of providing motive power to a generator by means of said rotating drive shaft.

In another preferred embodiment, the invention is a method of harvesting energy from the wind, said method comprising: producing a leading element and a following element; joining said elements with a hinge to produce a combination having cross-sectional shape that maximizes the aerodynamic lift on said combination; fixing a combination to a mast to produce a wind fin structure; exposing said wind fin structure to the wind to produce oscillation, thereby causing said mast to pivot back and forth at an oscillating frequency; converting the back and forth movement into rotation of a drive shaft to produce motive power; and providing said motive power to a generator.

Further aspects of the invention will become apparent from consideration of the drawings and the ensuing description of preferred embodiments of the invention. A person skilled in the art will realize that other embodiments of the invention are possible and that the details of the invention can be modified in a number of respects, all without departing from the concept. Thus, the following drawings and description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The features of the invention will be better understood by reference to the accompanying drawings which illustrate presently preferred embodiments of the invention. In the drawings:

Fig. 1 is an elevation view of a preferred embodiment of the invention.

Fig. 2A is a cross sectional view of the wing structure of the preferred embodiment of the invention of Fig. 1.

Fig. 2B is a cross sectional view of the trailing element of another preferred embodiment of the wing structure of the invention, the trailing element comprising a spring-loaded trim bias member.

Fig. 2B is a cross sectional view of the trailing element of another preferred embodiment of the wing structure of the invention, the trailing element comprising a permanent trim bias member.

Fig. 3 is a time lapse view of eight steps in the oscillation of the wing structure of a preferred embodiment of the invention of Fig 1.

Fig. 4 is an elevation view of another preferred embodiment of the invention.

Fig. 5 is a cross sectional view of the wing structure of the preferred embodiment of the invention of Fig. 4.

Fig. 6 is a time lapse view of eight steps in the oscillation of the wing structure of the preferred embodiment of the invention of Fig. 4.

Fig. 7 is top cross sectional view a convex surface of a preferred embodiment of the invention.

Fig. 8 is a top cross sectional view of another articulated wing structure of a preferred embodiment of the invention.

Fig. 9 is a plan view of a superimposition of the images of the four stages of oscillation of the wing structure of a preferred embodiment of the invention.

Fig. 10 is a plan view of the configurations taken by the leading element and the trailing element of a preferred embodiment of the invention over a full oscillation cycle.

Fig. 11 is a plan view of a preferred three element embodiment of the invention with the elements aligned in a desired configuration that maximizes lift.

Fig. 12 is a plan view of a preferred embodiment of the invention having a gearing arrangement.

Fig. 13 is a perspective view of a preferred embodiment of the invention having a gearing arrangement.

Figs. 14A through 14D are plan views of a preferred embodiment of the invention illustrating how the gearing arrangement constrains the form of the invention and transfers forces.

Figs. 15 through 18 are plan views of a preferred six element embodiment of the invention having a geared arrangement. For clarity only some of the gears are shown on Figs. 16 and 17.

Figs. 19A, 19B and 19C are three perspective views, at three different points in an oscillation, of a preferred six element of the invention having a geared arrangement.

Figs. 20A, 20B, 20C and 20D are plan views of a preferred three element embodiment of the invention having a linkwork arrangement, with the elements shown at a different stage of an oscillation sequence in each view.

Fig. 21 is a perspective view of a preferred three element embodiment of the invention having a linkwork arrangement.

Fig. 22 is a perspective view of a tall and thin form of a preferred three element embodiment of the invention having a linkwork arrangement.

Fig. 23 is a perspective view of a tapered form of a preferred two element embodiment of the invention.

Fig. 24A through 24H are elevation views of preferred embodiments of the invention. Fig. 24A illustrates a two element frame sheet embodiment, Fig. 24B illustrates a two element ribbed airfoil, Fig. 24C illustrates a two element ribbed, tapered embodiment, Fig. 24D illustrates a three element ribbed airfoil, Fig. 24E illustrates a two element stacked embodiment, Fig. 24F illustrates a framed sheet, single element standoff embodiment, Fig. 24G illustrates a ribbed airfoil, single element, stand-off embodiment, Fig. 24H illustrates a 3DL process sail, single element stand-off embodiment.

Fig. 25A and 25B are elevation views of embodiments of the invention constructed of fabric-like material attached to an articulated framework.

Figs. 26-30 are plan views illustrating a complete oscillation of a preferred embodiment of the invention.

Figs. 31 and 32 are perspective views of preferred embodiments of the invention that are guyed by spar and guy wire sets.

Figs. 33 and 34 are plan views of another two preferred embodiments of the invention.

Figs. 35 and 36 are sequence drawings of the steps in an oscillation of preferred embodiments of the invention.

Figs. 37-40 are perspective views of other preferred embodiments of the invention that are guyed by spar and guy wire sets.

Fig. 41 is a plan view illustrating the steps in the oscillation of a preferred three element embodiment of the invention.

Figs. 42-45 are plan views that illustrate the steps in the oscillation of a preferred two-element embodiment of the invention.

Figs. 46A and 46B are plan views illustrating the range of motion of and forces imposed on of a more preferred embodiment of the invention.

Fig. 47 is a graph of the lift coefficient of the embodiment of Figs. 46A and 46B.

Fig. 48 is a plan view of the embodiment of Figs. 46A and 46B that indicates dimensions of the theoretical system under study.

Fig. 49 is a plan view of the embodiment of Figs. 46A and 46B that indicates weight distribution of the theoretical system under study.

The following reference numerals are used to indicate the parts and environment of the invention on the drawings:

1 first stage
2 second stage
3 third stage
4 fourth stage
10 system, wind power generator system
11 frame, spar and guy wire set
12 wing structure, articulated wing structure, mechanism, wind fin, hinged wing structure
13 sleeve
14 mast
15 take-off arm, arm
16 power takeoff mechanism
18 generator, motor generator
19 crank arm

20	body, leading portion, leading form, leading element
22	flap, trailing portion, trailing form, trailing element, tail
23	fin
24	hinge, pivot
25	trim bias, trim bias member
26	hinge axis
28	mast pivot axis
30	clockwise clutch
32	counterclockwise clutch
34	bevel gear
36	gearbox
40	convex surface
42	standard airfoil
44	high lift region
46	transition region
48	inversion region
50	first element
52	second element
54	third element
56	fourth element
58	fifth element
60	gear mechanism
62	linkwork mechanism
63	fabric, fabric-like material
64	body frame
66	flap frame
70	body axis
72	limit of flap travel
74	weight
76	actuator

DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 1, a preferred embodiment of system 10 is presented. In this embodiment, system 10 comprises wing structure 12, mast 14, power takeoff mechanism 16 and generator 18. Preferably, wing structure 12 comprises body 20 and flap 23 with flap 23 being connected to body 20 by means of hinge 24 having hinge axis 26. Body 20 is preferably fixed to sleeve 13 which rotatably mounted on mast 14, and which oscillates around mast pivot axis 28 during operation of system 10. Power takeoff mechanism 16 preferably comprises two overrunning clutches (clockwise clutch 30 and counterclockwise clutch 32), bevel gear 34 and gearbox 36, although any mechanism for converting oscillating motion into rotary motion would suffice. Generator 20 preferably yaws with the wind direction. The stacked and opposing overrunning clutches 30 and 32 are driven by pinions (not shown) attached to sleeve 13. These clutches in turn drive bevel gear 34. This in turn drives gearbox 36 and motor generator 18.

Referring to Fig. 2, a cross sectional view of wing structure 12 is presented. Stand-off arm 15 is shown fixed to sleeve 13 and pivotably attached to flap 23.

Referring to Fig. 3, a time lapse view of eight steps in the oscillation cycle of wing structure 12 is presented. In this view, a half cycle is reached at step E.

Referring to Fig. 4, another preferred embodiment of system 10 is presented. In this embodiment, system 10 comprises wing structure 12, mast 14, power takeoff mechanism 16 and generator 18. Preferably, wing structure 12 comprises body 20 and flap 22 with flap 22 being connected to body 20 by means of hinge 24 having hinge axis 26. Body 20 is preferably fixed to sleeve 13.

Referring to Fig. 5, a cross sectional view of wing structure 12 is presented. Body 20 is shown fixed to sleeve 13 and pivotably attached to flap 22.

Referring to Fig. 6, a time lapse view of eight steps in the oscillation cycle of wing structure 12 is presented. In this view, a half cycle is reached at step E.

Referring to Fig. 7, convex surface 40 illustrates a shape of wing structure 12 at a point in its oscillation in accordance with a more preferred embodiment of the invention is presented. Convex surface 40 acts as the low pressure, high lift region of an airfoil in accordance with a preferred embodiment of the invention. Convex surface 40 is derived from standard airfoil 42, in a preferred embodiment, airfoil GO7955, that is also shown in Fig. 7 and that is one of a large family of airfoils (referenced in the software VisualFoil V. 4.1 by Hanley Innovations of Ocala, FL, 34483, the disclosure of which is incorporated by reference as if fully set forth herein). The term “maximum chord thickness” and “maximum chamfer” are defined in the software. In this embodiment, a user of the software gives standard airfoil 42 a maximum chord thickness of about three percent and maximum chamfer of about thirty percent to produce convex surface 40, which represents a maximally pivoted configuration of an articulated lifting (airfoil) surface in accordance with the invention, at one end point of an oscillation.

A variety of methods can be used to determine airfoil shapes. A person skilled in the art would know that research documents of the National Aeronautic and Space Administration (NASA) and its predecessor, the National Advisory Committee for Aeronautics (NACA), may used to determine airfoil shapes and their characteristics. A selection of shapes based upon desired lift/drag characteristics for given wind speeds is made, and this preferably determines the shape of a single fin system or a multiple element system. One of the shapes used herein, airfoil GO7955, is but one example. Another example based upon a modification of the CLARK Y airfoil is given in Fig 41. An approximation to the choice is then made with a single or multi-element form. The airfoil shape can change along the length of the fin system – each cross-section determined by an optimal airfoil choice based upon the wind gradient given for a chosen site.

Referring to Fig. 8, another embodiment of the articulated wing structure 12 of Fig. 4 is presented in cross section at one end point of an oscillation. In this embodiment, articulated wing structure 14 comprises leading element 20 and trailing element 22. Trailing element 22 is preferably joined to leading element 20 by hinge or pivot 24. In this embodiment, articulated wing structure 12 is capable of taking a maximally pivoted configuration that produces a lifting contour that is an approximation of the desired shape of convex surface 40 shown in Fig. 7, at the segment of highest lift shown in 44 of Fig. 9. Preferably, wing structure 12 is allowed to flex as well as rotate freely about mast 14 on sleeve 13.

Referring to Fig. 9, a superimposition of the stages 1-4 of oscillation of wing structure 12 is presented. In high lift region 44 of the swing (changing the angle of attack of the shape between first stage 1 and second stage 2) in the fluid stream, mechanism 12 exhibits the greatest efficiency: least drag, highest lift. For the remainder of the swing, a transition to the inverted form occurs in transition region 46 between second stage 2 and third stage 3, with the lift generating capability declining to zero and then reversing between third stage 3 and fourth stage 4 in inversion region 48.

Referring to Fig. 10, full oscillation cycle is illustrated, with highest lift achieved in configurations A-B and E-G, then G-H and K-A. Essentially no lift is generated in configurations C-D and I-J. The wind blows from below.

Referring to Fig. 11, a preferred three-element embodiment of articulated wing structure 14 is illustrated. Here, articulated wing structure 14 comprises first element 50, second element 53 and third element 54. With this embodiment, a closer approximation of the desired shape (illustrated in Fig. 7) is achieved by incorporating more than two elements into articulated wing structure 14.

In a preferred embodiment, embodiments of mechanism 14 having more than two elements are constrained to adopt a preferred airfoil shape. In one preferred embodiment, illustrated in Fig. 12, this is done with a geared arrangement.

In another preferred embodiment, illustrated in Fig. 21, this is done with a linkwork arrangement. The gearing or linkwork arrangement preferably has the following two properties: (1) it constrains the form to either a convex or concave shape, and (2) it ties each element downstream of first element 50 to first element 50 and thereby transfers forces affecting each element to the first one. Power is preferably extracted from first element 50.

As illustrated in Fig. 13, with a preferred embodiment of a gearing arrangement, gearing links alternate elements: e.g., for three elements 50, 52, 54, the linkage is element 50 to element 54. A preferred geared or linkwork system is located at several points along the length (vertical extent) of a vertical embodiment of wind fin 12, the number of gears and their placement to depend on the height of wind fin 12.

Gear linking can have a variety of configurations. Referring to Figs. 14A, 14B, 14C and 14C, a portion of the oscillation sequence is shown for a three-element embodiment with gear linking (as was shown for a different embodiment in Fig. 9). This particular approximation is carried out with a preferred geared mechanism that exhibits a linear and equal angular rate of change of the angular orientations of elements 50, 52 and 54.

The term "linear" means that an output is a constant multiple of an input. With a linear and equal gear arrangement, two gears of the same diameter are used. With a linear and unequal gear arrangement, two gears of different diameters are used. With a nonlinear linkwork arrangement, the angular output varies over the oscillation with an unvarying input.

In Fig. 15, six elements 50, 52, 54, 56, 58 and 60 are linked by gear tying elements 50 and 54, 52 and 56, 54 and 58 and 56 and 60. For multiple element systems, a gearing linkage would be E1-E3, E2-E4....EN-E(N+2). In Fig. 16, for clarification the gearing of three elements 50, 54, 58 are linked by gears linking elements 50 and 54 and 54 and 58. In Fig. 17, for clarification, the gearing of three elements 52, 56, 60 are joined by gears tying elements 52 and 56 and 56 and 60. In Fig. 18, all six elements 50, 52, 54, 56, 58 and 60 are shown in flexure: tied by gears linking elements 50 and 54, 52 and 56, 54 and 58 and 56 and 60. Referring to Figs. 19A, 19B and 19C, even element to odd element gearing staggered by height, is illustrated.

Referring to Figs. 20A, 20B, 20C and 20D, a portion of the oscillation sequence for a linkwork arrangement (as was illustrated for a different embodiment in Fig. 9) is shown. In Figs. 21-22, other preferred embodiments of a linkwork arrangement are illustrated. This approximation is carried out with a preferred linkwork mechanism that exhibits a linear and equal angular rate of change of the angular orientations of elements 50, 52 and 54.

Figs. 21 illustrate a preferred method of constraining three elements with a linkwork arrangement to either a convex or concave form, which approximates the preferred shape illustrated in Fig. 11. This approximation is carried out with a linkwork arrangement that exhibits a non-linear and unequal angular rate of change of the angular orientations of elements 50, 52 and 54. Fig. 22 illustrates a preferred tall and thin form of a three element mechanism with linkwork arrangement. Other geared and multiple element sets are possible but not illustrated.

Referring to Figs. 24A-24H, preferred embodiments of wind power generator 10 that operates on the basis of aerodynamic flutter is illustrated. Embodiments of wind power generator 10 may be designed to be far more attractive than a simple windmill. This is an important consideration in gaining approval for wind power projects in the face of community resistance.

Referring to Fig. 23, a preferred embodiment of fluttering wind power generator system 10 includes mast 14 and wing structure 12 comprising leading element 20 and trailing element 22. Figs. 24A, 24B, 24C, 24D and 24 illustrated alternative embodiments of system 10. In the embodiment shown in Fig. 24E, wing section 24 is divided vertically into a plurality sections. In one preferred embodiment these sections are independent, and in another preferred embodiment they are tied together.

Referring to Fig. 26, another preferred embodiment of wing section 12 is illustrated. In this embodiment, the length of leading element 20 is approximately equal to the length of trailing element 22. Elements 20 and 22 of wing structure 12 can be built-up like an aircraft wing with skin that conforms to symmetrical wing ribs having a thickness depends upon mast thickness. Alternatively, as shown in Figs. 25A and 25B, elements 20 and 22 can be constructed of fabric-like material 63 stretched within 64 body frame and flap frame 66.

In another preferred embodiment, moveable weights (not shown) are included in at least some sections of body 20. These weights are move in a controlled manner along a pathway transverse to mast 14, which would be horizontal in the embodiments shown. The control of the weight movement is designed to facilitate the flapping of wing structure 12. The pathways may be small tubes, in which the weights are resident, or tracks on which the weights are slidably but securely fastened. In one preferred embodiment, weight movement control is informed by a sensor assembly.

In preferred embodiments, the momentum of wing structure 12 movement affects a shift in the position of flap 22, which is shown over a complete oscillation in Fig. 6 and sequence in the time sequence diagrams, Figs. 27-30. As illustrated in Fig. 27, upon perturbation of wing structure 12, body 20 and flap 22 rotate counterclockwise around mast pivot axis 28 because lift acts on the convex side of wing structure 12. At the maximum extent of counterclockwise rotation shown in Fig. 28, momentum carries flap 22 past body axis to limit of flap travel 72 and the direction of lift changes and clockwise rotation begins. At an intermediate stage of clockwise rotation shown in Fig. 29, lift increases. At the end of clockwise rotation shown in Fig. 30, wing structure 12 moves into a configuration that is a mirror image of the configuration at the beginning of flutter shown in Fig. 27.

Systems 10 may be positioned in clusters or individually. Also, they may be mounted at tops or edges of buildings. Preferred embodiments have an approximate maximum height of 61 meters (200') (as illustrated). This large vertical extent (although system 10 could be reoriented to have a large horizontal extent) permits the generation of a reasonable amount of power, with the back and forth fluttering motion used to rotate a power-takeoff mechanism as is well known in the mechanical arts. In preferred embodiments, system 10 generates power without posing the danger to birds that a traditional windmill poses.

Referring to Fig. 31, another preferred embodiment of system 10 is illustrated that operates as a flapping wind power generator on the basis of hinged wing structure 12 flapping in the wind. In this embodiment, winged wing structure 12 is connected to a mast 14 and comprises leading portion 20 and trailing portion 22. Leading portion 16 preferably pivots about mast pivot axis 28 which is guyed by spar and guy wire set 11; while trailing portion 22 pivots about hinge axis 26. In preferred embodiments, the flapping action is self sustaining and needs no mechanical assist.

Referring to Fig. 32, another preferred embodiment of system 10 is a flapping wind power generator 10 is illustrated that operates on the basis of flap 23 (e.g., a single body wing structure) attached to mast 14 by stand-off arms 15. The arms 32 pivot about the mast pivot axis 28 while single body wing structure 23 pivots about hinge axis 26. In this embodiment, the flapping action is self sustaining and needs no mechanical assist. This system is also preferably guyed, as shown in Fig 31.

Referring to Fig. 33, a top view cross section of another preferred embodiment of the hinged wing structure of Fig. 31 shows leading portion 20 fixed, on one side, to mast 14 and, on the other side, connected to trailing portion 22 by pivot 24. Trailing portion 18 includes weight 74 that facilitates the flapping motion. Hinged wing structure 12 is connected to generator 18 by crank arm 19.

Referring to Fig. 34, a top view cross section of another preferred embodiment of the single body wing structure of Fig. 32 shows arm 15 fixed, on one side, to mast 22 and, on the other side, connected to flap 23 by pivot 24. Flap 23 includes weight 28 that facilitates the flapping motion. Arm 15 is connected to generator 18 by crank arm 19.

Referring to Fig. 35, a sequence drawing of the steps in the oscillation of hinged wing structure 14 are presented. Steps F to G and steps L to A show transition portions of the flapping sequence, in which the trailing edge portion 22 of hinged wing structure 12 continues its rotation and the lift direction of the airfoil as a whole reverses.

Referring to Fig. 36, a sequence drawing of the steps in the oscillation of the single body wing structure 23 is presented. Steps F to G and steps L to A show transition portions of the flapping sequence in which the single body wing structure on a stand-off arm continues its rotation, and the lift direction of the airfoil as a whole reverses.

Referring to Figs. 37-45 system 10 that comprises a wind power generator that operates on the basis of flapping in the wind is illustrated. In this embodiment, he large vertical extent of system 10 permits the generation of a reasonable amount of power (although the generator could be reoriented to have a large horizontal extent), with the back and forth flapping motion of wing structure 12 being used to rotate a power takeoff element as is well known in the mechanical arts. System 10 preferably includes frame 11 having mast 14 and wing structure 12 which comprises main body 20 and flap 22. In a preferred embodiment, actuator 76 includes a number of sensors and possesses sufficient computing intelligence to determine a substantially optimal point in time to swing flap 22 from one position to another, thereby facilitating the flapping of wing structure 12. In another preferred embodiment, there is no such actuator and the momentum of wing structure 12 movement affects the shift in position of flap 22.

Time sequence diagrams, Figs. 42-45, illustrate the steps in the oscillation of a preferred embodiment of wing structure 12. In Fig. 42, body 20 and tail 22 rotate together to approximately 30 degrees from the wind direction due to lift generated by the wind. Power is extracted during this phase of movement. In Fig. 43, only tail 22 rotates left through about 30 degrees. In Fig. 44, body 20 and tail 22 rotate together over approximately 30 degrees due to lift generated by the wind. Power is extracted during this phase of movement. In Fig. 45, only tail 22 rotates to the right through approximately 30 degrees.

In summary, preferred embodiments of the disclosed wind power generation technology has the following virtues: (1) the wind fins do not oscillate so rapidly that ultra-high-strength materials are required; (2) forces are distributed along the length of the mast rather than being concentrated at the top of the structure, as is the case with wind turbines; therefore, the structure does not need to be as complex and robustly constructed, reducing the overall system cost and increasing longevity; (3) the mast can either be free-standing for shorter systems, or guyed for taller systems; therefore, simple, relatively inexpensive, low-load bearing structures can be used with this new technology; (4) the body of the fin can be made of many different materials, ranging from inexpensive durable fabrics for smaller units, to built-up forms with fiberglass or aluminum skins for larger units; (5) power extraction is at the ground level, below the main flapper element; this facilitates ready access to the generator for maintenance; (6) in order to avoid destruction during high winds, the hinged fins can easily be lined up and locked using a simple, inexpensive device, allowing the system to feather or wind vane; (7) unlike Darrieus-type VAWT systems (but like most HAWT systems), the Wind Fin is self-starting; and (8) the disclosed technology does not have the spacing problem of both horizontal-axis and vertical-axis wind turbines; Wind Fin systems can be installed in clusters, closely side-by-side, without diminishing their effectiveness.

Theoretical calculations pertaining to power performance and cost-effectiveness of a more preferred embodiment (e.g., the embodiment of Fig. 24B) are performed as follows:

For a rotating motion of the embodiment shown in Figs. 46A and 46B:

Power, P = moment, $M \times \omega$	[mkg/sec]
ω = angular velocity	[1/sec]
Moment, $M = F \times r = (L \cos\alpha + D \sin\alpha) \times r$	[mkg]
Lift, $L = c_L \times A \times r/2g \times v^2$	[kg]
Drag, $D = c_D \times A \times r/2g \times v^2$	[kg]
c_L, c_D = lift coefficient, drag coefficient	[--]
A = area of the fin	[m^2]
v = wind velocity	[m/sec]
ρ= air density	[kg/m^3]

g = acceleration of gravity [m/sec^2]

Radius, r = distance of lift from rotation center [m]

The integrated power over the entire angle of oscillation:

$$P=2 \times \omega \int_{\alpha_{min}}^{\alpha_{max}} [L_{(\alpha)} \times \cos\alpha + D_{(\alpha)} \times \sin\alpha] \times r_{(\alpha)} d\alpha \qquad [mkg/sec]$$

In order to obtain the oscillating frequency of the wing, the oscillating frequency of a torsional pendulum is used:

$\omega = \sqrt{}M_{av}/J$ [1/sec]

where M = the average torsional moment of the fin

$$M = \int_{\alpha_{min}}^{\alpha_{max}} [L_{(\alpha)} \times \cos\alpha + D_{(\alpha)} \times \sin\alpha] \times r_{(\alpha)} d\alpha \qquad [mkg]$$

and J = the moment of inertia, $J = \int y^2 dm$ [mkg/sec^2]

where y is the distance of the mass from the rotational center (the mast)

The frequency of a test model measuring 12 by 6 inches was tested and its frequency was measured at 105 beats per minute. The formula above was used to calculate this frequency and a cycle frequency, ω = 9.64 [1/sec], which would yield a beat frequency of 92.1 beats per minute. This is an agreement of 88 percent, and helps to justify the theoretical deduction as a viable means of scaling up the measured values for a larger-scale model, especially because the theory is offset on the conservative side and would predict a lower power output than can reasonably be expected.

In order to obtain the power of a larger-size system, the lift and drag coefficients were calculated with VisualFoil (Hanley Innovations) software (cited above). In applying results from software modeling, the following procedure was used: Observing the behavior of the test fin, an average lift coefficient was established between the angle of –30 to +30 degrees (see Fig. 47).

Because the drag coefficient is much smaller than the lift coefficient, and also contributes very little because it is multiplied with the sine of the angle, it was neglected. Thus the above equation reduces to the following form: $P = 2 \times \omega \times L_{av} \times \cos\alpha \times r$. Consistent with the lift coefficient software program, r was assumed at 40 percent of chord length. Further, since the $\cos\alpha$ is close to one, an average angle of 15 degrees was assumed ($\cos\alpha = 0.96$).

In order to make predictions from theory as to both power output and cost-effectiveness, we designed two different models. The first was a scale-model Wind Fin with a fin that would be 6 ft. high and 1 ft. wide, constructed with an aluminum skin 0.1 inch thick (0.1 lb/in^3).

1) Weight of fin $W = 12 \times 72 \times 2 \times 0.1 \times 0.1 = 17.28\text{lb} = 7.84$ [kg]
and the mass $= W/g = 7.84/9.81 = 0.80$ [kgsec^2/m]

2) Moment of inertia, $J = 1/3 \times m \times l^2$ with $l = 12\text{inch} = 0.305$[m] $J = 0.247$ [mkgsec^2]

3) The moment on the fin $M = c \times q \times A \times r$
where $c = c_{av} = 1.65$ $q = \rho/2g \times v^2$
$= 4.89$ [kg/sqm] @ 20mph = 8.9 [m/sec]
$A = 6$ sqft = 0.555 [sqm] and $r = 0.4 \times l = 4.8\text{inch} = 0.122$ [m]
Thus the moment, $M_{av} = 0.546$ [mkg]

4) The frequency

$$\omega = \sqrt{M_{av}/J} = 4.7 \text{ [1/sec] or 44.9 beats per minute}$$

5) The power $P = 2 \times \omega \times L \times \cos\alpha \times r = 2 \times \omega \times M \times \cos\alpha$

or P = 2 x 4.7 x .546 x .96 = 4.92 [mkg/sec] = 48.2 [Watts]

The second theoretical Wind Fin system designed for modeling consisted of a fiberglass fin measuring 20 ft. tall and 3 ft. wide. The mast for the system would be a six-inch diameter aluminum tube (schedule 40, OD = 6.625", ID = 6.065", t = 0.280"). The fiberglass skin on the fin would be ¼ inch thick starting at the mast and diminishing to 1/16 inch at the trailing edge. The fin would have a foam core with 2 lb/ft^3 foam density (see Fig. 48).

To assess the frequency of this oscillating fin, a linear distribution of weight was assumed with the maximum weight at the mast, diminishing to zero at the trailing edge.

Total weight of the fin:

1) Skin: (1/4 + 1/16)/2 x 36 x 12 x 0.072 x 2 = 9.72 [lb/ft] = 4.41 [kg/ft]
2) Mast: 6" diameter Schedule 40 AL pipe 6.5 lb/ft
3) Foam Core: W = 6 x 12/2 x 36 x 2/1728 = 1.5 lb/ft = 0.68 kg

To calculate the moment of inertia, the fin profile was divided into four sections with the following mass distribution. (See Fig. 49) The weight distribution, based upon a coarse estimate (only four portions), shifts the weight away from the mast (and accounts for the omitted weight of the hinge). This increases the moment of inertia, thus lowering the frequency and therefore leads to a conservative estimate of the power output.

Thus, the moment of inertia is calculated as follows:

1.74E-3 + 2.9E-3 + 18.8E-3 + 31.4E-3 + 20.5E3 [m kg sec^2/ft]

Thus the total moment of inertia J = 75.3E-3 [m kg sec^2/ft]

And the aerodynamic moment M = c_L x q x A x r x cos =

1.65 x 4.89 x .278 x .365 x .96 = .786 [m kg/ft]

Thus the fin frequency $\omega = \sqrt{M/J}$ = 3.25 [1/sec] = 31.1 cycles/minute and the Power, P = 2 x ω x M x h = 2 x 3.25 x 0.786 = 5.11 [m kg/sec/ft] = 50.1 [Watts/ft]

Thus, with a 20 ft. tall Wind Fin system, power production would be 20 x 50.1 = 1,002 watts. The estimated year 2005 labor and materials cost related to the construction of a prototype 20 ft. by 3 ft. Wind Fin is $1,800, broken down as follows: labor, $600, materials: aluminum mast, $310; generator, $200; clutches, $150; tube, $160; foam, $150; resin, $80; cloth, $80; hinges, $50, bearings, $20. The applicant estimates that, in full production, a manufacturer could sell a Wind Fin of this size for $1,800. The profit would come from reduced labor and materials costs provided by economies of scale and discounts from large-volume wholesale purchase on the materials.

Preliminary wind-chamber tests and computer modeling have shown that preferred embodiments the disclosed technology is expected to be comparable if not superior in performance to current state-of-the-art wind turbines of similar size—at approximately half the system cost. Theoretical calculations based on preferred embodiments predict that a Wind Fin measuring 20 feet tall by 3 feet wide on a thirty foot mast in a 20 mph wind would generate slightly over 1kW of electricity. This is a significant improvement in performance over state-of-the-art wind turbines of comparable size.

Table 1 compares the estimated performance and cost of the Wind Fin to the performance and cost of state-of-the-art products from two leading small wind-turbine companies, Bergey Windpower and Southwest Windpower. It compares data pertaining to these companies' leading 1kW products, Bergey's XL.1 Wind Turbine and Southwest Windpower's Whisper 200 Wind Turbine (formerly the H80), to the above-described 1kW computer model of the Wind Fin.

Table 1. Performance and Cost Comparison of Wind Fin to Leading Commercial Wind Turbines

Item	Bergey Windpower XL.1 Wind Turbine	Southwest Windpower Whisper	Wind Fin

		200 Turbine	
Size of system	8.2-foot rotor diameter; 30-foot tilt-up tubular tower	10-foot rotor diameter; 30-foot tilt-up tubular tower	20-foot tall, 3-foot wide oscillating fin; 30-foot tall mast
Comparable power, at 20 mph (watts)	425	800	1002
Total system cost (uninstalled)	$3,400	$3,315	$1,800
$/Watt at comparable power	$8.00	$4.14	$1.80

The results in Table 1 show that the Wind Fin is expected to compete very favorably in both performance and cost categories. Despite their 1kW ratings, the Bergey Windpower XL.1 generates only 425W at 20 mph and the Southwest Windpower Whisper 200 generates 800W at 20 mph—according to their published power curves. The manufacturer's price (including tower) for the Bergey Windpower XL.1 is $3,400 and the manufacturer's price (with tower) for the Southwest Windpower Whisper 200 is $3,315, compared to the predicted manufacturer's price for a 1kW Wind Fin of only $1,800. This means that the system cost per watt at a 20 mph rated speed would be $8.00 with the Bergey Windpower XL.1 and that with the Southwest Windpower Whisper 200 would be $4.14, compared to only $1.80 for the Wind Fin.

In conclusion, Table 1 suggests that the Wind Fin is likely to significantly outperform and be significantly more cost-effective than state-of-the-art wind turbines of comparable size from leading commercial manufacturers. This, combined with the Wind Fin's lower purchase price, environmental advantages, and improved aesthetics, is expected to enable the Wind Fin to readily penetrate the marketplace.)

Many variations of the invention will occur to those skilled in the art. Some variations include offset arms. Other variations call for wing structures that maximize lift during the power cycle. All such variations are intended to be within the scope and spirit of the invention.

Although some embodiments are shown to include certain features, the applicant specifically contemplates that any feature disclosed herein may be used together or in combination with any other feature on any embodiment of the invention. It is also contemplated that any feature may be specifically excluded from any embodiment of the invention.

CLAIMS

What is claimed is:

1. An apparatus for extracting power from a moving fluid stream, said apparatus comprising:

a mast;

a sleeve that pivots about said mast;

a wing structure selected from the group consisting of:

at least two stand-off arms, each of which stand-off arms having two ends, a first end that is fixed to said sleeve and a second end upon which a hinge is mounted, and a symmetrical airfoil having a forward edge that is attached each said hinge, and

a first airfoil portion having two ends, a first end that is fixed to said sleeve and a second end upon which a pivot is mounted, and a second airfoil portion having a forward edge that is attached each said pivot, wherein said airfoil portions are configured to, as a combination, present airfoil surfaces to the moving fluid stream that generate lift first in one direction that is transverse the direction of movement of the moving stream and then in another direction that is opposite said one direction during an oscillation of said airfoil portions in the moving fluid stream; and

a power take-off mechanism that comprises a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box;

wherein said wing structure is configured to flutter back and forth in the moving fluid stream which is operative to cause said sleeve to pivot back and forth; and

wherein said pivoting movement of said sleeve is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches.

2. An apparatus for extracting power from a moving fluid stream, said apparatus comprising:

a mast;

a sleeve that pivots about said mast;

at least two stand-off arms, each of which stand-off arms having two ends, a first end that is fixed to said sleeve and a second end upon which a hinge is mounted;

a symmetrical airfoil having a forward edge that is attached each said hinge; and

a power take-off mechanism that comprises a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box;

wherein said plurality of stand-off arms and said symmetrical airfoil are configured to flutter back and forth in the moving fluid stream which is operative to cause said sleeve to pivot back and forth; and

wherein said pivoting movement of said sleeve is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches.

3. The apparatus of claim 2 further comprising a trim bias element that is attached to said symmetrical airfoil.

4. The apparatus of claim 2 wherein said symmetrical airfoil is selected from the group consisting of:

a framed sheet airfoil;

a ribbed airfoil; and

an inflated sail airfoil comprising a laminate sail comprising fibers that are laid up between sheets of mylar in a grid pattern.

5. An apparatus for extracting power from a moving fluid stream, said apparatus comprising:

a mast;

a sleeve that pivots about said mast;

a leading element having two ends, a first end that is fixed to said sleeve and a second end upon which a hinge is mounted;

a trailing element having a forward edge that is attached each said hinge and a following edge; and a power take-off mechanism that comprises a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box;

wherein said leading element and said trailing element are configured to flutter back and forth in the moving fluid stream which is operative to cause said sleeve to pivot back and forth; and

wherein said pivoting movement of said sleeve is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches.

6. The apparatus of claim 5 further comprising a trim bias element that is attached to said following edge.

7. The apparatus of claim 4 wherein said leading element is a symmetrical airfoil and said trailing element further comprises a second symmetrical airfoil that is pivotably attached to said following edge.

8. An apparatus for extracting power from a moving fluid stream, said moving stream having a direction of movement, said apparatus comprising:

a mast;

a sleeve that pivots about said mast;

a first airfoil portion having two ends, a first end that is fixed to said sleeve and a second end upon which a first hinge is mounted;

a second airfoil portion having a forward edge that is attached each said first hinge and a rear edge; and

a power take-off mechanism that comprises a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box;

wherein said airfoil portions are configured to, in combination, present airfoil surfaces to the moving fluid stream that generate lift first in one direction that is transverse the direction of movement of the moving stream and then in another direction that is opposite said one direction during an oscillation of said airfoil portions in the moving fluid stream, which oscillation is operative to cause said sleeve to pivot back and forth; and

wherein said pivoting movement of said sleeve is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches.

9. The apparatus of claim 8 wherein a second hinge is mounted on said rear edge and said apparatus further comprises:

a third airfoil portion that is attached to said second hinge.

10. The apparatus of claim 9 further comprising:

a gear mechanism that links said first airfoil portion to said third airfoil portion.

11. The apparatus of claim 9 further comprising:

a linkwork mechanism that links said first airfoil portion to said third airfoil portion.

12. The apparatus of claim 8 wherein each of said airfoil portions comprises a framed sheet.

13. The apparatus of claim 8 wherein each of said airfoil portions comprises a ribbed airfoil.

14. The apparatus of claim 8 wherein said second airfoil portion is tapered along its height.

15. The apparatus of claim 8 wherein each of said airfoil portions comprises a plurality of stacked elements.

16. An apparatus for extracting power from a moving fluid stream, said apparatus comprising:

a mast;

a first airfoil portion that is connected to said mast;

a second airfoil portion that is pivotably attached to said first airfoil portion by a hinge; and a power take-off mechanism that is driven either directly by a pivoting movement of said mast and said first airfoil portion or by a pivoting movement of said first airfoil portion with said mast remaining stationary;

wherein said airfoil portions are configured to, as a combination, present airfoil surfaces to the moving fluid stream that generate lift first in one direction that is transverse the direction of movement of the moving stream and then in another direction that is opposite said one direction during an oscillation of said airfoil portions in the moving fluid stream;

thereby maximizing the aerodynamic lift of said combination in the moving stream, which in turn maximizes the conversion of the energy of the moving stream into useful power.

17. The apparatus of claim 16 wherein said second airfoil portion comprises a weight.

18. An apparatus for extracting power from a moving fluid stream, said apparatus comprising:

a mast assembly;

a leading airfoil portion having a leading edge that is connected to said mast assembly and a following edge;

a plurality of following airfoil portions, each of which has a front edge and a rear edge, the front edge of a first of said following airfoil portions being pivotably attached to the following edge of said leading airfoil portion, and the front edge of each other following airfoil portion being pivotably attached to the rear end of another following airfoil portion; and

a power take-off mechanism that is driven either directly by a pivoting movement of said mast and said first airfoil portion or by a pivoting movement of said first airfoil portion with said mast remaining stationary;

wherein said airfoil portions are configured to, in combination, present airfoil surfaces to the moving fluid stream that generate lift first in one direction that is transverse the direction of movement of the moving stream and then in another direction that is opposite said one direction during an oscillation of said airfoil portions in the moving fluid stream.

19. The apparatus of claim 18 further comprising:

a gear arrangement or a linkwork arrangement that links said leading airfoil portion and a third following airfoil portion.

20. The apparatus of claim 18 further comprising:

a gear arrangement or a linkwork arrangement that links said second following airfoil portion and a fourth following airfoil portion.

21. The apparatus of claim 19 further comprising:

a first link arm having that is fixed to said leading airfoil portion, said first link arm having a first end;

a second link arm that is fixed to said third following airfoil portion, said second link arm having a second end; and

a lever arm that links said first end to said second end.

22. The apparatus of claim 18 further comprising:

a pair of overrunning clutches, a drive shaft that is connected to said pair of overrunning clutches, a gearbox that is connected to said drive shaft and a generator that is connected to said gear box;

wherein said moving fluid stream is operative to cause said mast to pivot back and forth; and

wherein said pivoting movement of said mast is converted to rotational movement of said drive shaft in a single direction by means of said pair of overrunning clutches.

23. The apparatus of claim 18 further comprising:

a crank arm that is connected to said first airfoil portion and to said power take-off mechanism;

wherein pivoting movement of said first airfoil portion is converted into longitudinal back and forth movement of said crank arm.

24. A method of generating power comprising:

placing the apparatus of claim 5 in a location that experiences a sustained wind;

initiating the fluttering of said leading element and said trailing element which causes said sleeve to move back and forth;

converting the back and forth movement into rotation of said drive shaft to produce motive power; and

providing said motive power to a generator.

25. A method of generating power comprising:

the step of placing the apparatus of claim 2 in a location that experiences a wind;

the step of allowing the combination of said stand-off arms and said symmetrical airfoil to flutter in said wind, causing said sleeve to pivot back and forth;

the step of converting the back and forth movement into the rotation of said drive shaft; and

the step of providing motive power to a generator by means of said rotating drive shaft.

26. A method of harvesting energy from the wind, said method comprising:

producing a leading element and a following element;

joining said elements with a hinge to produce a combination having cross-sectional shape that maximizes the aerodynamic lift on said combination;

fixing a combination to a mast to produce a wind fin structure;

exposing said wind fin structure to the wind to produce oscillation, thereby causing said mast to pivot back and forth at an oscillating frequency;

converting the back and forth movement into rotation of a drive shaft to produce motive power; and

providing said motive power to a generator.

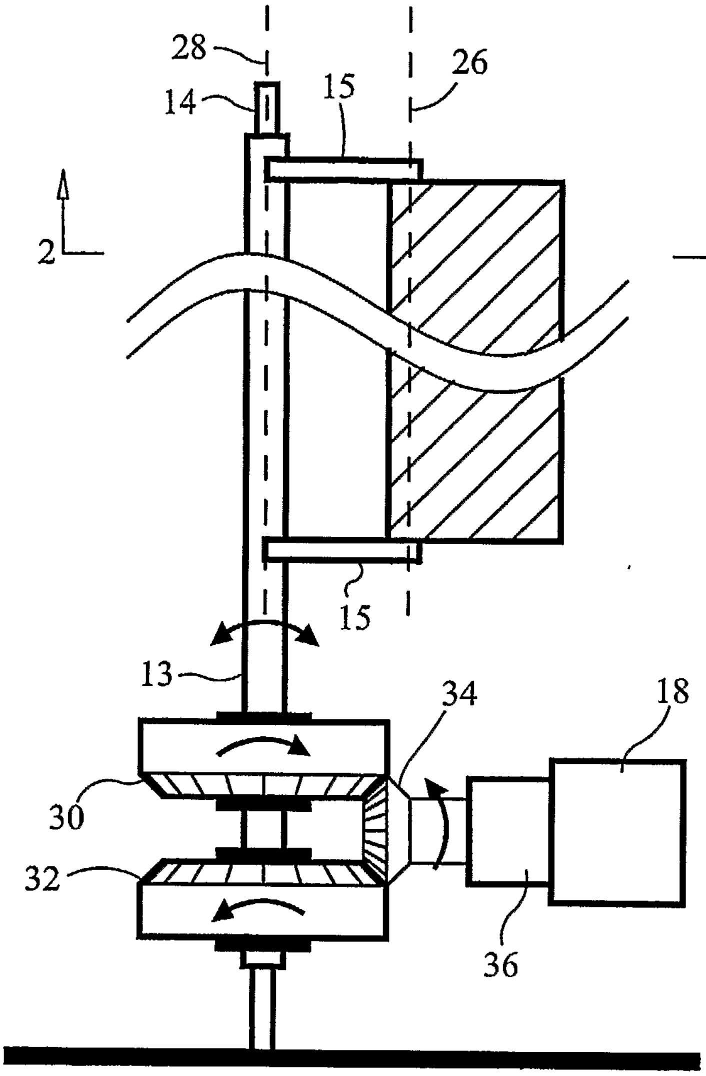


FIG. 1

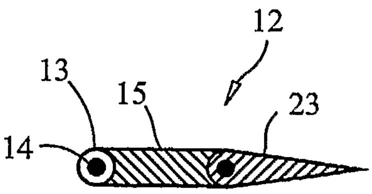


FIG. 2A

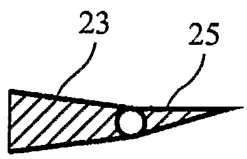


FIG. 2B

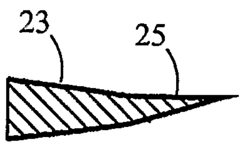


FIG. 2C

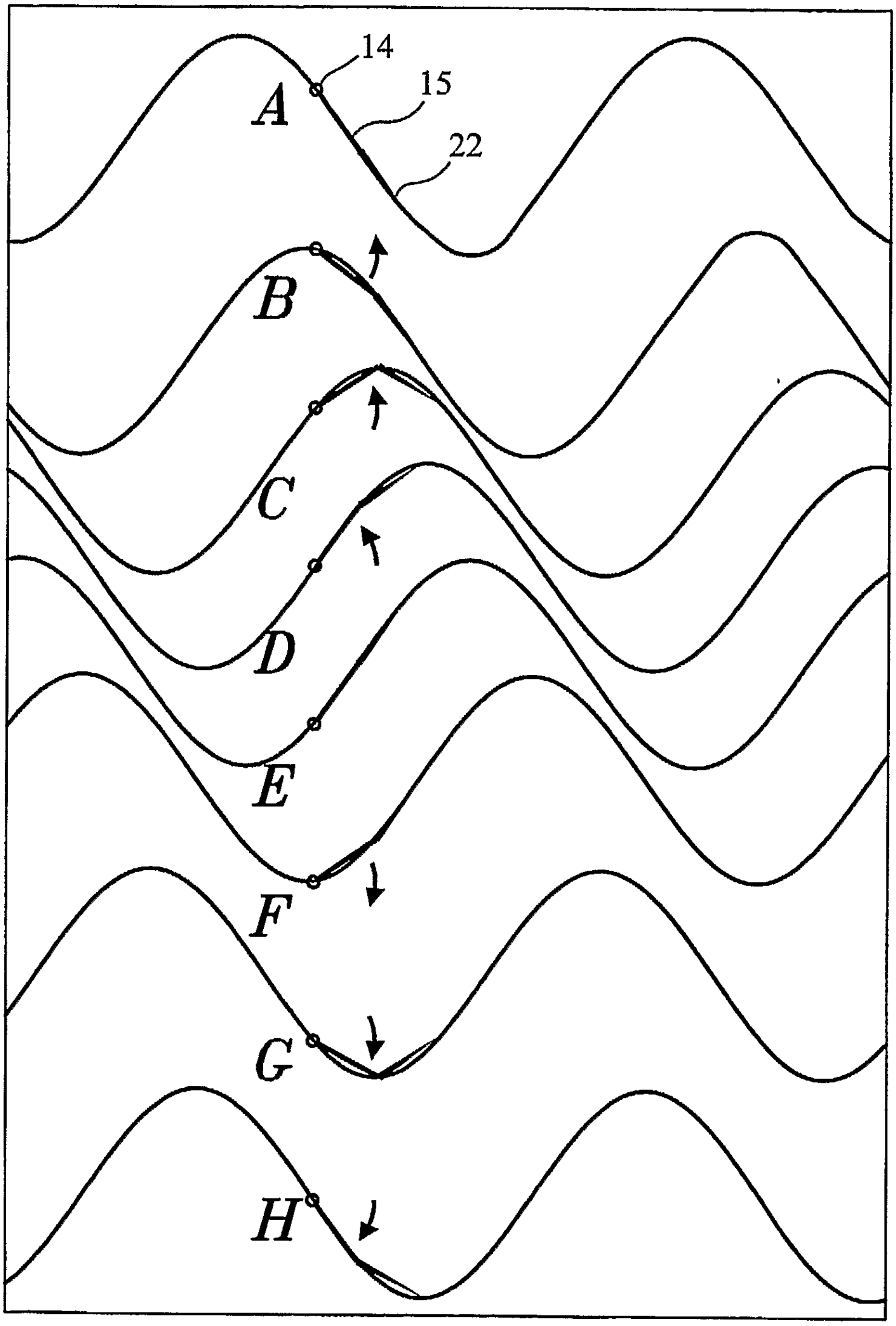


FIG. 3

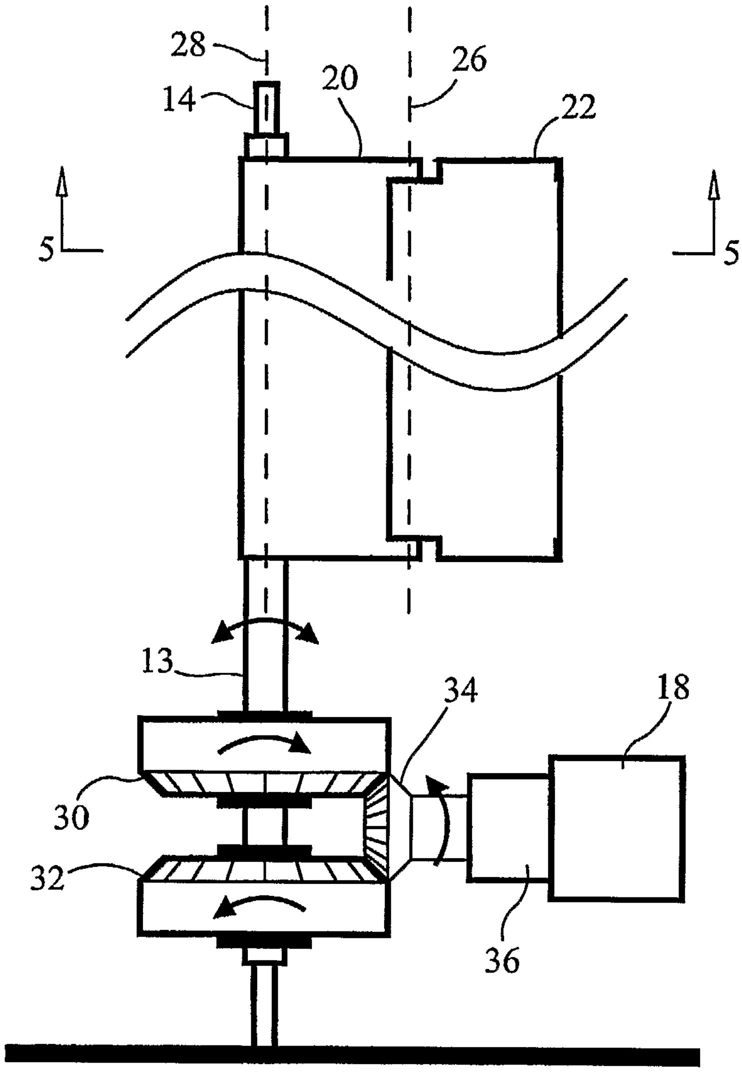


FIG. 4

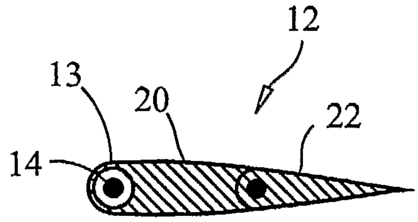


FIG. 5

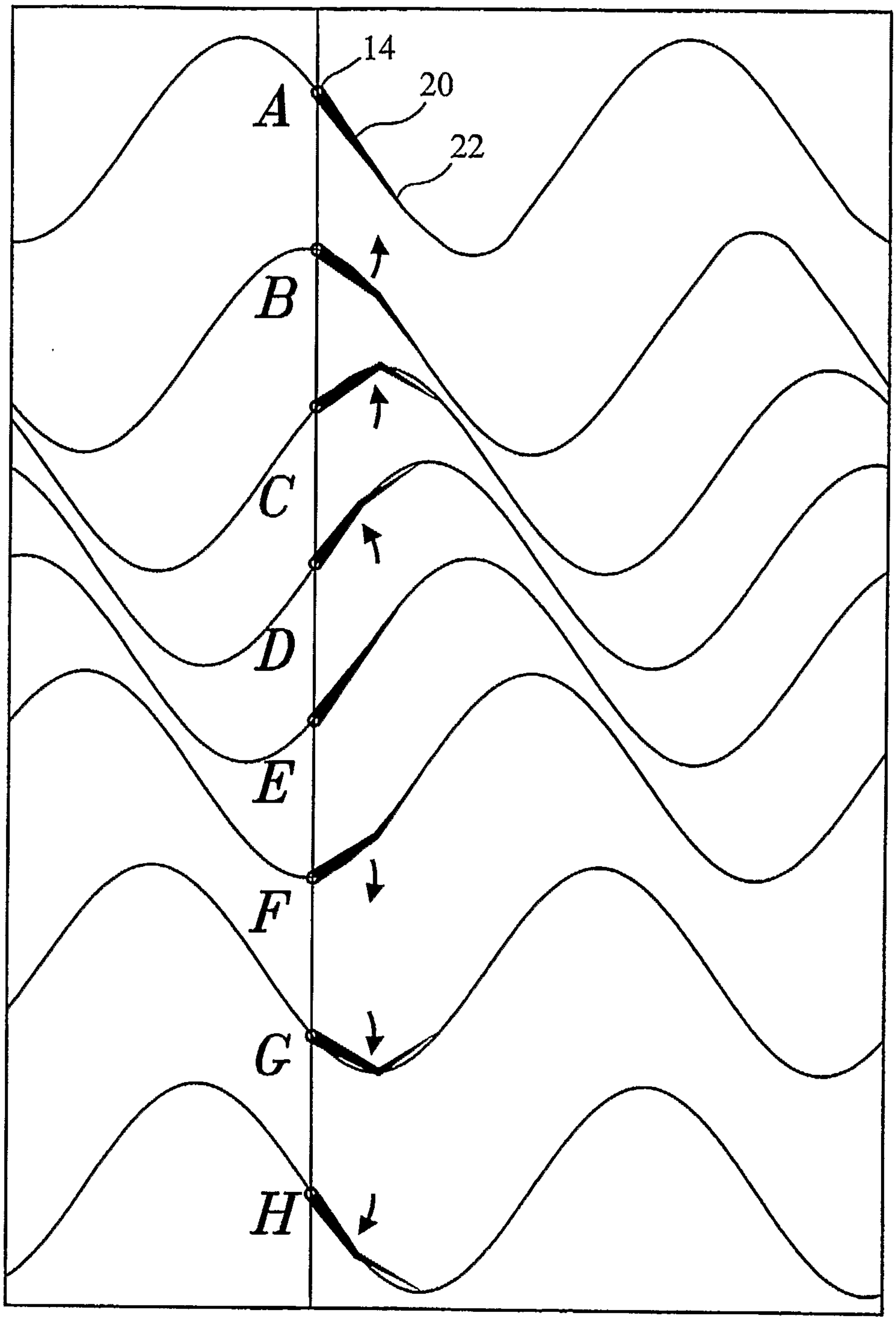


FIG. 6

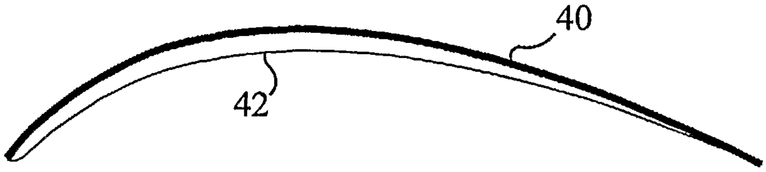


FIG. 7

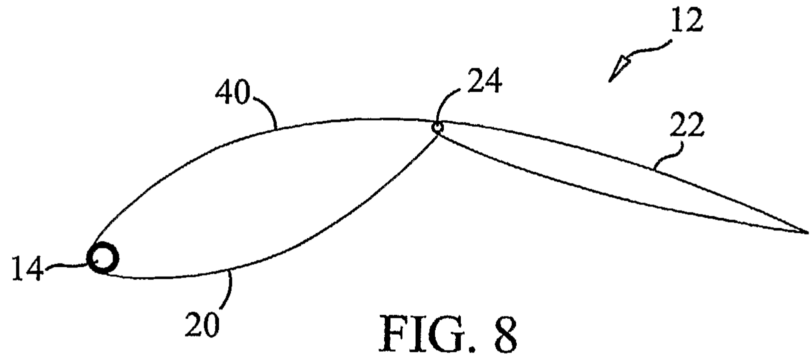


FIG. 8

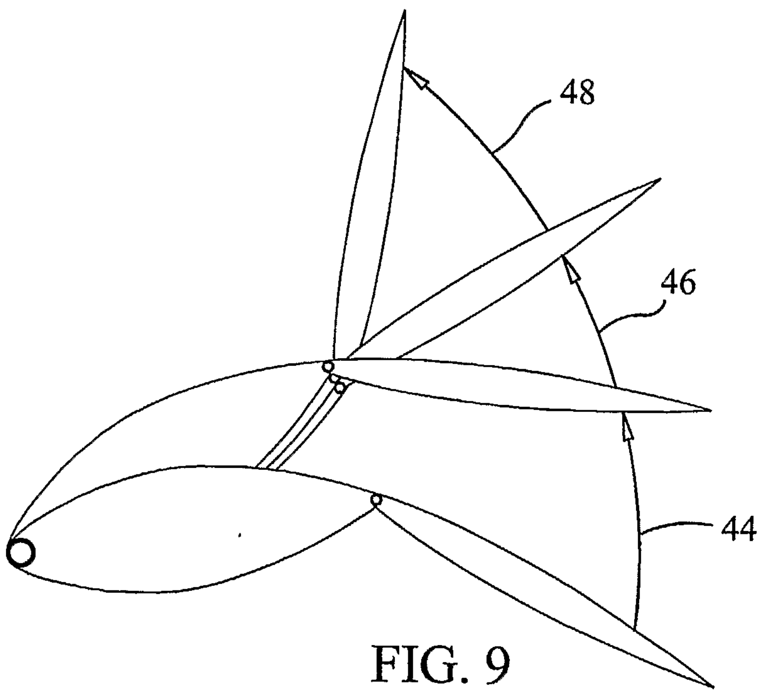


FIG. 9

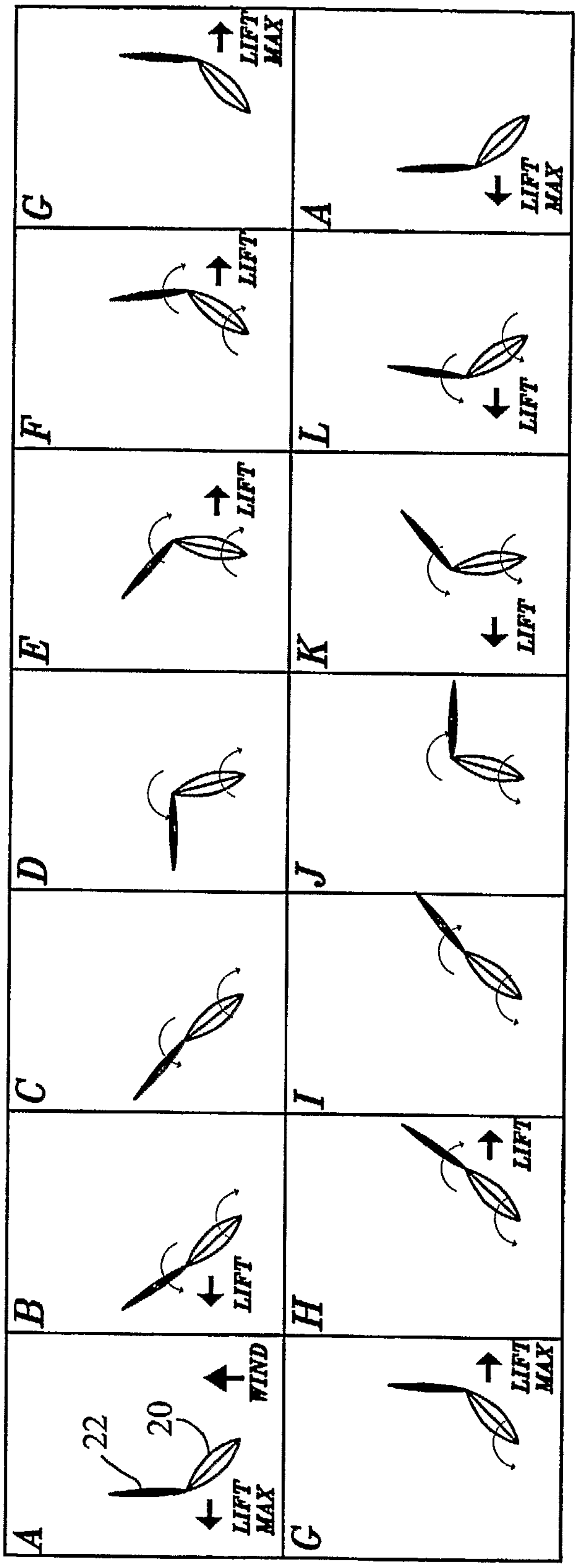

A
22
20
LIFT
MAX
WIND
B
LIFT
C
D
E
LIFT
F
LIFT
G
LIFT
MAX
G
LIFT
MAX
H
LIFT
I
J
K
LIFT
L
LIFT
A
LIFT
MAX

FIG. 10

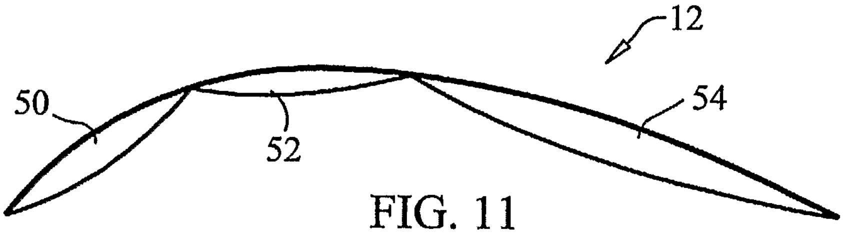


FIG. 11

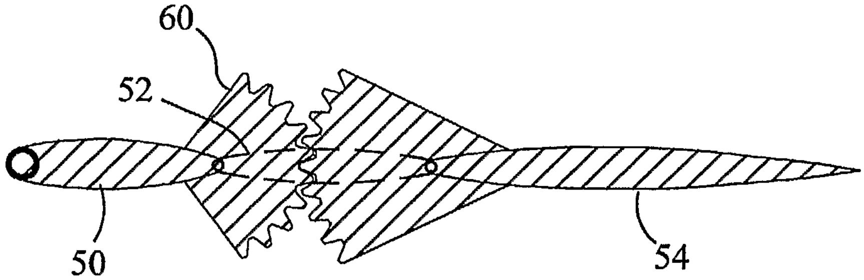


FIG. 12

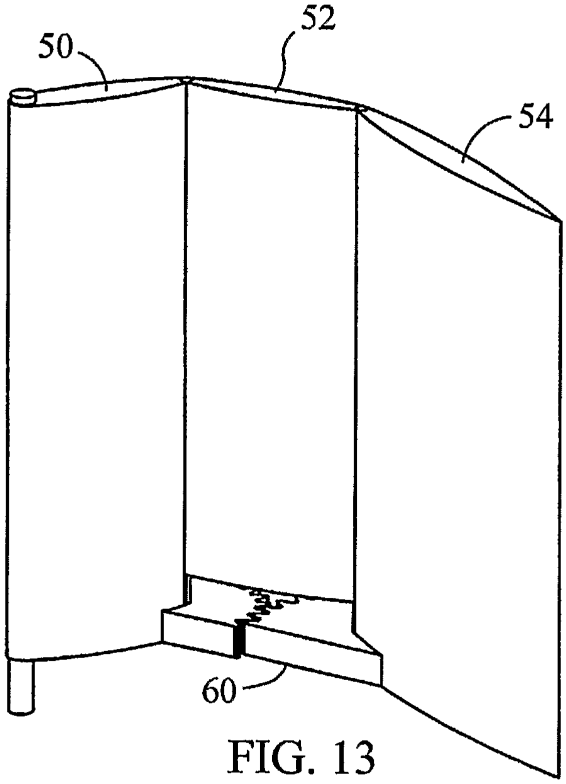


FIG. 13

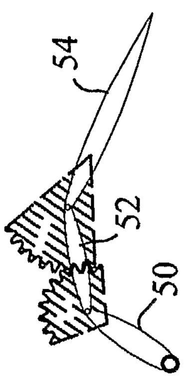


FIG. 14D

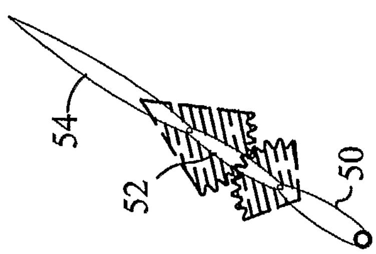


FIG. 14C

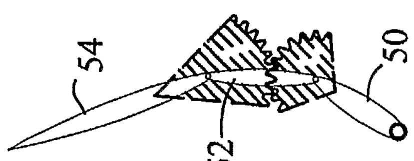


FIG. 14B

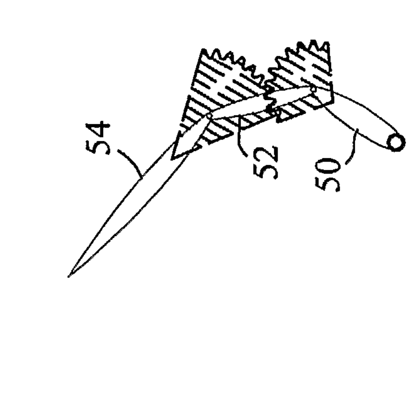


FIG. 14A

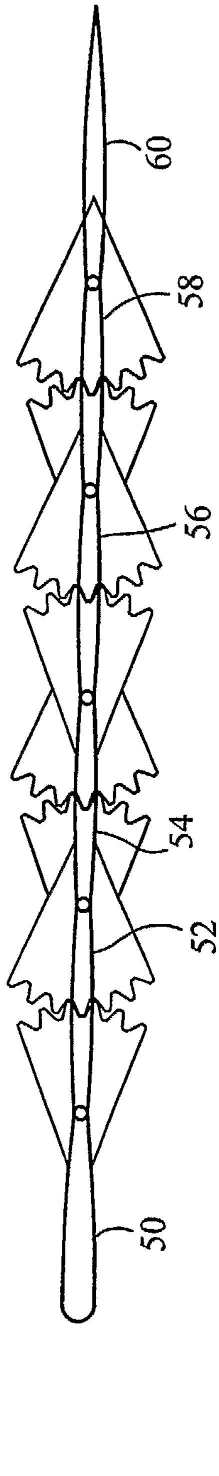


FIG. 15

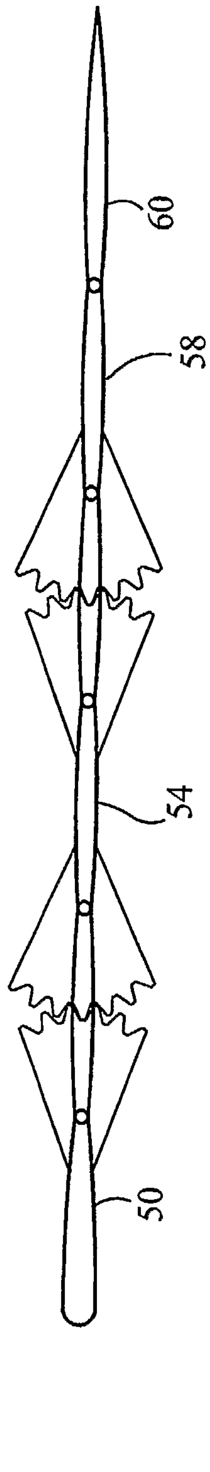


FIG. 16

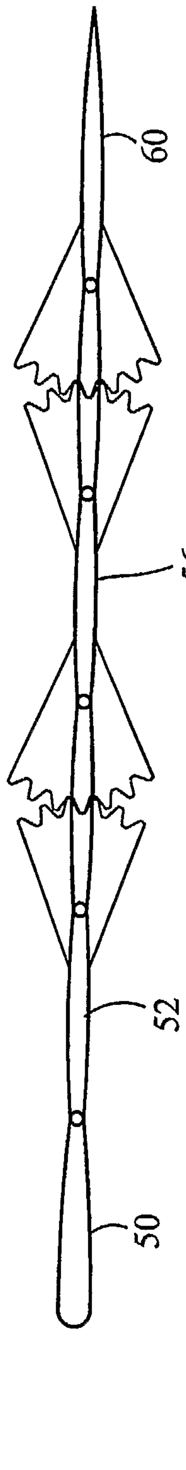


FIG. 17

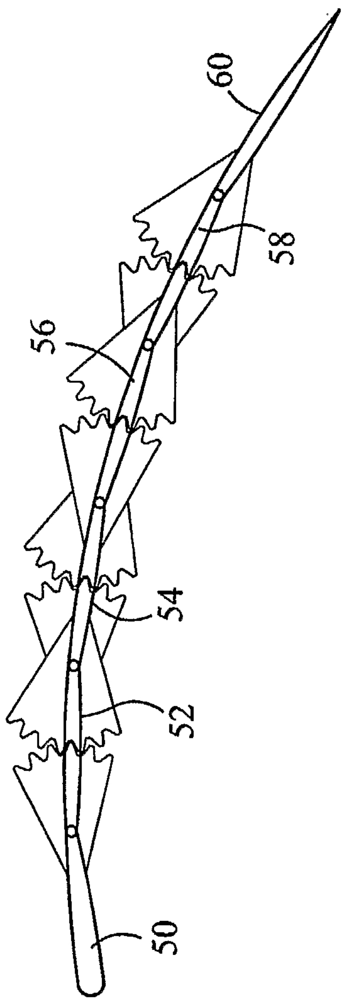


FIG. 18

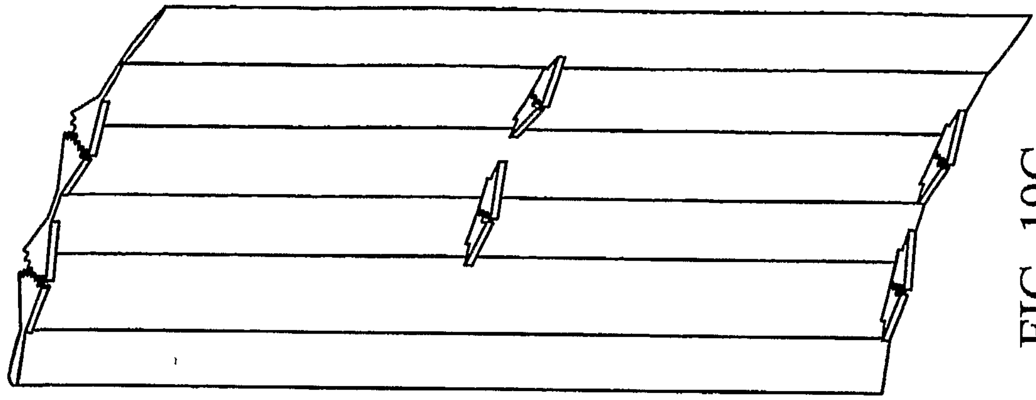


FIG. 19C

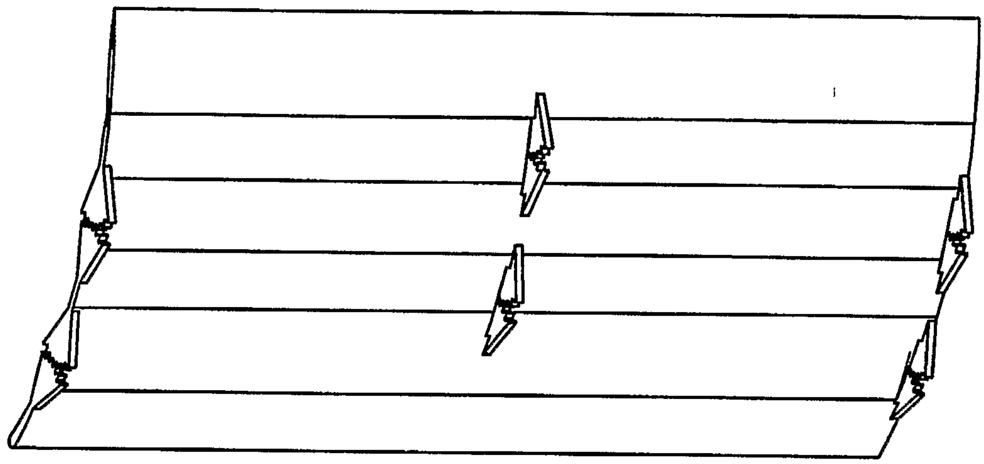


FIG. 19B

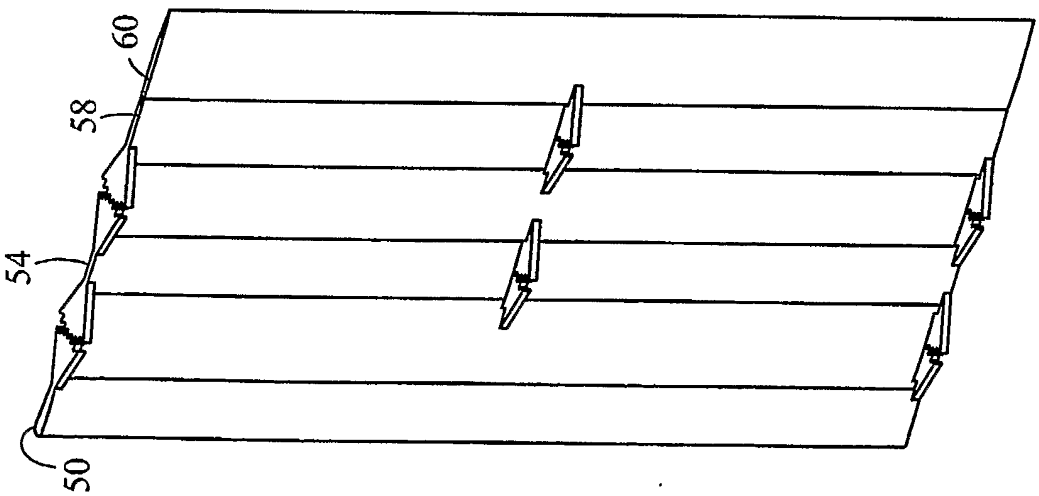


FIG. 19A

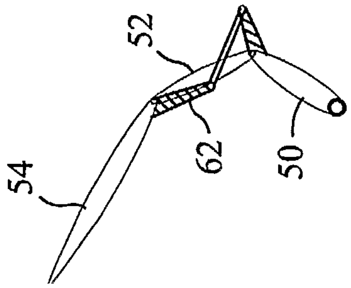


FIG. 20A

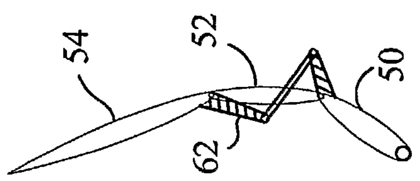


FIG. 20B

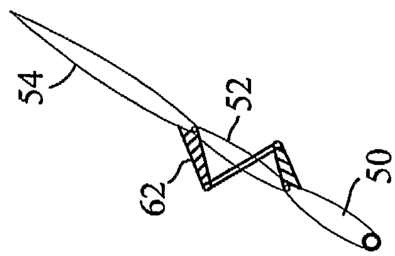


FIG. 20C

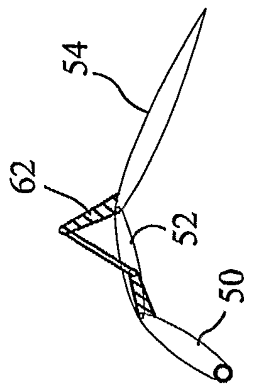


FIG. 20D

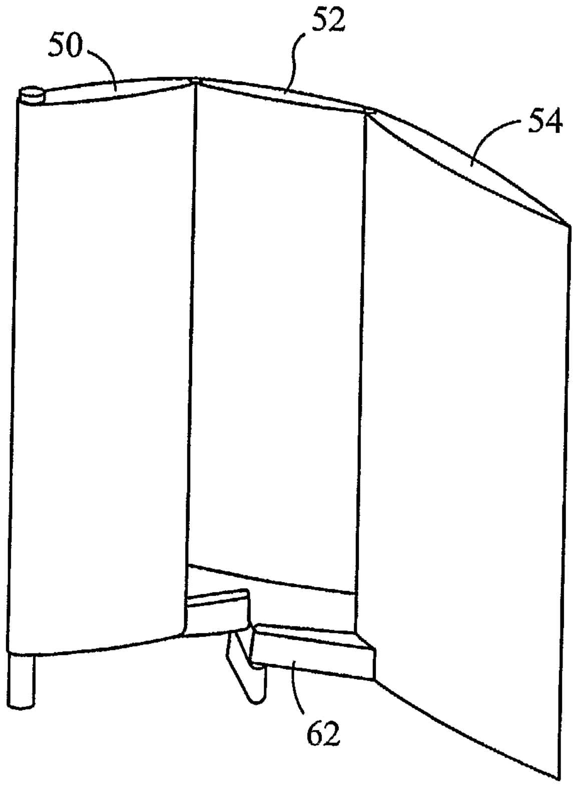


FIG. 21

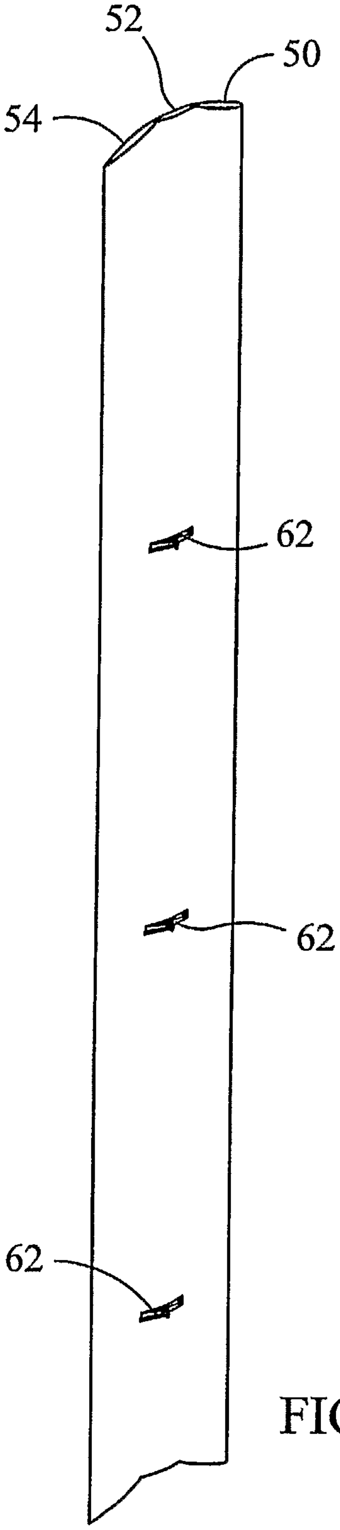


FIG. 22

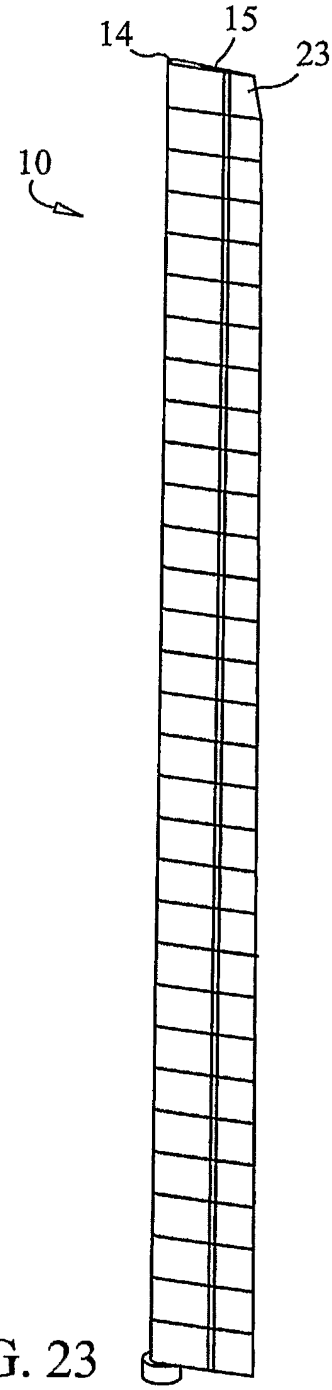


FIG. 23

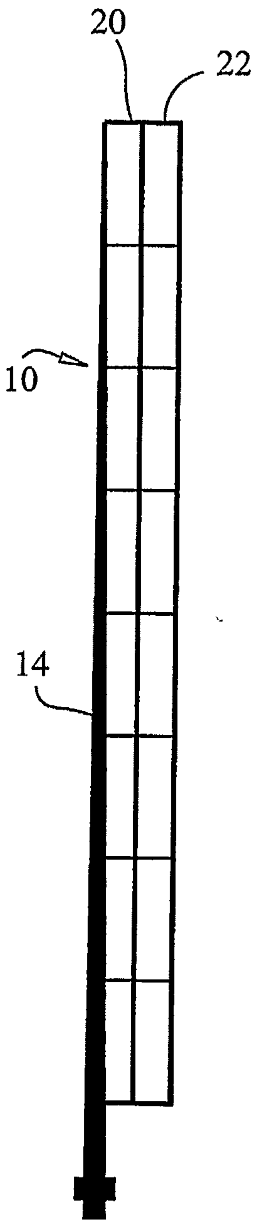


FIG. 24A

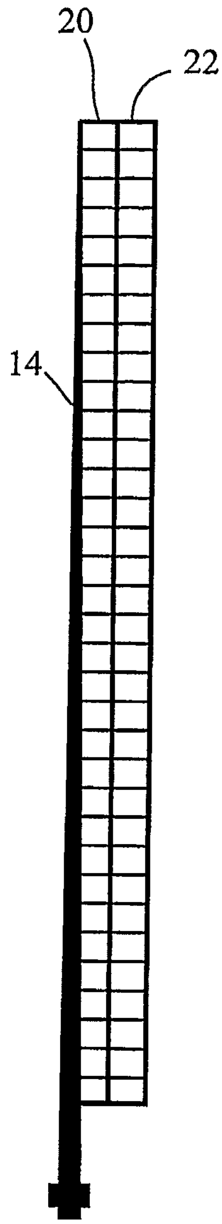


FIG. 24B

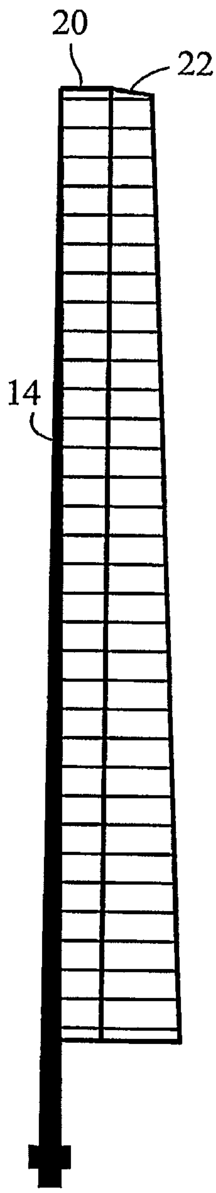


FIG. 24C

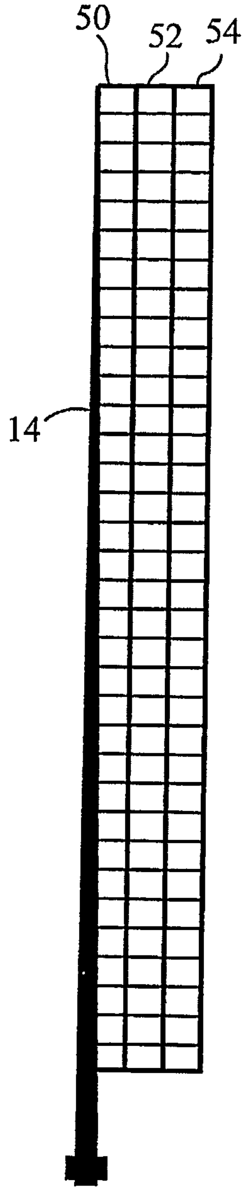


FIG. 24D

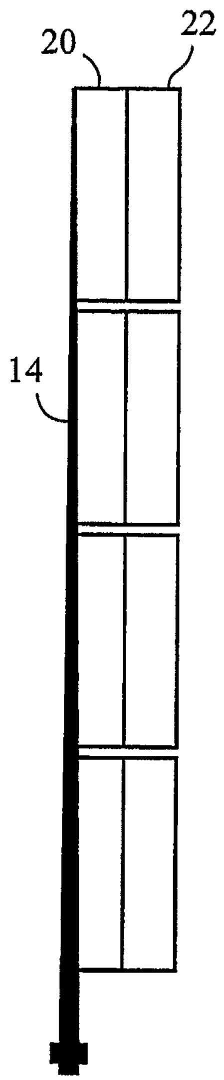


FIG. 24E

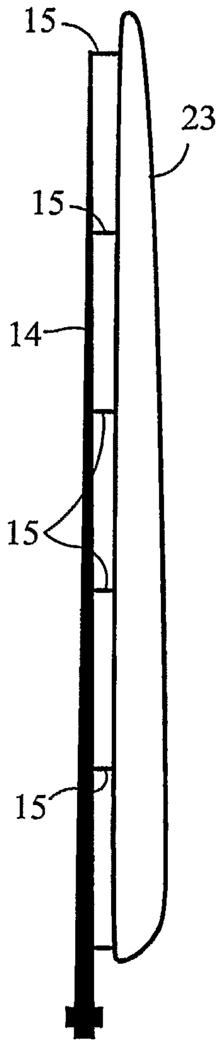


FIG. 24F

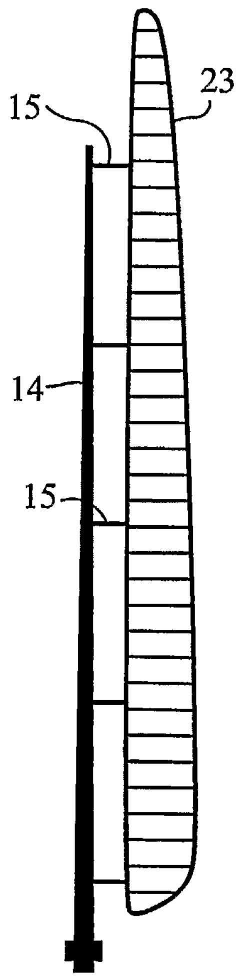


FIG. 24G

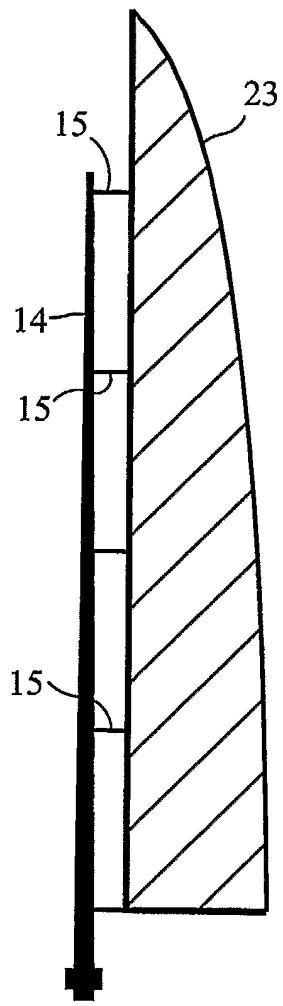


FIG. 24H

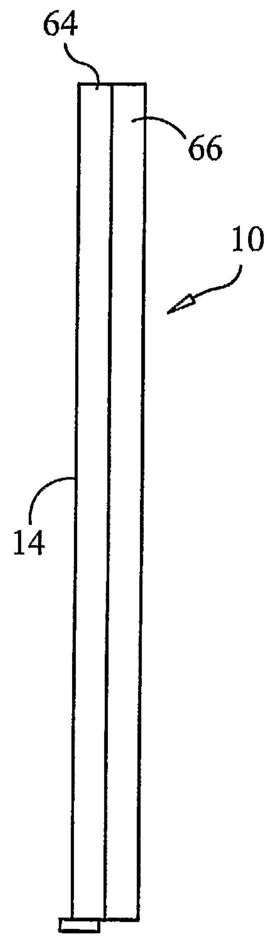


FIG. 25A

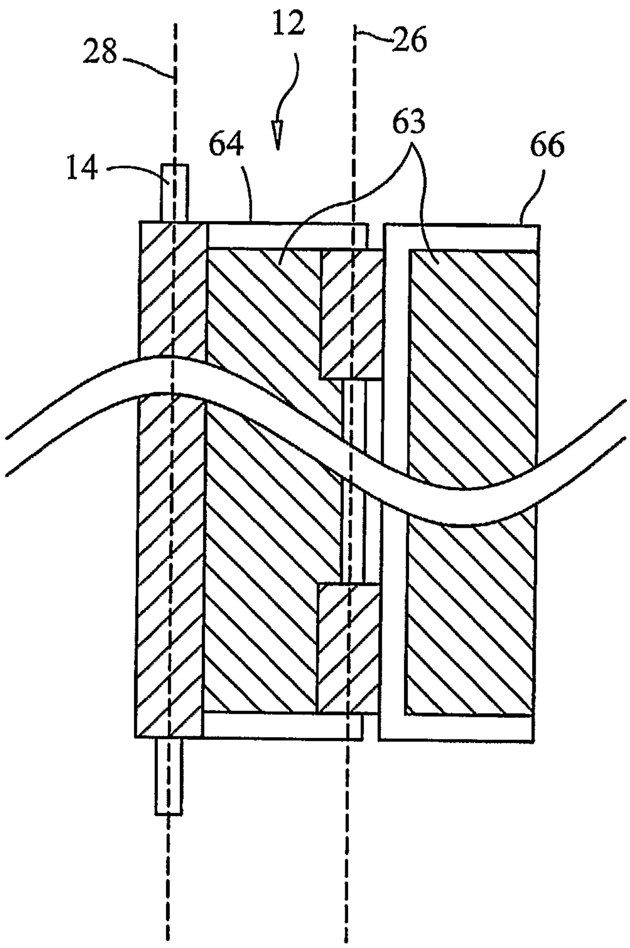


FIG. 25B

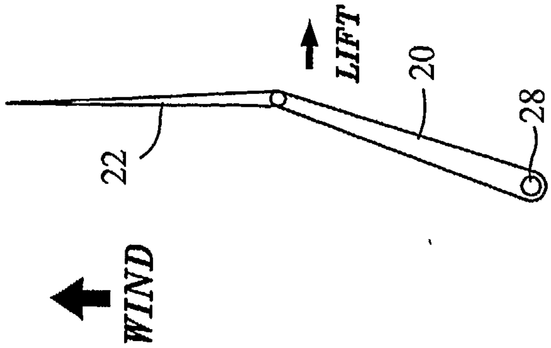


FIG. 30

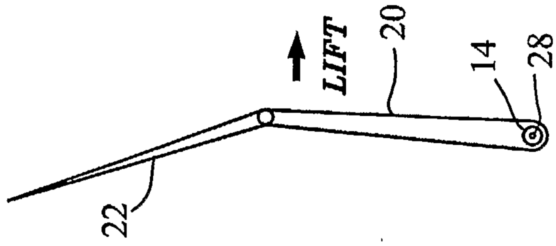


FIG. 29

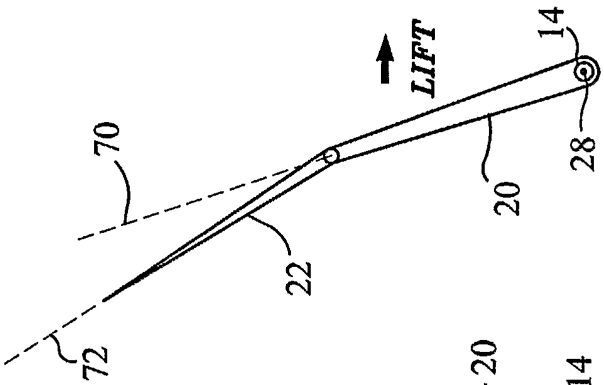


FIG. 28

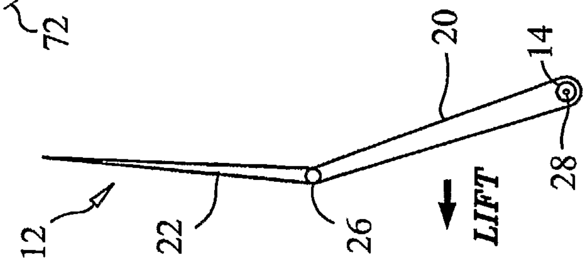


FIG. 27

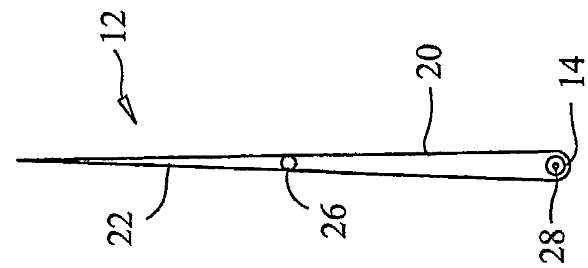


FIG. 26

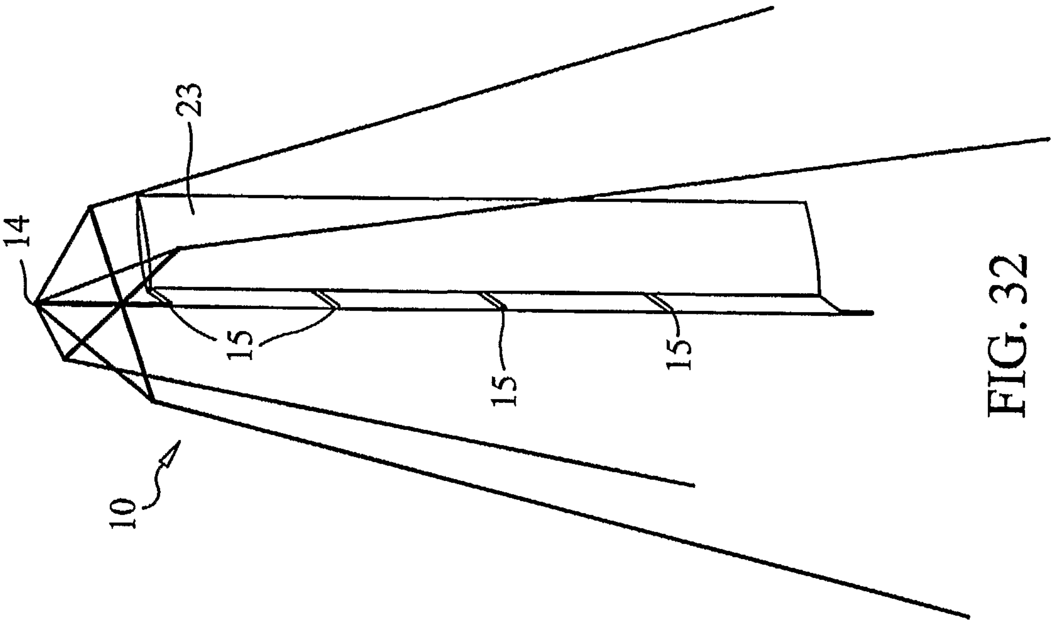


FIG. 32

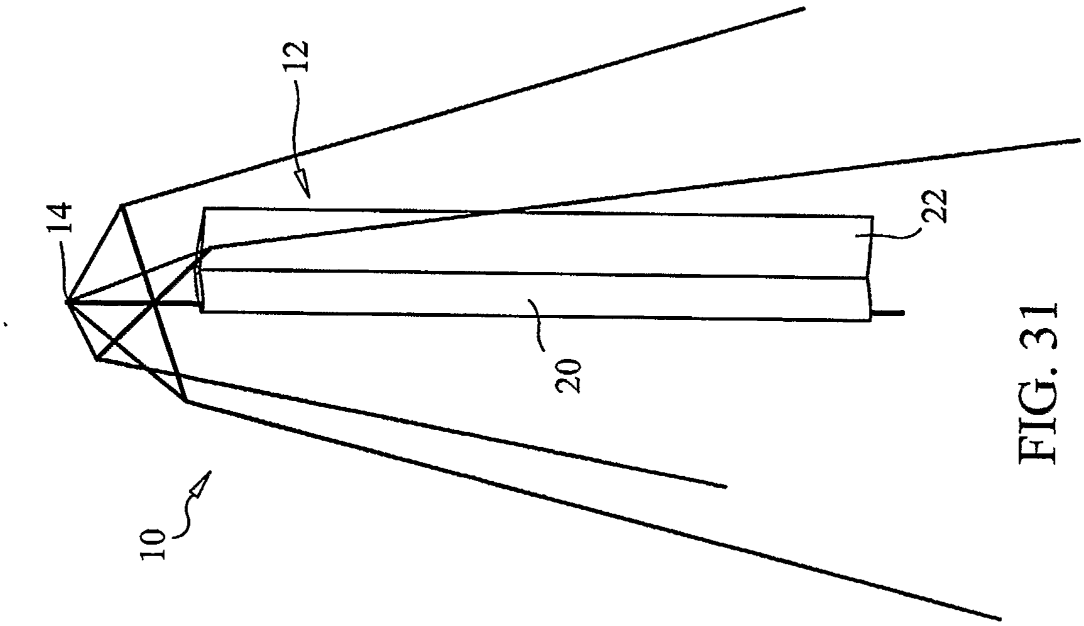


FIG. 31

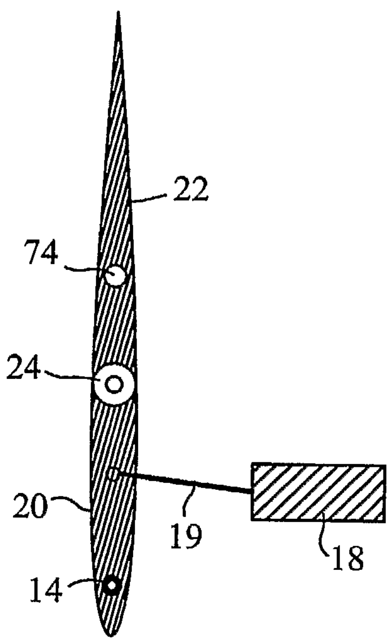


FIG. 33

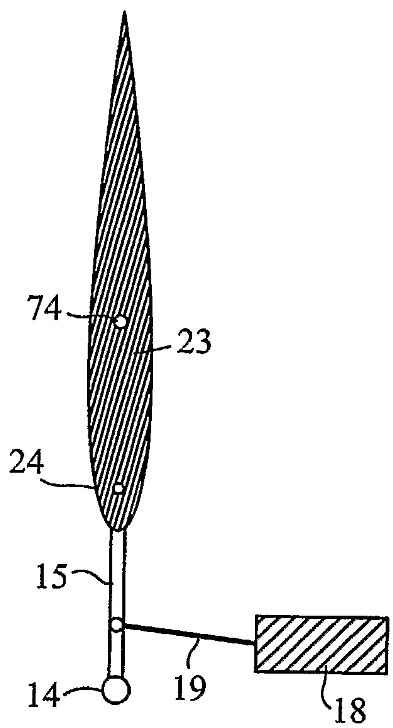


FIG. 34

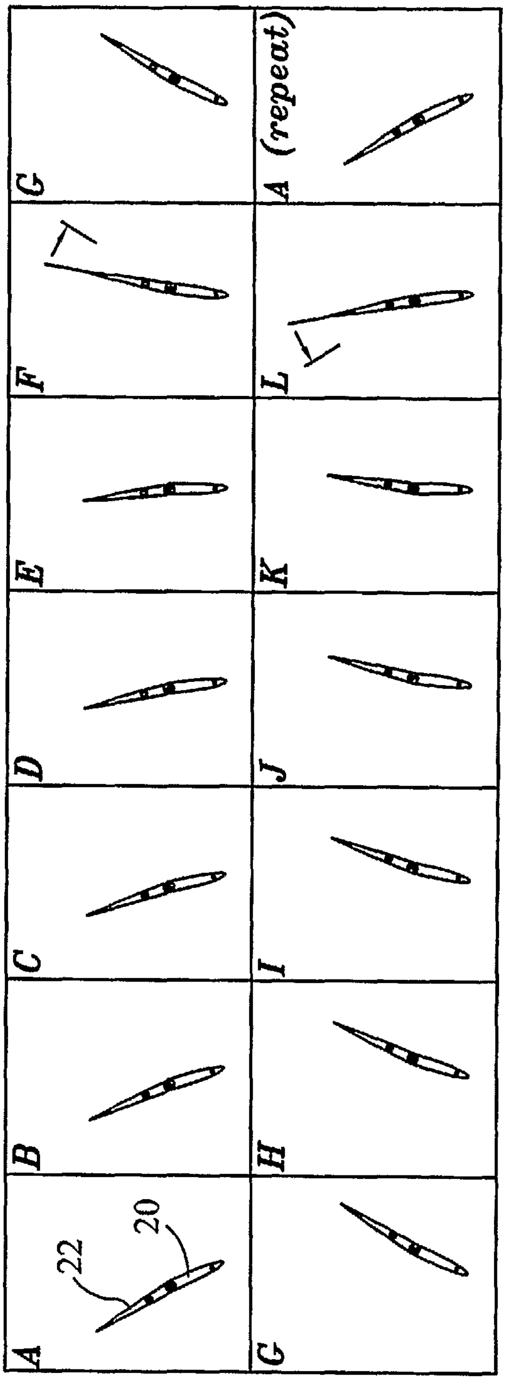


FIG. 35

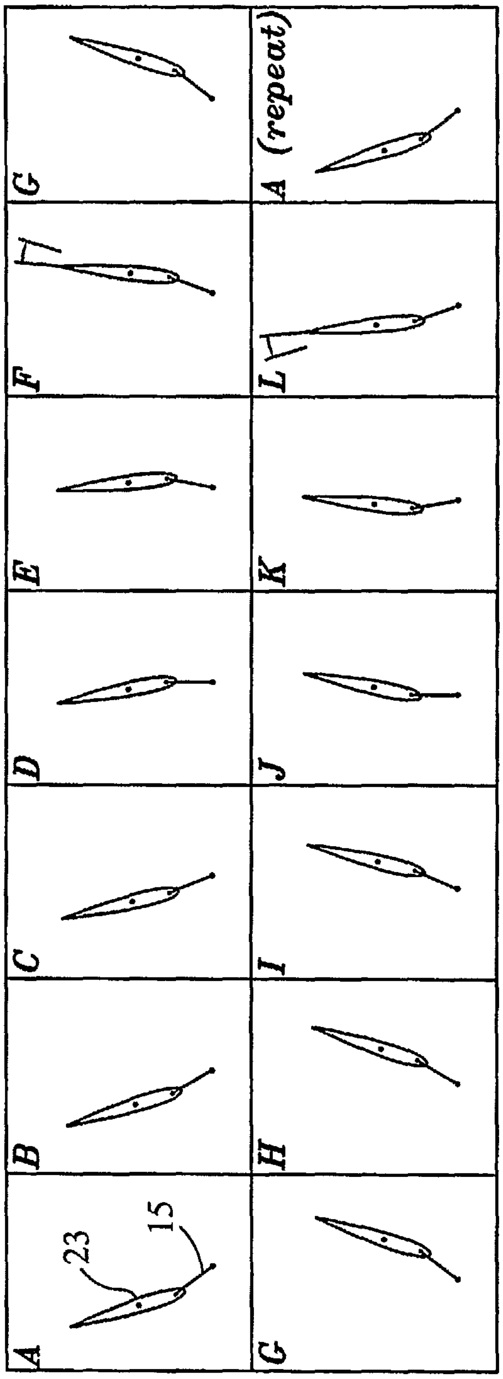


FIG. 36

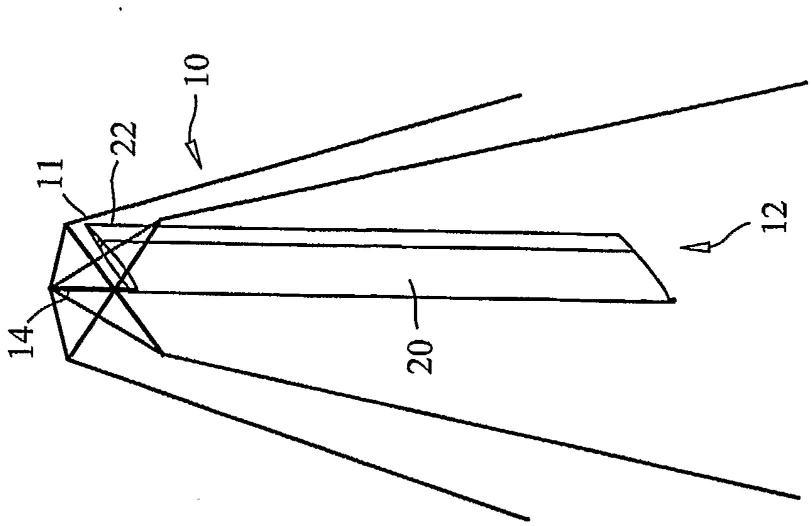


FIG. 38

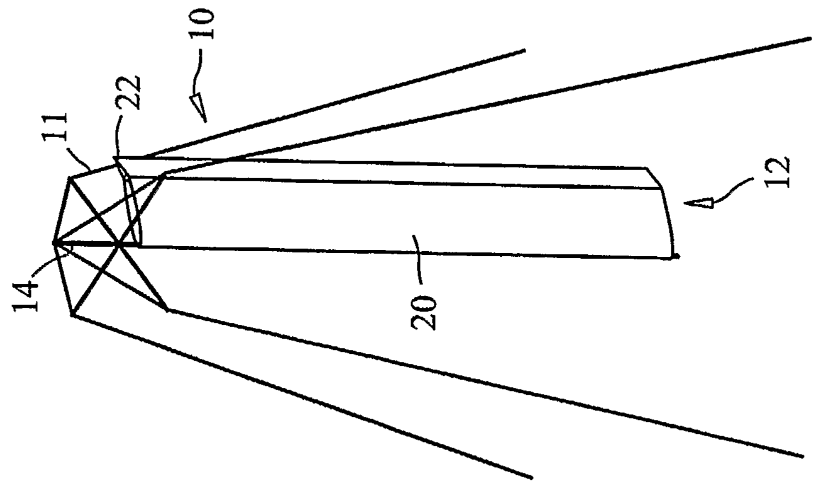


FIG. 37

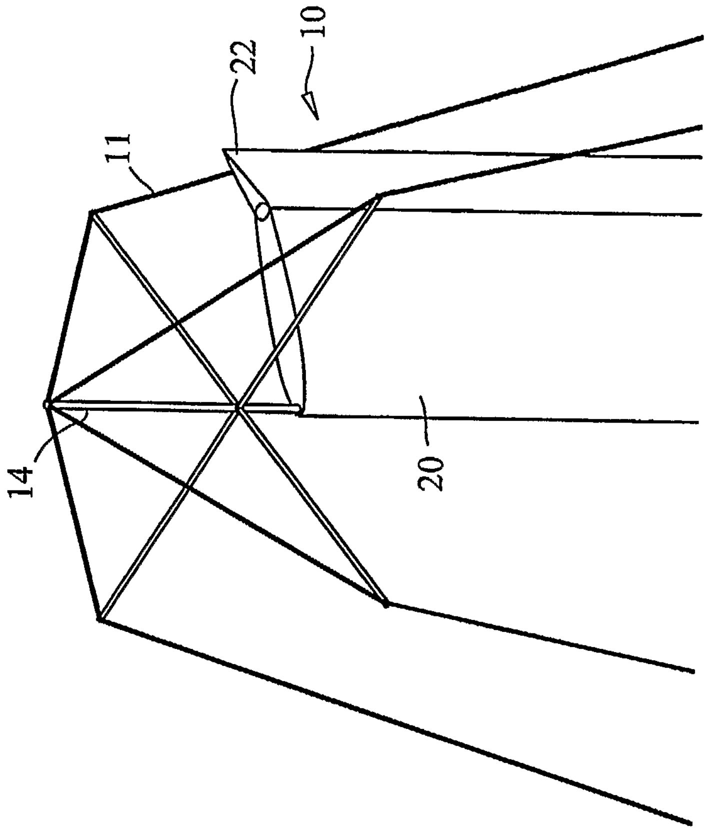


FIG. 40

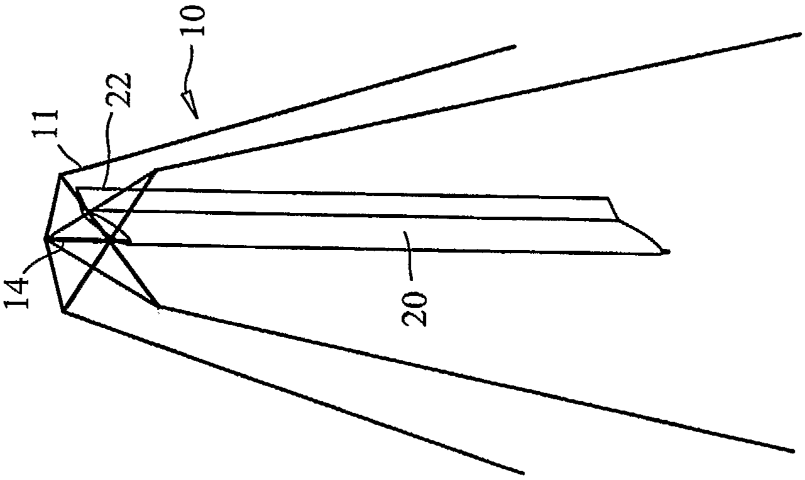


FIG. 39

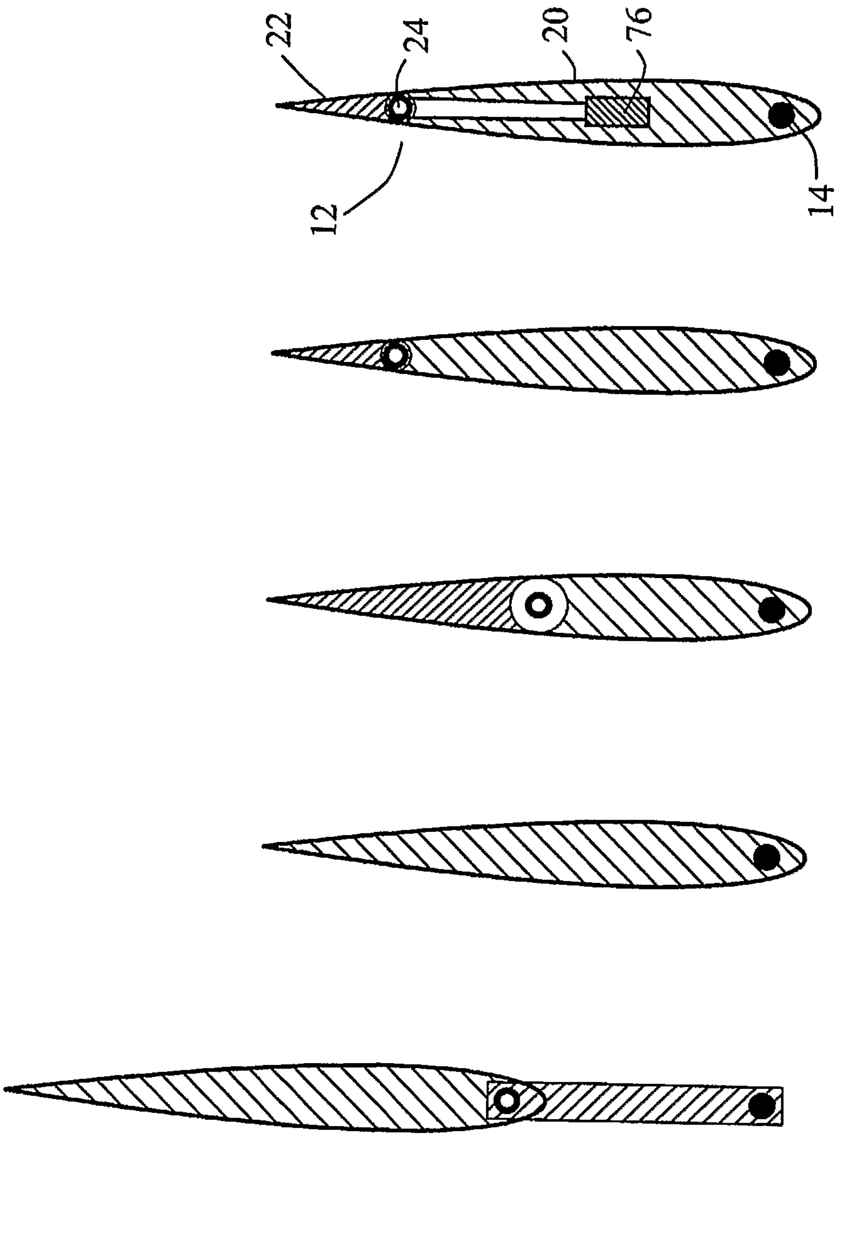


FIG. 41

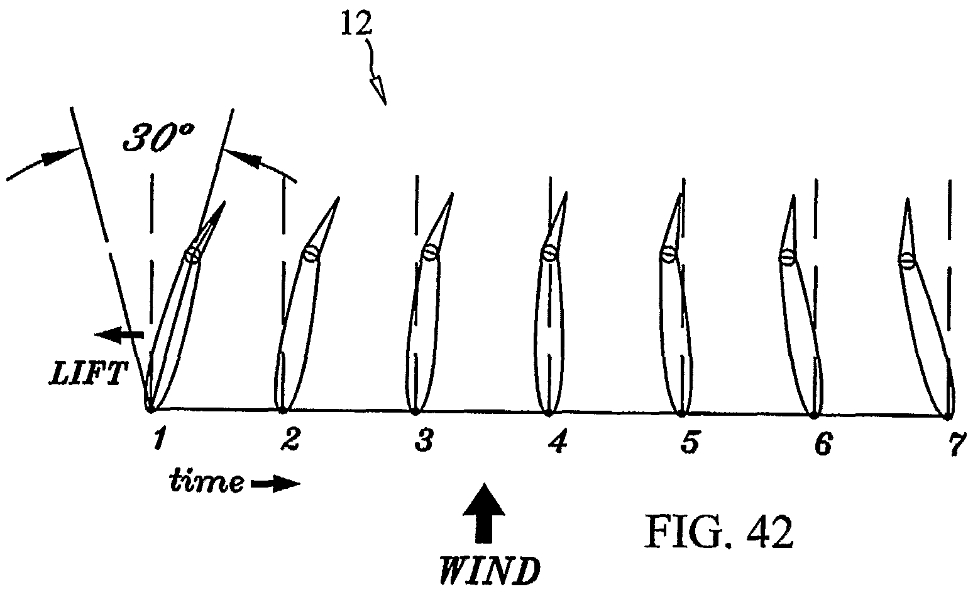


FIG. 42

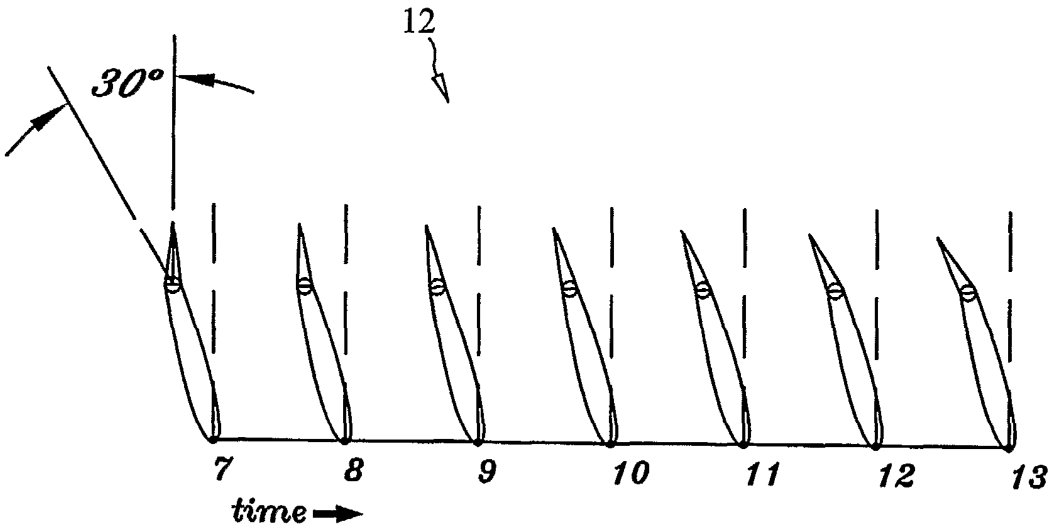


FIG. 43

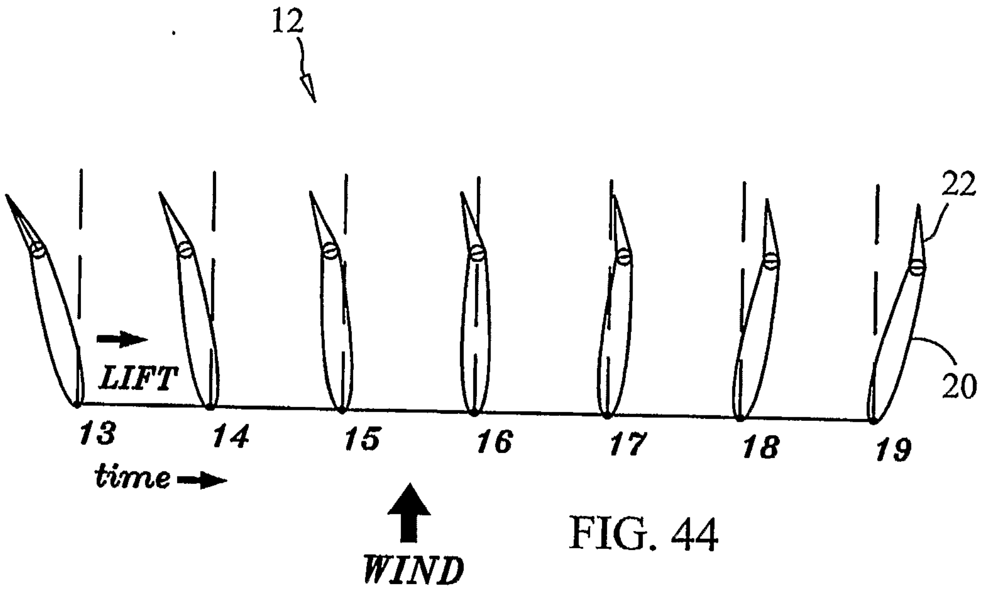

12
22
LIFT
20
13
14
15
16
17
18
19
time
WIND

FIG. 44

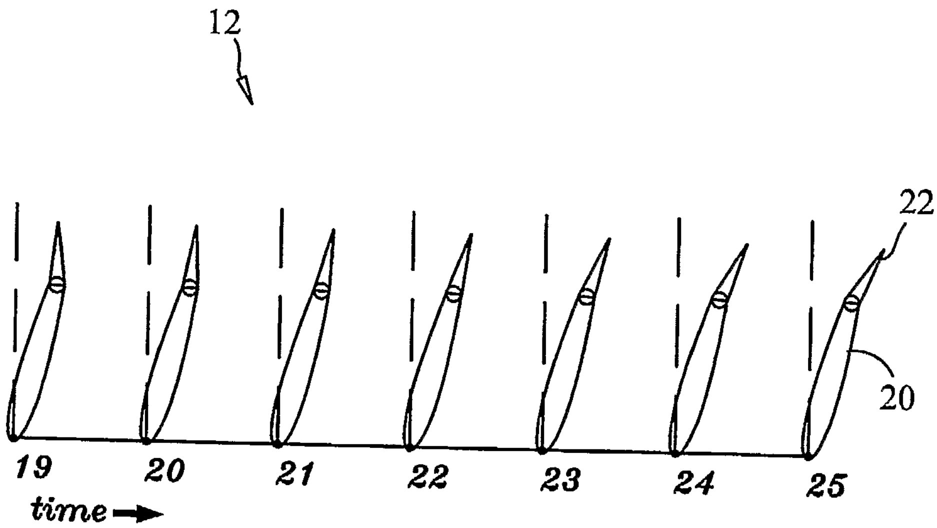

12
22
20
19
20
21
22
23
24
25
time

FIG. 45

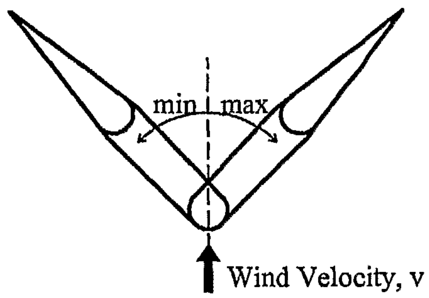


FIG. 46A

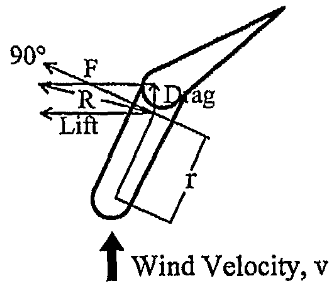


FIG. 46B

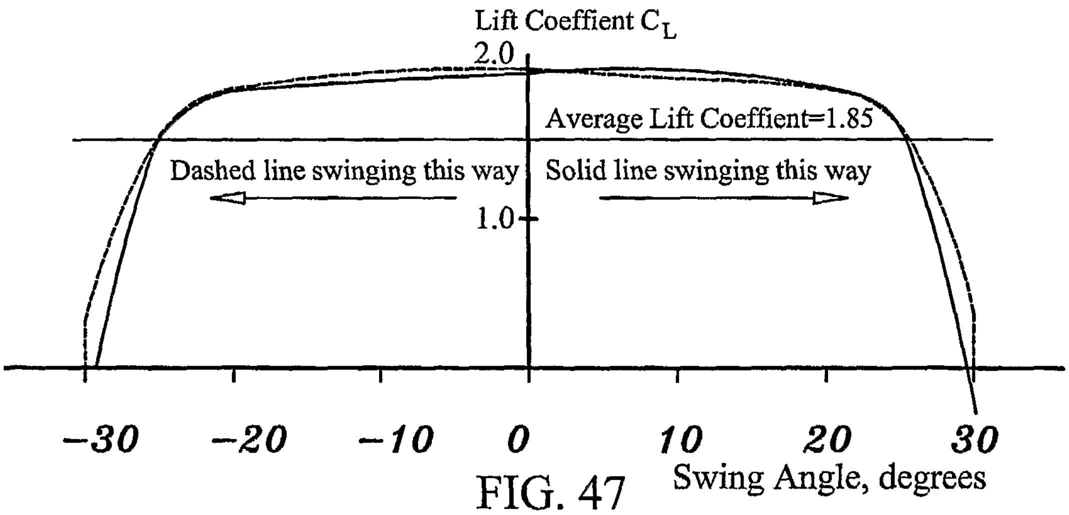


FIG. 47

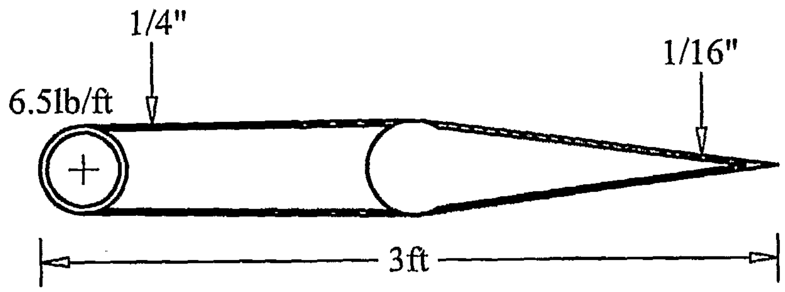


FIG. 48

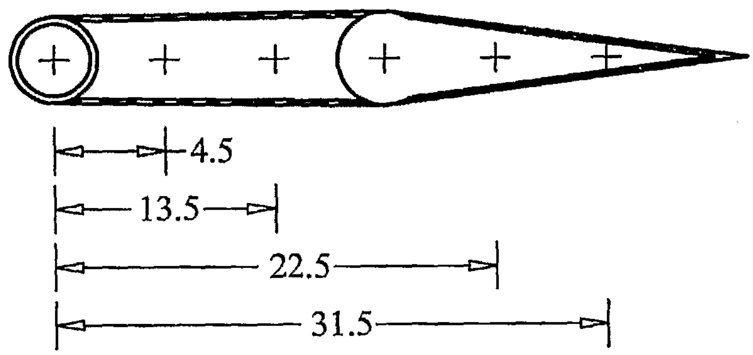


FIG. 49