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WO 2007/034193 A2 **DE 003232186 A1**
US 7188808 B1 **US 3987987 A**
US 20020040948 A1

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INT CL **F03B, F03D**
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(54) Abstract Title: **Power generator using oscillations of a kite**

(57) A wind energy device comprises a kite, which is controlled to follow a repeatable path of movement through the atmosphere, for example a figure-of-8 or circular path. This movement causes an angular oscillation in the tether 34, which is connected to a yoke 14 of an electric generator or hydraulic or pneumatic pumping mechanism 20A, 20B. The device can be used on land or could be mounted on a ship. Also disclosed is a lightening conductor comprising fullerenes, and a kite tether comprising fullerenes.

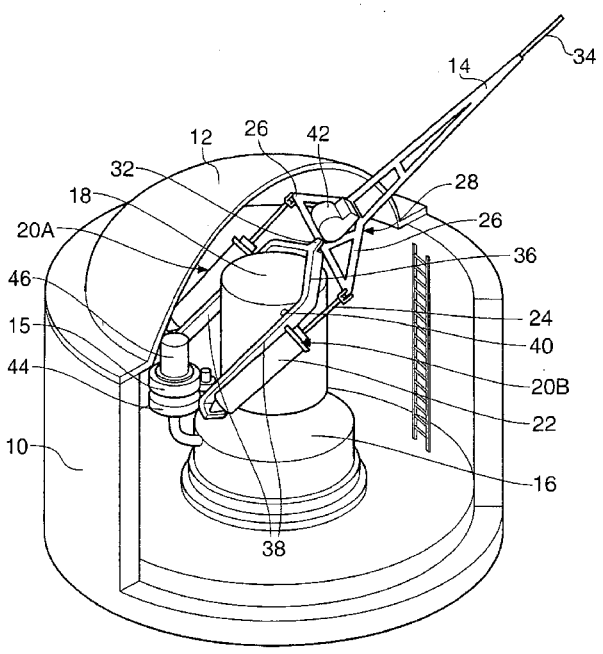

Fig. 1

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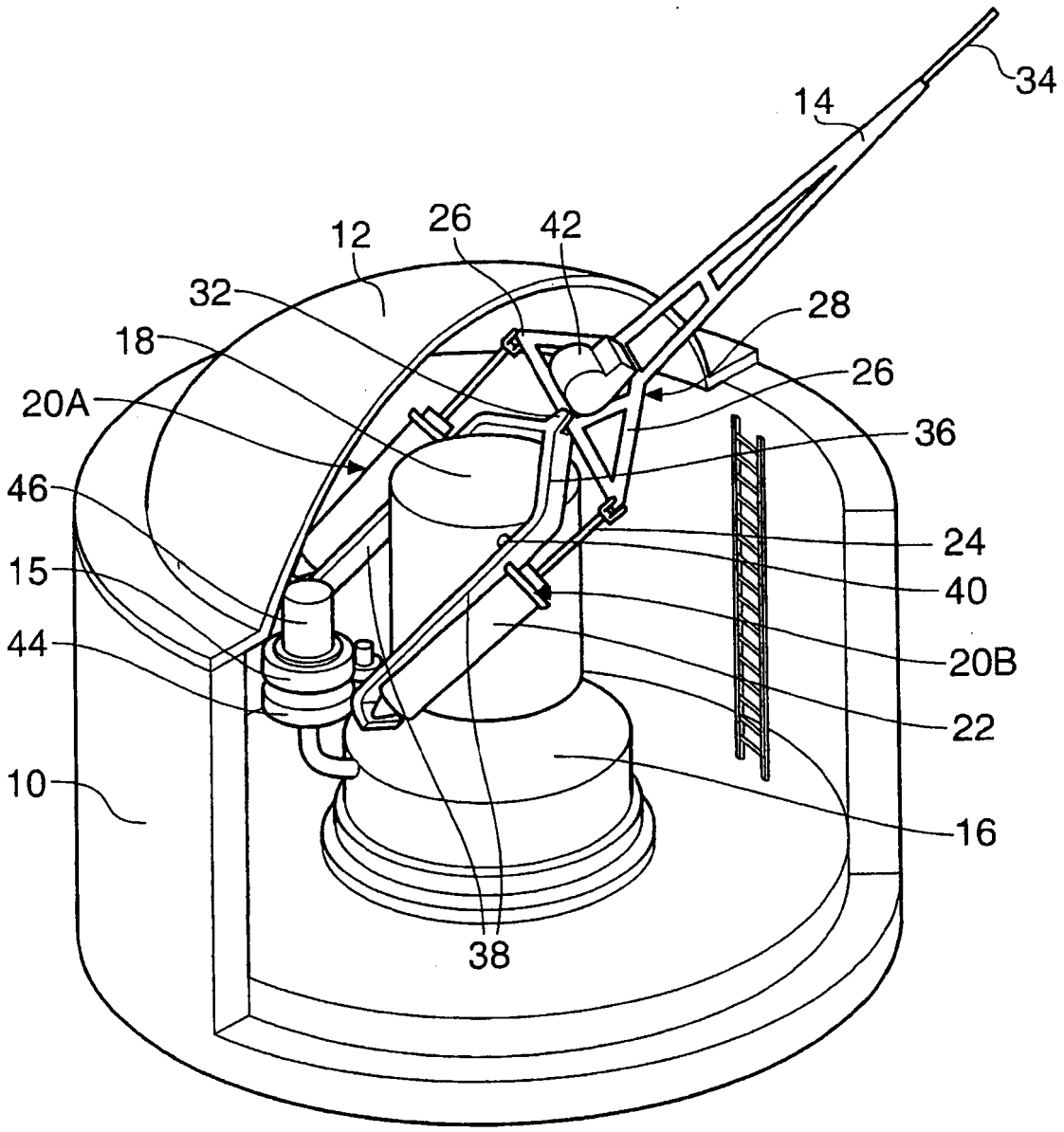


Fig. 1

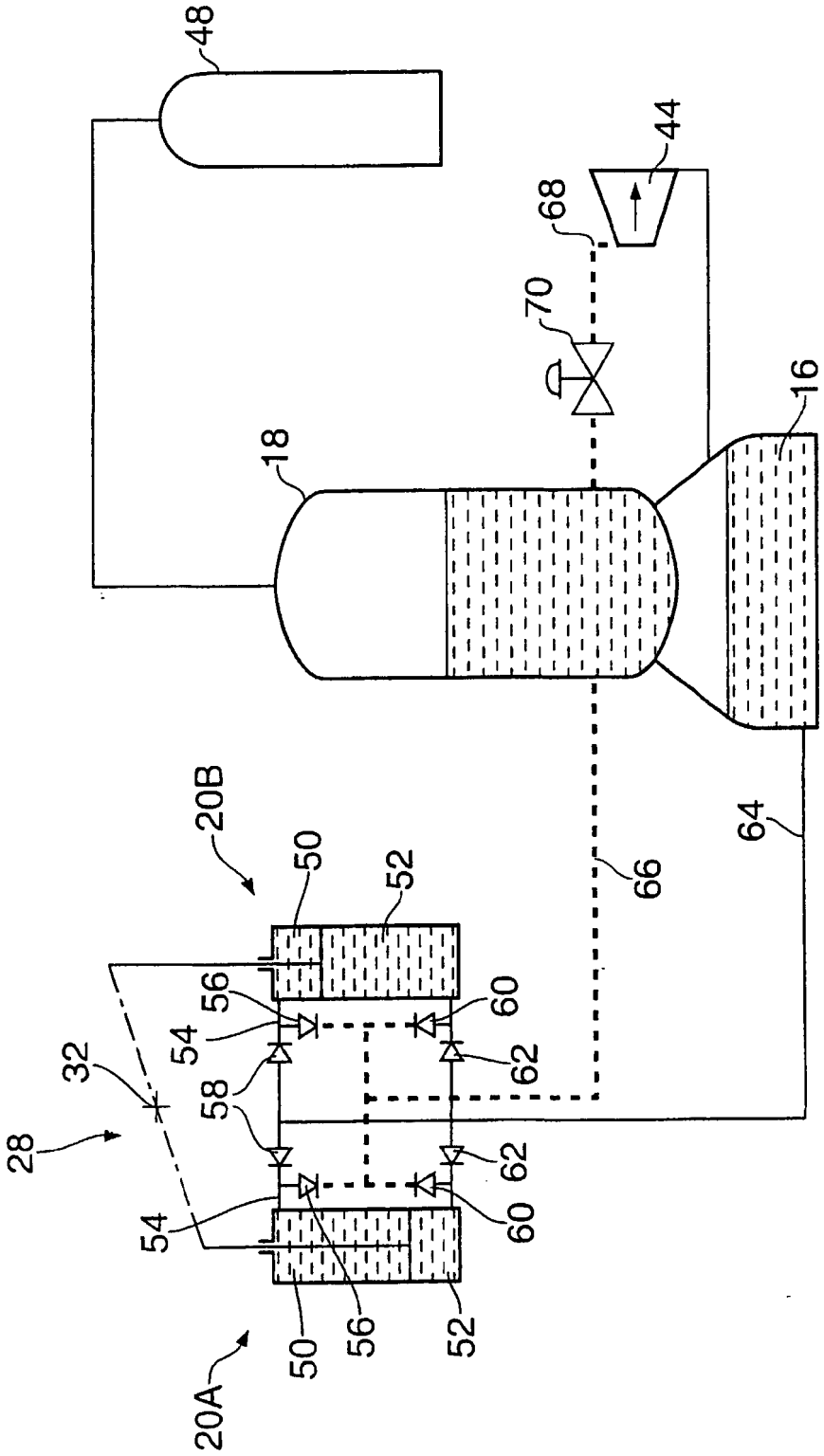


Fig. 2

Fig. 3(a)

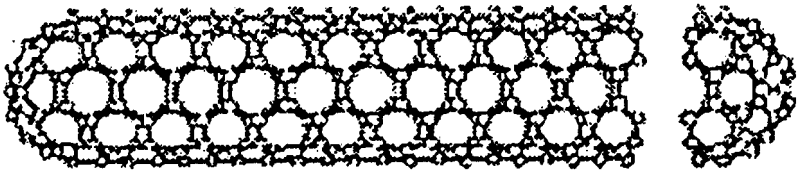


Fig. 3(b)

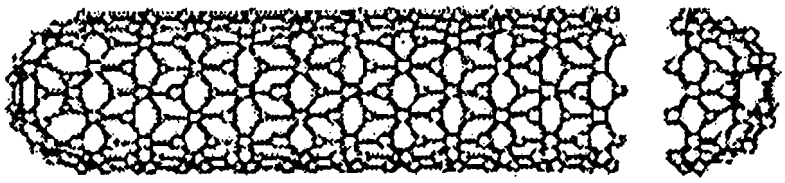
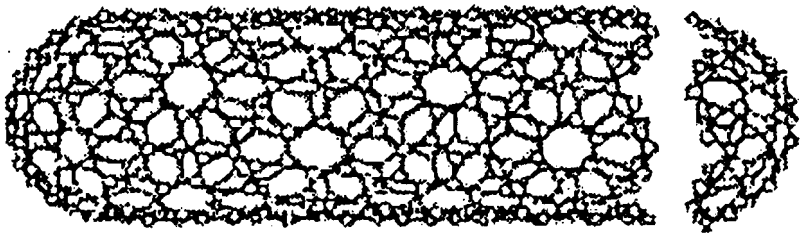


Fig. 3(c)



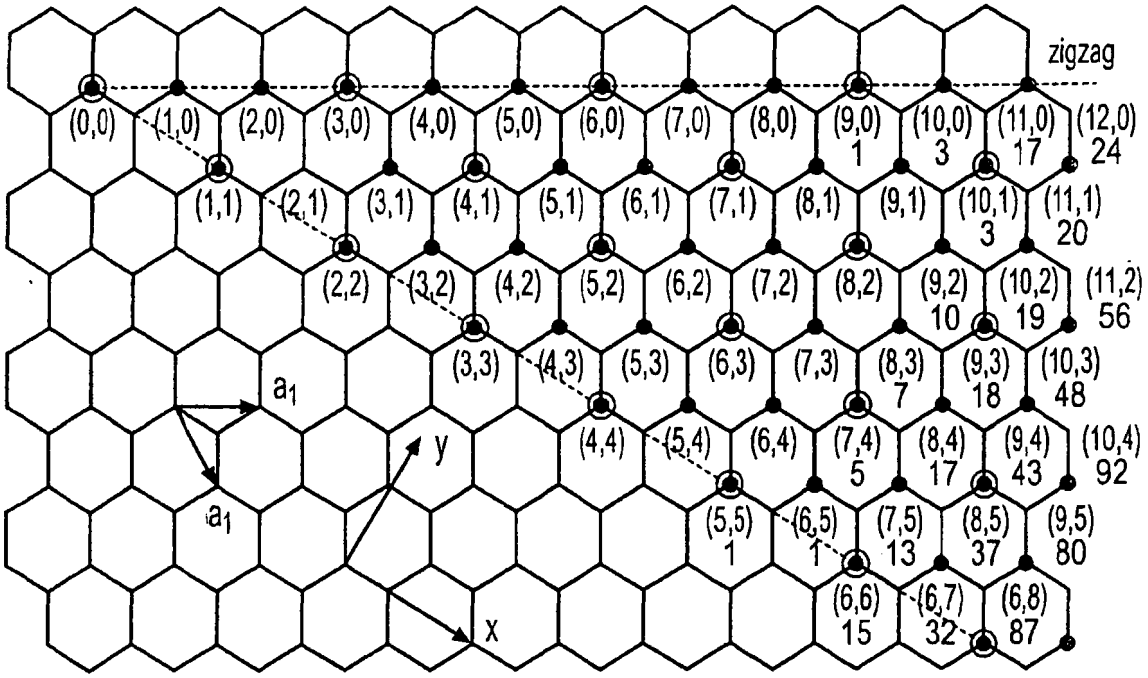

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Fig. 4

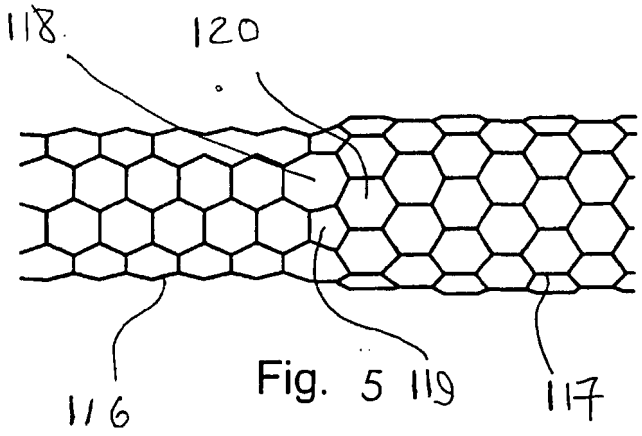
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Fig. 5

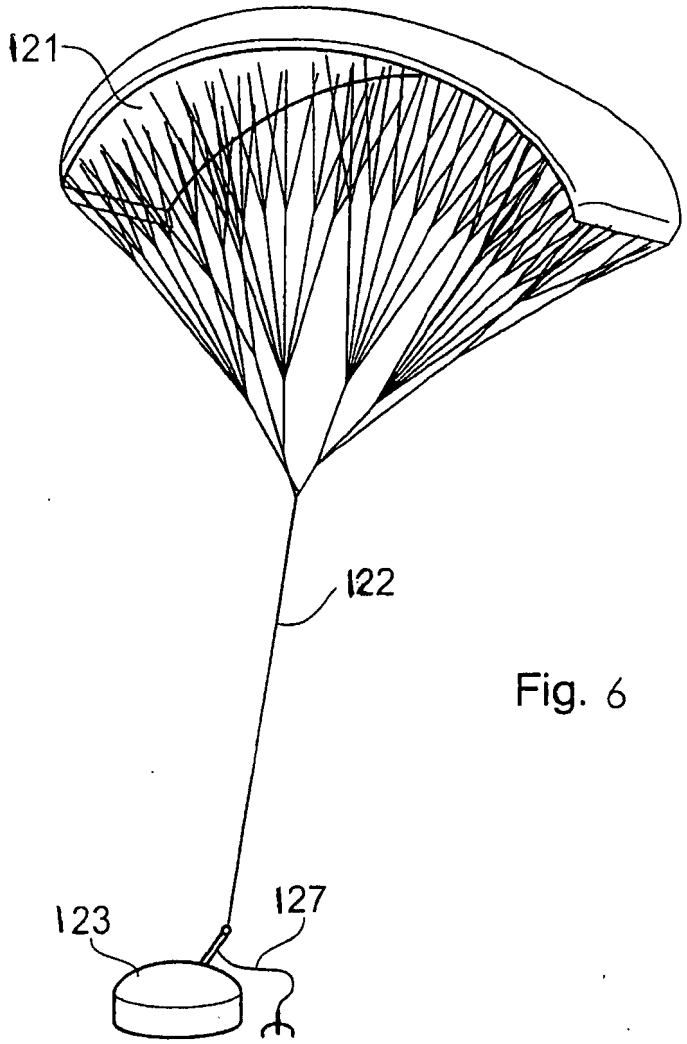

Fig. 6

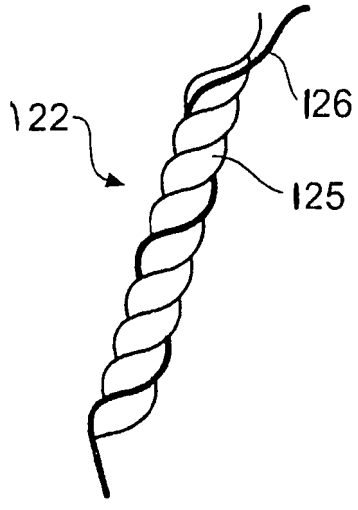

Fig. 7

APPARATUS AND METHOD FOR EXTRACTING ENERGY FROM THE WIND AND IMPROVEMENTS IN OR RELATING TO LIGHTENING CONDUCTORS

An aspect of the present invention is concerned with improvements in or relating to apparatus and methods for converting wind energy to other forms of energy, and particularly, but not exclusively, to a method and apparatus for generating power from wind energy.

With the shrinking of fossil fuel supplies as an energy source and concerns regarding nuclear fuel sources, much has been written and proposed concerning the subject of obtaining energy from so-called 'natural' sources. Wind energy is currently one of the most topical solutions and the provision and construction of electricity generating stations driven by windmills has become almost widespread. However, windmills are recognised to be extremely costly to erect, require operation for a considerable period before they become economical, and, to many, are unsightly in that they are required to be large, as a consequence of which they dominate landscapes, with rotor blades as long as 80 metres. They thus contribute to the visual pollution of the countryside. In addition they are not silent in operation although the noise level is low, and thus they contribute to noise pollution as well. They are also a hazard to wild life, resulting in the death of many birds colliding with the rotors.

While wind energy is considered to be a very important potential source, there is nevertheless a need to find alternative ways of utilising it which is less costly to implement, is more immediately viable commercially and does not intrude upon landscapes.

It is therefore an object of the invention to provide an alternative method and apparatus for converting wind energy into other usable forms of energy, in particular, but not exclusively, electrical energy.

The present invention utilises the potential that kites have for so doing and provides, in one aspect, a method of converting wind energy to electrical and/or other forms of energy which comprises utilising the motion of a kite in the atmosphere to effect oscillatory motion and impart that motion to ground or sea based means whereby to pump fluid or to generate electrical energy.

Previous proposals have been put forward for harnessing wind energy by the use of kites.

In published US patent application 2005046197, there are disclosed both systems and apparatus in which one or more kites are tethered by lines to winches and repeatedly winched in and paid out. Energy is 'collected' from permitting a kite to travel out under wind pressure and the movement is used to create mechanical or electrical energy via the winch, with net energy being that acquired when the kite is allowed to travel out minus the energy required to reel it in again.

United Kingdom patent GB489139 discusses use of kites to carry a wind-driven turbine driving a dynamo, in which the tethering line is used to carry electric current from the dynamo. The proposal was that the dynamo could be supported between kites and by more than one train of kites.

US patent 4047832 discloses use of an aerofoil to which a turbine generator is attached whereby the profile of the aerofoil causes wind to flow across the aerofoil and operate the generator.

German patent DE 19502948 discloses an electrical energy plant using a wind turbine supported by a number of suspension cables beneath a box kite. The suspension cables may be attached to the kite at one end and tethered to the ground at the other end, with winch motors used to allow the wind turbine to be raised to optimum height. The winch motors are described as being mountable on a circular guide track allowing rotation of the turbine to face the wind direction, the kite being raised initially with the aid of a helium balloon.

US patent US 4486669 also discloses use of wind generators suspended in the air by a kite, but attached to the earth by a high strength cable to which are attached electric cables and a natural gas pipe. This proposal suggests the use of numerous small wind generators mounted in a box-like kite enclosure, raised to the desired elevation by rotary blade power with the assistance of a gas balloon. The wind

generator kite is raised and lowered to the proper elevation for maximum electrical output.

There are also a number of published documents relating to the control and management of kites for harnessing wind energy. These comprise International (PCT) Patent Application No WO 01/92102A1, International (PCT) Patent Application No. WO 03/097448A1 and International (PCT) Patent Application Nos. WO2005/100147A1, WO2005/100148A1 and WO2005/100149A1, which latter relate to the use of kites to provide a supplementary traction force for shipping.

Only the last mentioned proposal uses the motion of the kites themselves to harness the wind energy.

The present invention also utilises movement of a kite, or an array of kites, but in this case to operate a stationary (that is ground or sea-based apparatus) by constraining the kite(s) to follow a closed-loop and repeatable path of movement in the atmosphere and to employ the transverse forces thus generated. One advantageous, but not the only, configuration of a repeatable path is that of a figure-of-eight movement of a kite, or array of kites, which are harnessed to one or more tethering lines. By use of suitable sensor means, the precise form including elongation of such a path can be closely controlled.

In accordance with the present invention, the kite, or kites, is/are connected to the ground- or sea-based means by one or more tethering lines which will be under

tension and cause oscillation of a yoke of said means when the kite arrangement follows its repeatable path of movement. The yoke is connected to one or more reciprocably movable members that can rock or oscillate to cause movement of fluid, generation of electrical current or of potential energy.

Thus, the present invention provides, in one aspect, a method of converting wind energy to other forms of energy which comprises utilising the motion of a kite or kites in the atmosphere to effect oscillatory motion of ground- or sea-based means whereby to convert kinetic energy created by movement of the kite(s) in the atmosphere to kinetic energy, potential energy or electrical energy via said means.

The motion of the kite(s) is such that, when suspended in the atmosphere, it/they will oscillate in a wide arc of movement and so cause oscillation of the yoke, sufficient to effect reciprocatory movement of members such as pistons of piston-and-cylinder arrangements which can pump fluid, for example to drive turbines or to operate as gas compressors. In addition, the motion of such a yoke can be used to move a core back-and-forth within a coil to generate electric current.

The oscillatory movement of the kite, or array of kites if such is used, to move the yoke may be generally such that it causes the yoke to move from side to side. Alternatively, if lateral width is restricted as where a field of such kites is deployed, the or each kite or kite array may be constricted to follow a path of movement which imparts a generally vertical movement to the yoke, while the kite follows its generally repeatable path.

In each case, the kite, or kite array, is advantageously fitted with sensors which can control stays by which the kite (array) is connected to the tethering line, to adjust the length of the stays to ensure that the kite (array) follows the required path of movement.

Such a kite or kite array is capable of being flown at heights of 300 to 500 metres and can be deployed both at sea, at the seashore, on sea- or ocean-going vessels, or on land or, where required, from buildings. Obviously, such kites will not be used or deployed in or close to recognised air lanes or corridors but they can be brightly coloured to limit the risk of stray low-flying aircraft venturing too close. They are, in any event, less of a collision risk for birds.

The movement of a kite deployed at a height of say 300 metres may be in an arc of as much as 60°, such that the arc itself spans a width also of 300 metres. The yoke to which such a kite is attached will also exercise a movement of about 60° allowing for flexing of the tethering line and the length of the yoke is thus a measure of the stroke effected by the piston of a piston-and-cylinder arrangement or the core of a solenoid.

Apparatus according to the present invention for harnessing wind energy may, in one aspect of the invention, comprise means arranged to be coupled to such a kite or kite array, positioned in the atmosphere, the means having degrees of movement

permitting oscillatory movement thereof to generate kinetic, potential and/or electrical energy.

As referred to above, said means comprises a yoke for coupling to the kite arrangement, the yoke being mounted for reciprocal motion about a fulcrum and being arranged to be coupled to reciprocable means whereby oscillation of the yoke can be translated into linear or rotary motion.

The yoke itself may be of any convenient design and may be directly coupled to the reciprocable means or may be coupled indirectly by rotary means to the reciprocable means. Thus the yoke can be connected to a rotatable crank arrangement which itself imparts the reciprocating motion. The yoke is then connected in accordance with appropriate gearing ratios that ensure that the required reciprocation stroke is effected.

To this end, in one aspect of the present invention, the reciprocable means comprises one or more piston-and-cylinder arrangements arranged to pump fluid. In an alternative aspect the reciprocable means may comprise a core of magnetic or ferromagnetic material arranged to move within a coil to generate electrical current. The reciprocable means may comprise a combination of piston-and-cylinder arrangements and/or such transducer arrangements. Depending upon the efficiency of such arrangements, piston-and-cylinder arrangements and transducer arrangements may be deployed in groups.

The present invention also provides apparatus for converting wind energy to kinetic or electrical energy, the apparatus comprising a yoke mounted for rocking motion about a fulcrum, the yoke being couplable to a kite by a tether line, the yoke having opposed arms, and pivotally coupled to ends of those arms, reciprocable converter means for converting rocking motion of the yoke caused by motion of the line when in use to reciprocating motion of the converter means.

The tether line may be coupled to the yoke via an extension of the yoke, which is for example in the form of an A-frame, extending upwardly from the fulcrum about which the yoke oscillates. Alternatively, two lines may be used, each tethered to a respective one of the opposed arms of the yoke.

The yoke and the converter means are mounted for 360° pivotal movement about a vertical axis so that the yoke can swivel with change in direction of wind and consequent change in position of the kite and line or lines.

As mentioned above, in one preferred embodiment of the invention, the reciprocating converter means comprises piston-and-cylinder arrangements and ideally comprises first and second piston-and-cylinder arrangements one of the piston and cylinder of each of which is pivotally connected to a respective one of each or the opposed arms of said yoke, and the other or each of which is pivotally coupled to a frame which is pivotally coupled to the yoke at the fulcrum. With such an arrangement, the pistons, if they are connected to the ends of the arms of

the yoke, can pivot to self align with the direction of the line to which the kite is attached.

Where piston-and-cylinder arrangements are used, each piston-and-cylinder arrangement is connected to a source of fluid such that fluid can be drawn into the respective cylinder and expelled therefrom by movement of the piston relative to the cylinder. The piston-and-cylinder arrangements are each double acting so that fluid can be drawn into and pumped from the cylinder on each stroke of the respective piston.

The precise nature of the apparatus is of course determined by the use to which it is to be put.

For example, if the apparatus is intended for use in providing energy for a single building, where the apparatus is mounted say on the roof of the building, the piston-and-cylinder arrangements may be provided in a pneumatic line where they are caused by the oscillation of the kite arrangement to pump air under pressure to storage tanks from which air can be subsequently released to drive pneumatically driven turbines for providing electrical power for the building. Such storage tanks can be housed deep in the foundations of the building, for example in hollow piles forming part of the buildings foundation.

Alternatively, the piston-and-cylinder arrangements may be used directly in a gas or fuel line to effect pumping of the gas/fuel through a gas/fuel supply line.

However, it is foreseen that the present invention has its primary application in the generation of electrical energy.

Where used on ships, it is known for such apparatus to be used directly to augment, or supplement the vessels' own power supply and thereby increase the fuel economy of the vessels by reducing dependency on fuel stored on board the vessels.

Where used on land or when mounted off-shore, with connection to the national grid, apparatus according to the invention can be used to supply electrical energy to the national grid either at a national or local level.

To achieve this objective, one of two of the solutions provided by the present invention can be adopted.

As a first solution, each piston-and-cylinder arrangement is ideally connected to a fluid-impelled electricity generator, such as a water powered turbine, where the turbine is connected to a pressurised water source in a closed loop water circulation system, and the turbine is connected electrically via an alternator to a local power supply system or to the national grid or high-voltage electricity transmission system. The manner in which such connection can be made is well known to those skilled in the art and need not be further described herein.

Pressurisation of the water supply can be enhanced by a pressurised gas supply to ensure that an evenly pressurised and constant feed of water to the turbine occurs.

As a second solution, the piston-and-cylinder arrangements can be substituted by or supplemented by arrangements in which a solenoid winding is mounted in place of or with the cylinder (e.g. alongside it) and a core, which replaces the piston, is arranged to move in and out of the winding, the winding being then linked to external electricity supply systems.

The transducer means provided in each case, may comprise first and second solenoids, each having a core member, mounted such that relative movement can be effected between each solenoid and its respective core by movement of said yoke, to generate electrical current in the solenoid.

The apparatus thus far described will also include a casing protecting the system of yoke and transducer means from adverse weather conditions and/or vandalism. The casing may be of circular shape and be provided with an apertured domed roof through which the A-frame or like extension can project, the roof being mounted on bearings affixed to the casing to permit the roof to rotate freely so that the A-frame is aligned with the direction of such wind as may be blowing.

The kites themselves may be of any suitable design, for example the so-called flexifoil type, peel type or delta type and may be inflated airfoils, which permit rapid response to steering from tether lines.

Steering may be achieved by way of computer-controlled autopilot linked to wind strength and an inertia sensor on the kite.

Operating at the length envisaged (800 metres or more) above ground level, the kites and their tether lines could be used as radio tuners such as for mobile telephone systems.

Use of the large surface area of a kite to carry a visual e.g. advertising message is also envisaged.

Another aspect of the present invention relates generally to lightening conductors, and particularly to lightening conductors having improved properties.

Fullerenes have been attracting much interest in recent times because of their electrical and physical properties. Fullerenes are large, closed-cage carbon clusters having properties which are not found in any previous compound. They were accidentally discovered when unexpected results in the mass spectre of evaporated carbon samples were being examined. Subsequently carbon nanotubes were discovered and have been investigated by many researchers all over the world. They can be considered as an almost one-dimensional form of a fullerene, and this

large aspect ratio (the ratio between length and diameter) results in interesting electronic, mechanical and molecular properties.

Single walled nanotubes can be considered as long wrapped grapheme sheets having a length to diameter ratio in the region of a thousand so that they can be considered as effectively one-dimensional structures. In fact, a single walled nanotube consists of two separate regions having different physical and chemical properties. The first region is the sidewall of the tube and the second region is the terminating portion or end cap. The end cap structure may resemble or be derived from a smaller fullerene. The sidewall structure may, for example, be a so-called armchair structure, a zigzag structure or a chiral structure. In the structures the carbon atoms are placed in hexagons or pentagons to form the end cap structures.

A closed structure comprising only pentagons and hexagons can be created, and it can be shown from Euler's theorum that a structure consisting only of pentagons and hexagons requires 12 pentagons to form a closed cage. One pentagon with 5 surrounding hexagons provides a curved end surface enclosing a volume such as the end of a tube. It is known that the distance between pentagons in a fullerene shell tends to a maximum in order to obtain a minimal local curvature and thus minimal surface stress in order to achieve a more stable structure. The smallest stable structure that can be made in this way is denominated C_{60}, the next largest C_{70} and so on. All fullerenes are composed from an even number of carbon atoms because each hexagon requires the presence of at least 2 carbon atoms so that

whether there are an odd number or an even number of hexagons there are still only an even number of carbon atoms.

A single walled nanotube may adopt a cylindrical form generated when a grapheme sheet is wrapped in a certain direction. Cylindrical symmetry requires that the formation of a closed cylinder is only achieved when the sheet is "rolled" in a limited number of directions. For this purpose two atoms in the grapheme sheet are selected, a first to serve as an origin, and the sheet is then rolled until the two atoms coincide. The vector from the first atom to the other is called the chiral vector and its length is equal to the circumference of the nanotube. The nanotube axis extends perpendicularly with respect to the chiral vector. Single wall nanotubes, with the different chiral vectors may have quite dissimilar properties such as optical activity, mechanical strength and electrical conductivity. If the lattice vectors of the grapheme sheet are called a_1 and a_2 the chiral vector can be defined as:

$C_H = NA_1 + MA_2$

The grapheme sheet has a so-called zigzag axis and the angle formed between this and the chiral vector determines the properties of the nanotube. It can be shown that in the region of 30 degrees this results in nanotubes having metallic properties the conductivity of which can be varied, for example by defects or deformations in the nanotubes such as bends and junctions which may be inward or outward.

Depending on their chiral vector, therefore, carbon nanotubes with a small diameter may be semi-conducting or metallic. The differences in conducting

properties are caused by the molecular structure resulting in a different band structure and thus a different band gap. The differences in conductivity can be derived from the known properties of the grapheme sheet from which the nanotube is formed. Resistance to conduction is determined by quantum mechanical aspects and has been shown to be independent of the nanotube length.

In the main carbon nanotubes have a very large Young's modulus in their axial direction and are thus extremely flexible and resilient. These properties, especially the very high conductivity of the nanotubes, make the material suitable for use as or incorporation in lightening conductors.

Conventional metal lightening conductors are also subject to fatigue, cracking and other wear or aging defects, and this can affect the conductivity detrimentally such that a lightening strike could result in diversion of the discharge from the track predetermined by the conductor to the protected building or structure. By use of fullerenes in the lightening conductor material, however, the increased flexibility results in less risk of cracking or fracture with age, and the highly conductive nature of the material means that less material is needed in order to achieve the given conductivity. According to one aspect of the present invention therefore, a lightening conductor has a conductive constituent comprising or including fullerenes.

The fullerenes may be single walled carbon nanotubes. This, of course, is non limitative since other structures of fullerenes may be used, in particular multi-walled carbon nanotubes.

Preferably the fullerene chiral vector lies at less than 30 degrees to the zigzag axis. Likewise, it is preferred that the scale or quantities (nm) defining the multiple values of the latter spectres in the chiral vector are such that the nanotubes are metallic with a high conductivity.

Lightening conductors having great flexibility are particularly suitable for protecting balloons or kites from lightening strike since the flexibility resulting in durability and security are highly desirable properties in a situation where, because of the nature of the structure (balloon or kite) flexing of the lightening conductor is expected to take place continually. It's suitability for use in protecting such structures does not, of course, detract from the value as a lightening conductor for conventional ridged structures such as buildings, bridges and the like.

Accordingly, the present invention also comprehends a balloon or kite tether or control or communication line for these or other structures in which a fullerene constituent is incorporated into the material such as to form a continuous conductive path from any point on the tether to ground.

A balloon or kite tether or a control or communications line incorporating or providing a lightening conductor as defined hereinabove is also comprehended within the scope of the present invention.

Likewise, the invention can be considered to extend to a balloon or kite having a tether, control or communications line substantially as defined herein.

Various aspects of the present invention will now be more particularly described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a cut-away perspective view of apparatus according to an embodiment of an aspect of the present invention; and

Figure 2 is a schematic fluid circuit diagram of the apparatus shown in Figure 1.

Figure 3 is a schematic diagram illustrating different chiralities of single walled nanotubes;

Figure 4 is a schematic representation illustrating the hexagon lattice of a single walled nanotube illustrating the range of properties with varial chiral angle;

Figure 5 is a schematic representation of a single walled nanotube with a hexagonal lattice and at transition point from a metallic to a semi-conducting form by the introduction of pentagons and heptagons;

Figure 6 is a schematic view of a kite the tether of which is provided with a nanotube-enhanced lightening conductor; and

Figure 7 is an enlarged view of a part of the tether of Figure 6 showing a three-strand rope-like structure with a nanotube filament inserted therein.

Referring first to Figure 1, Apparatus illustrated therein comprises an outer casing 10 which is generally cylindrical and has a domed roof 12 which has an aperture through which a link arm or tether arm 14 projects, the function and purpose of which is described below.

The roof 12 is rotatable about a central vertical axis on bearings 15 at the top of the cylindrical wall of the casing, and, in the example shown in Figure 1, is intended to be fitted to the ground. In other embodiments (not shown) the casing may be adapted to float on water, typically the sea, and to this end, the casing may be anchored to the seabed or carried on a stabiliser platform (not shown) to which anchors are attached.

In other embodiments of the invention, the casing 10 may be mounted on sea- or ocean-going vessels.

Within the casing 10 and centrally located therein is a tank 16 which provides a liquid reservoir. Mounted on the tank 16 is a pressurised container 18 whose purpose is described below.

Mounted on diametrically opposed sides of the container 18 are two piston-and-cylinder arrangements 20A and 20B, each comprising a single cylinder 22 and having a piston 24 slidably mounted therein. The piston rod 24a of each arrangement 20 is pivotally connected to an arm 26 of a yoke 28 of which the

tether arm 14 forms part. The yoke 28 is formed as one inverted T-shape with the limit arm 14 comprising the stem and the transverse arms 26 extending laterally. It is mounted so that it can oscillate about a fulcrum 32.

The link arm 14 is attached at its free and to a tether line 34 to the upper end of which is secured a kite (not shown). The kite itself may be of any suitable type (preferably of flexifoil, peel or delta type) provided that it can be controlled to fly in a path such that the line by which it is attached to the yoke 28 imparts an oscillatory movement to the yoke about the fulcrum 32. Conveniently, such a path may be a figure-of-eight shape. To this end, the kite may be fitted with sensor devices capable of adjusting the contours and/or attitude of the kite so that it follows a desired path of movement, in order to cause movement of the yoke. This may be achieved by computer controls with signals transmitted from a computer (not shown) located in the base housing 10 to the kite by a signal line carried on the tether line 34 or a separate control line (not shown) with which the motion of the kite is controlled.

The oscillatory motion of the yoke 28 causes alternate reciprocal movement of the pistons 24 in their respective cylinders 22. The cylinders 22 are carried on the arms of an inverted U-shaped frame 36 which is pivoted to the container 18. The U-shape frame 36 is pivotally connected to the container at 40 so that the frame 36 can pivot about a horizontal axis A-A, thereby accommodating any two-dimensional excursion of the link arm 14 resulting in change in the angle or orientation of the yoke.

The construction and arrangement of the apparatus is such that, under the influence of the kite, and the tension in the line 34, the apparatus can be caused to rotate and the frame 36 and yoke 28 to adopt an attitude which is determined by the angle of the line 34. A winch 42 is mounted on the yoke for the purpose of allowing the line to be paid out to permit the kite to rise to an optimum altitude, or for bringing the kite down when necessary.

As can be seen more clearly in Figure 2, the cylinders 22 of the two piston-and-cylinder arrangements 20 are hydraulically connected to a reservoir of fluid, i.e. water, which is maintained in the tank 16, so that with each intake stroke of a piston, water is drawn into the respective cylinder. This movement of the piston occurs as the respective arm of the yoke is moved away from the cylinder to whose piston the arm is connected. This motion is caused by movement of the kite and its line as the kite is caused to oscillate in the atmosphere.

Viewing Figure 1, it can be seen that the link arm 14 is shown in a neutral or intermediate position, namely one in which both pistons 24 are at substantially the same position in their stroke within their respective cylinders 22. Movement of the link arm 14 and thus of the yoke 28 to the right, or clockwise, as viewed in Figure 1, will depress the piston 24 of the arrangement 20A into its cylinder while the piston 24 of the arrangement 20A is drawn up within its cylinder 22. The reverse will occur when the oscillation is in the opposite direction. As described with reference to Figure 2 below, this movement to draw in and expel water from the

cylinders can then be used to power a water turbine 44. The water turbine can be connected to an alternator (not shown) to produce an electrical output in the form of an A/C current. The output current can then be supplied to energy storage facilities or direct to the national grid.

The schematics of the apparatus are shown in Figure 2.

The piston-and-cylinder arrangements 20A and 20B are double-acting arrangements and the pistons 24 are shown pivotally coupled to the yoke 28. The cylinders 22 are hydraulically connected to a header tank provided by the container 18. The header tank 18 is maintained under super-atmospheric pressure by pressurised gas supplied from a gas pressuriser 48.

The piston 22 of each arrangement separates the cylinder into an 'upper' and 'lower' cylinder compartment 50, 52 respectively. The upper compartment 50 is hydraulically connected via a respective port 54 to one-way valves 56, 58 and, similarly, the lower compartment is connected via a respective port 59 to one-way valves 60, 62. These valves permit flow of water from the storage tank 16 and to the high pressure header tank 18. To this end, each valve 58 permits flow of water from the storage tank 16 via a fluid line 64 into the upper compartment 50 of the cylinder 22 on the downward stroke of the piston within the cylinder and, similarly, each valve 62 permits ingress of water into the lower compartment 52 of a cylinder from the storage tank during the upward stroke of the respective piston.

The valves 56 and 60 on the other hand are arranged to open when water under pressure is expelled from the respective cylinders. The valves are connected in a high pressure fluid line 66, shown in dashed line, connected to the header tank to deliver water under pressure thereto from either the upper or lower compartments 50, 52 of the cylinders 22 when the respective pistons move in the cylinders to expel water from the respective compartments 50, 52.

Water under constant pressure can then be delivered to drive the water turbine 44 via hydraulic line 68 under control of control valve 70. A return line 72 is provided for delivering water from the turbine 44 back to the storage tank 16. The reciprocating pistons thus deliver 'pulses' of pressure to the tank 18, which is 'smoothed' by the effect of the gas compressed within it.

The entire water supply system shown in Figure 2 is a closed system in so far as it requires only the water within the system to function, water under pressure being delivered to the turbine and then returned to the reservoir provided by the storage tank 16. The pressurised gas supply ensures that water is delivered under a substantially constant pressure to the turbine 44.

The water turbine 44 is connected to energy storage systems or may be used directly to power installations and, where provided, for sea going vessels.

It will be appreciated from the foregoing that though the illustrated embodiment discloses the use of a pair of piston-and-cylinder arrangements, it would be equally

cylinder arrangements namely to induct liquid and by outlet valve means through which liquid can be expelled to drive a liquid-impelled electricity generator or turbine for generating electricity, the turbine being connected to the liquid tank so that liquid can be returned thereto from the turbine. (but fluid may be a gas!)

23. Apparatus according to claim 24 wherein each piston-and-cylinder arrangement is connected to a header container arranged to supply liquid under at least substantially constant pressure to said electricity generator or turbine.

24. Apparatus according to claim 25 wherein the header container is pressurised by a gas supply.

25. Apparatus according to claim 19 wherein the reciprocating converter means comprises transducer means.

26. Apparatus according to claim 25 wherein the transducer means comprises first and second solenoids, each having a coil and a core member, mounted such that relative movement can be effected between each solenoid coil and its respective core member by movement of said yoke, to generate electricity in the solenoid.

27. Apparatus according to any one of claims 22 to 26 wherein the transducer means further comprises an alternator for generating electricity with alternating current.

possible to have other arrangements thereof. For example, instead of a single piston-and-cylinder arrangement coupled to an arm of the yoke, it would be possible to provide pairs of such arrangements in parallel relationship.

In an alternative to the above described embodiment, the oscillatory movement of a kite and its tether and of the associated yoke may be used to move a core relative to a solenoid to generate current directly, thereby eliminating the need for water storage and a turbine.

The yoke itself may be used to assist in launching the kite. Typically the yoke may be up to 10 metres in height, which is high enough to help catch the wind in the airfoils of the kite even in light winds. It is also possible to form the kite as an inflatable airfoil and to inflate it in the channel of a wing prior to launch while being held up by the yoke.

In all embodiments of the invention, it is desirable that the line tethering the kite to the yoke is a lightweight line so as to reduce overall weight of the kite plus line. The kite may be of any suitable dimensions but it is considered that a kite having a surface area of 5000 square metres would be usable.

An alternative embodiment may be formed with the generation unit formed on a floating body, tethered as a buoy. Such an arrangement allows easy adaptation to accommodate changes in seal level which are expected in the future consequent on the climate change which is widely forecast. A water-borne unit also may be made

capable of both pumping water and generating electricity. This is also true of units located near a body of water. Use of the system to power desalination plants is envisaged, and units may be made which are capable of commuting between electricity generation and water pumping.

It is envisaged that, with adequate safety measures, an array of kites associated with a plurality of apparatuses according to the invention could be launched at night so that they could be used during the hours of darkness and pulled down during daylight hours. Launching of kites can be by use of hydrogen or helium filled balloons with appropriate release mechanisms for detaching the balloons when the kites have attained the required altitude. When it is desired to retrieve the kite(s), operation of the winch can be effected to do so. When flown at night, the kites may have warning lights attached to them. If used during daylight hours, they may be highly coloured to avoid aircraft straying into their paths.

It is also envisaged that the kite or kites may be self-buoyant structures for example, in the form of a hydrogen or helium filled balloon so that the kites remain airborne even when there would be insufficient wind for a conventional kite structure to remain airborne. The kite or kites may be integrally formed as a helium filled balloon having sufficient volume to ensure self-buoyancy of the kite(s) structure. It is envisaged that such a self-buoyant kite could remain airborne for a period of six to twelve months for example, before it was necessary for the kite to be pulled down for routine maintenance purposes.

The tether line may also serve as a lightening conductor, thereby providing protection from lightening strikes for the immediately surrounding area. This can be achieved by using modern materials such as carbon fibre nano tubes which are highly conductive and have a very high strength-to-weight ratio. Protection of forests from lightening-induced forest fires may thus be achieved by installing the kites more.

Referring first to Figure 3, there is shown at 3a, 3b and 3c three different chiral structures of single walled nanotubes, Figure 3a illustrating the so-called armchair structure, Figure 3b showing the so-called zigzag structure and Figure 3c showing a chiral structure. The end caps at the right hand end of each nanotube have been shown separately in order to represent that the length of the tube is very much greater than that illustrated, and may be in the region of 1000 times the transverse dimension of the tubes.

Figure 4 shows a possible structure of a single walled nanotube composed of hexagons. The zigzag access is identified a-b and the chiral vector a-c is shown at the maximum value of 30 degrees. At different angles of the chiral vector the properties of the nanotube may differ. For example at the chiral vector angle shown for the vector a-c the nanotube has metallic properties and thus high conductivity. At lower angles the properties may be semi-conductor, as illustrated by the intersection d of Figure 4.

In Figure 5 a single walled nanotube is graphically represented having a metallic section 116, a semi-conductor 117 and a transition region 118 composed of pentagons 119 and heptagons 120.

Figure 6 illustrates a kite 121 restrained by a tether 122 linked to a ground structure 123 which, as described earlier in this description, includes a pumping arrangement driven by reciprocating motion of the tether caused by driving the kite in a figure-of-eight motion. The tether 122 incorporates a nanotube filament as illustrated in Figure 7 which shows the three strand twisted rope structure 125 with a highly conductive nanotube filament 126 threaded therein. As can be seen in Figure 6 the nanotube conductive element is directly connected to ground by a loop 127.

CLAIMS

1. A method of converting wind energy to another form of energy which comprises utilising the motion of a kite or kites in the atmosphere to effect oscillatory motion of an element or member carried on ground-or water based means whereby to convert kinetic energy of the kite(s)moving in the atmosphere to kinetic energy, potential energy or electrical energy via said means.

2. A method according to claim 1 wherein the kite is controlled to follow a closed loop path of movement in the atmosphere.

3. A method according to claim 2 wherein the closed loop path of movement is a path which is substantially repeatable.

4. A method according to claim 3 or claim 4, wherein the kite is constrained to follow a figure-of-eight movement.

5. A method according to any of claims 2 to 4, wherein the closed loop path of movement has a generally horizontal major axis about which the path is described.

6. A method according to any one of claims 1 to 5, wherein the kite is connected to said ground- or water-based means by a tether line which is under

tension in use and causes oscillation of a yoke of said element or member, which yoke is connected to one or more movable members which can reciprocate to cause movement of fluid or generation of electricity.

7. A method according to any one of claims 1 to 6, wherein said means is designed to be land-based.

8. A method according to any one of claims 1 to 7 wherein said means is designed to be water-bourne.

9. A method according to claims 8 wherein said means is designed to be mounted on a vessel, such as a sea-going vessel.

10. A method according to claim 7 wherein said means is designed to be or to be mounted on a building.

11. A method according to claim 10, wherein said ground or water-based means is arranged to induct air from the atmosphere and to compress that air for storage or for driving one or more pneumatically driven turbines for supplying electricity to the building.

12. Apparatus for converting wind energy to another form of energy and comprising one or more kite tethered to ground or water-based means and means for controlling it to follow an oscillatory path of movement, the ground or water-

based means having elements or members thereof capable of oscillatory movement driven by the oscillatory movement of the kite or kites to convert energy derived from movement of the kite or kites into kinetic, potential and/or electrical energy.

13. Apparatus according to claim 12 wherein the said ground or water-based means comprises a yoke for coupling to the kite or kites, the yoke being mounted for reciprocal motion about a fulcrum and being convertible to linkage means whereby oscillation of the yoke can be translated into linear or rotary motion.

14. Apparatus according to claim 13 wherein the said linkage mechanism comprises one or more piston-and-cylinder arrangements arranged to pump a fluid.

15. Apparatus according to claim 13 or claim 14, wherein the said linkage mechanism is connected to one or more solenoids each having a respective coil and core, each solenoid entirely to generate electricity upon relative reciprocating motion of the solenoid coils and cores and the solenoid being electrically connectable to an external electricity power system.

16. Apparatus according to any one of claims 13 to 15 wherein said linkage mechanism includes a frame pivotally coupled to the said yoke at said fulcrum.

17. Apparatus for converting wind energy into kinetic, potential or electrical energy, comprising a yoke mounted for rocking motion about a fulcrum, a case for connecting the yoke to a kite by one or more tether lines, the yoke having opposite

arms, each coupled to reciprocating energy converter means operable to convert rocking motion of the yoke caused by motion of the said tether line or lines when in use to reciprocating motion of the energy converter means.

18. Apparatus according to claim 19 wherein the yoke and the converter means are mounted for 360° turning movement about a vertical axis.

19. Apparatus according to claim 17 or claim 18 wherein the reciprocating energy converter means comprises first and second piston-and-cylinder arrangements one of the piston and cylinder of each of which is pivotally connected to said yoke, and the other or each of which is pivotally coupled to a frame which is pivotally coupled to the yoke at the fulcrum.

20. Apparatus according to claim 19 wherein each piston-and-cylinder arrangement is connected to a source of fluid such that fluid can be drawn into the respective cylinder and expelled therefrom under pressure by movement of the piston relative to the cylinder.

21. Apparatus according to claim 19 or claim 20 wherein each piston-and-cylinder arrangement is a double acting piston-and-cylinder arrangement.

22. Apparatus according to claim 21 further comprising a closed system water supply in which each piston-and-cylinder arrangement is connected by inlet valve means to a liquid storage tank during an intake stroke effected by the piston-and-

28. Apparatus according to any one of claim 17 to 21 wherein the piston-and-cylinder arrangements are adapted to compress air drawn from the environment and to pump compressed air into storage from which air can be delivered to drive pneumatically operated turbines or other fluid-powered containers.

29. Apparatus according to any one of claims 17 to 28 mounted in a roofed casing which permits the apparatus to turn with changes in wind direction so that at least one kite can be controlled to follow the wind.

30. Apparatus for converting wind energy to kinetic, potential or electrical energy, substantially as hereinbefore described with reference to the accompanying drawings.

31. A method of converting wind energy to electrical or other forms of energy substantially as hereinbefore described with reference to the accompanying drawings.

32. A lightening conductor the conductive constituent of which comprises or includes fullerenes.

33. A lightening conductor as claimed in Claim 32, in which the fullerenes are single walled carbon nanotubes.

34. A lightening conductor as claimed in Claim 32, in which the fullerenes are multi-walled carbon nanotubes.

35. A lightening conductor as claimed in any preceding claim, in which the fullerene chiral vector lies at less than 30 degrees to the zigzag access.

36. A lightening conductor as claimed in any of Claims 32 to 34, in which the scalar quantities (n,m) defining the multiple values of the lattice vectors in the chiral vector are such that the nanotubes are metallic with a high conductivity.

37. A balloon or kite tether, control or communication line in which a fullerene constituent is incorporated into the material or associated therewith such as to form a continuous conductive path from any point on the line to ground.

38. A balloon or kite tether, control or communications line incorporating or provided with a lightening conductor as claimed in any of Claims 32 to 36.

39. A balloon or kite tether, control or communications line substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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Application No: GB0711535.5 **Examiner:** Peter Middleton

Claims searched: 1-31 **Date of search:** 15 September 2007

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	1, 12, 17	US2002/040948 A1 (RAGNER) see abstract and figures: kite following figure of 8 path, generating power by axial movement of cable
A	1, 12, 17	US3987987 A (PAYNE) see abstract and figures: kite generates energy by back-and-forth movement
A	1, 12, 17	DE3232186 A1 (FISCHER) see WPI abstract accession number 1984-057129 [10]: kite generates energy by unwinding / winding cable on drum
A,P	1, 12, 17	WO2007/034193 A2 (NICHOLSON) see abstract and figures: kite generates power by axial movement of cable.
A,P	1, 12, 17	US7188808 B1 (OLSON) see abstract and figures: kite generates power by axial movement of tether

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

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Worldwide search of patent documents classified in the following areas of the IPC

F03B; F03D

The following online and other databases have been used in the preparation of this search report

Online: WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
F03D	0011/04	01/01/2006

35

Subclass	Subgroup	Valid From
H02G	0013/00	01/01/2006