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(54) Title: SUPPORT FOR WATER TURBINE

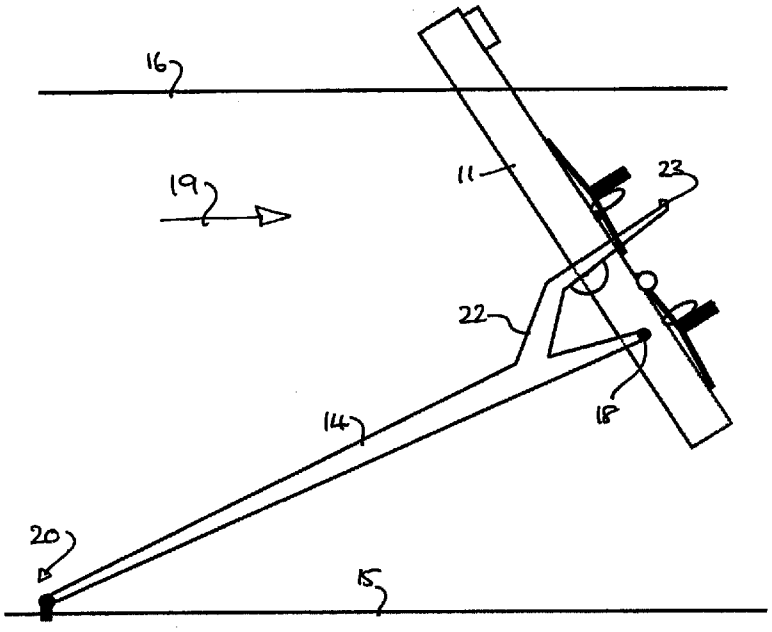

Fig3

[Continued on nextpage]

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EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(57) Abstract: An underwater turbine mounting includes a rigid tether having one end attached thereto at a pivot, and the other end adapted for connection to an underwater anchorage. The mounting is pivotable between a deployment condition and an operating condition solely by adjusting the buoyancy thereof.

Support for Water Turbine

This invention relates to turbines for the generation of power from water currents, especially those from coastal regions or river estuaries.

Many systems have been proposed for the mounting of such turbines in the stream flow. A particular problem is how to arrange that turbines can be delivered, deployed in an operating position and then recovered for maintenance or removal.

A feature of some such systems is the use of a mounting frame with variable buoyancy to assist in the deployment and recovery stages. GB 2348249B (Armstrong) for instance discloses the use of variable buoyancy to roll a mounting frame about an inclined longitudinal axis passing through an underwater anchorage, from a deployed operating position to a horizontal floating maintenance position. GB 243441 OA (Todman) discloses the use of variable buoyancy combined with controlled flexure of a mounting frame about a rigid tether arm to achieve a similar effect, but without roll rotation. Several other proposals have been made on the basis of flexible tethers such as cables, for instance GB 225601 1A (Fraenkel).

Other factors to consider include the stability of pitching of the turbines in operating flows (i.e. rotation about a transverse horizontal axis through the underwater anchorage) Some prior disclosures, such as those referenced above and GB 2409885A (MCT), use surface penetration by one or more parts of the mounting to achieve buoyancy-driven passive pitching stability, so that under varying flow and drag conditions the turbines will rise and fall within controlled limits. Others, wishing to achieve complete submersion of their turbines, use instead of surface-piercing members, active control surfaces to achieve such stability (e.g. WO 00/423 18A Dehlsen). Some, for instance GB 2422878B (Mackie), propose surface-piercing members to control pitching and active control surfaces to regulate roll of a flexibly tethered turbine.

The present invention provides an alternative arrangement with movement from a floating deployment condition to a substantially submerged operating position by adjustment of ballast.

According to the invention there is provided an underwater turbine mounting comprising a buoyant elongate frame adapted to mount one or more stream flow turbines thereon, a rigid arm having a pivotal connection at one end to said frame, the other end of said arm being adapted for connection to an underwater anchorage, and means to vary the buoyancy of said frame whereby said frame is pivotable in use about said connection between a substantially horizontal maintenance position and a substantially upright operating position.

Movement between the maintenance and operating positions is substantially determined by variation of buoyancy, for example by addition or removal of ballast water via suitable pumps, valves and the like. Compressed air may be used to purge water ballast from a buoyancy chamber. Movement may be controlled by a brake or the like acting between the frame and the arm, for example a caliper brake of one component gripping a brake surface of a relatively movable component.

In one embodiment the frame comprises one or more buoyancy chambers, and may be defined by a substantially hollow vessel adapted for movement between a floating deployment/maintenance condition and a submerged or partially submerged operating condition.

Movement between the maintenance and operating conditions may be assisted by drag of the stream flow and/or by turning of the water turbines in a favourable direction. The turbine(s) may be allowed to auto-rotate, or may be driven to generate a propulsive force in the desired direction, or several turbines may rotate in different directions - in each case additional drag is generated to the intent that movement of the mounting is assisted.

In one embodiment the mounting is provided with one or more active drag surfaces deployable between an active condition in which drag is induced to move the

mounting arcuately, and a substantially inactive condition in which arcuate movement is not induced.

In one embodiment a variation of buoyancy turns the mounting substantially towards the operating condition, whereupon active drag surfaces are deployed to urge or assist the mounting into the operating condition.

In use the frame supports one or more stream flow turbines, typically horizontal axis turbines arranged on the downstream side of the frame. The frame pivots substantially through a right angle between the operating and maintenance conditions, and such an arrangement allows the turbines to be substantially or wholly out of the water in the maintenance condition of the mounting.

The arm may comprise a towing member of the mounting when in the deployment condition, and for this purpose may float or be latched to the frame so as to project substantially ahead thereof. In the towing condition the leading end of the arm (the anchorage end) is substantially at the surface. Upon reaching the deployment location, the arm is unlatched and lowered for connection to an underwater anchorage whilst remaining attached to the frame. The anchorage provides a pivotal connection to permit rise and fall of the mounting in the stream flow, and for tidal installations may permit pivoting of the arm about a substantially vertical axis so as to permit generation on both a rising and falling tide. The articulation at the anchorage is preferably provided at the end of the arm so as to provide for maintenance thereof at the surface, for example in the form of an universal joint. The arm may comprise the articulation and a plug and socket arrangement at the anchorage, with a suitable latch.

In a preferred embodiment the arm and frame abut in the operating condition so as to prevent over-rotation of the frame when pivoting to the operating condition. Any suitable abutment may be provided, including direct contact between the arm and frame, or the use of a stay sliding in a collar to an end stop. The abutment may include a compliant and/or resilient buffer, and may permit some relative angular motion about the mean position, typically no more than ±10°. The arm and frame may be latched in the operating condition at a substantially fixed angular relationship.

In use the mounting trails in the stream flow, and accordingly stream flow drag may be utilized to assist motion from the maintenance to the operating condition. In particular, buoyancy may be varied to move the frame to a condition just short of the (upright) operating condition. This arrangement ensures that a reverse movement is assured if buoyancy is increased. Final movement to the operating condition may be by way of active drag surfaces and/or by an actuator. The actuator may for example comprise a motor operable about the pivot axis between the arm and the frame, a grab device, a nudge device or any other suitable apparatus for obtaining the final increment of movement to the operating condition.

Alternatively, the ballast chambers may be subdivided into separate sections to enable the trimming of the frame as it nears its engagement position with the tether arm. In one embodiment, the frame may have in its near-vertical position separate fore and aft chambers (with respect to the stream flow direction), adding or removing ballast water differentially will enable adjustment of the angle of the frame to the vertical so that the correct position for latching can be achieved. Typically slow incremented movement is achieved. For trimming of the frame rotation between the horizontal and vertical positions, differential ballasting in chambers disposed along the upright axis of the frame (in the deployed condition) may be used.

In one example the arm is substantially straight and pivoted to the frame at the rear thereof with respect to stream flow direction (in the maintenance condition). Such a connection is below the mid-point of the frame when in the operating condition, and in one embodiment adjacent the lower end thereof. In another example the arm is cranked downwardly in the deployment condition in the manner of an elbow, and is connected substantially at the mid-point of the elongate frame.

In another example, the arm may be connected further towards the bow of the frame (in the maintenance condition), with a lower extension of the arm fixing against the stern, or lower part, of the frame in the operating condition.

The invention also provides a method of deployment of a stream flow turbine mounting solely by adjustment of buoyancy thereof.

Other features of the invention will be apparent from the following description of a preferred embodiment shown by way of example only in the accompanying drawings, in which :-

Fig. 1 is a side elevation of a first embodiment of the invention in the deployment condition;

Fig. 2 corresponds to Fig. 1 and shows the first embodiment in the maintenance condition;

Fig. 3 shows the first embodiment during movement to the operating condition;

Fig. 4 shows the first embodiment in the operating condition;

Fig. 5 shows a perspective view of a twin boom embodiment in the operating condition;

Fig. 6 shows a second embodiment of the invention in the operating condition;

Figs. 7 and 8 show a third embodiment of the invention, respectively in the deployment and operating condition.

Figs. 9 to 11 show a further embodiment of the invention, respectively in the deployment, maintenance and operating condition, and

Fig. 12 shows a further embodiment of the invention in the operating condition.

With reference to Figs. 1-4, a stream flow turbine assembly 10 comprises a support 11 for turbines 12,13, and a rigid tether 14. The underwater ground surface (e.g. sea bed) is indicated at 15, and the water surface at 16. An underwater anchor 17 is provided at one end of the tether 14 for fixing to the underwater ground surface or to a pre-positioned underwater mounting. The other end of the tether 14 is connected to the support via a pivot 18. The anchor 17 comprises an universal joint or the like, and a plug in male projection for a socket of an underwater anchorage.

Fig. 1 illustrates a deployment condition in which the assembly 10 is floated to an installation site, for example by being towed by a tug. The draft of the assembly is small, and the turbines 12,13 are arranged on the upward facing surface of the support 11 so as to be out of the water. The tether 14 may act as a towing arm for the assembly, and the anchor 17 constitutes a towing point substantially at the surface.

It will be appreciated that the support is buoyant, and this may be arranged in any suitable manner, for example by providing a suitable buoyancy chamber or chambers for the support. The support may itself comprise a closed hollow structure having the desired buoyancy. As will become apparent the buoyancy of the support is adjustable to permit the assembly to adopt a generating condition.

The tether 14 although typically buoyant, may be supported in the deployment condition of Fig. 1 by being locked or latched to the support 11 in a suitable manner. For example a removable locking pin 24 or the like may be provided, which may be automatically actuated.

Fig. 2 illustrates a maintenance condition of the assembly in which the tether 14 is released from the deployment condition and is anchored to the underwater ground surface 15. The tether anchorage 20 comprises an articulation which permits the support 11 to rise and fall with change in the level of the surface 16, for example as a tide rises and falls. This anchorage may also permit the support to yaw in response to changes in the stream flow direction, for example to accommodate reversal of tidal flow.

A brake 21 is provided to act between the tether 14 and the support 11, and may be used to damp or restrict relative motion if desired; a caliper brake is suitable.

In the maintenance condition of Fig. 2, the turbines are out of the water, and in a position suitable for maintenance, repair or replacement. Access for example from a boat is straightforward, and the support may be provided with suitable work platforms or the like.

Fig. 3 illustrates a transition of the assembly from the maintenance to the operating condition. The buoyancy of the support is reduced by progressive addition of ballast, typically in the form of water admitted into the buoyancy chamber or chambers. The support is arranged to sink at the trailing end, and thus swings relatively about the pivot 18 (clockwise) until approaching the operating condition of Fig. 4. At this point it may be preferable for buoyancy control to be suspended or to cease, so that reverse motion of the support can be assured. Drag from the stream flow, indicated by arrow 19, may be used to assist in pivoting the support 11 to the generally vertical orientation of Fig. 4.

The turbines may also be allowed to auto-rotate or to be driven in reverse in order to enhance drag for the purposes of assisting movement to or from the maintenance condition. Where several turbines are provided, typically in different horizontal planes of use, differential rotation may be used to enhance movement. Controlling the speed of the turbines allows fine control of frame movement.

Alternatively active drag surfaces may be deployed, a motor may act via the pivot axis 18, or a push/pull device may be provided between the tether 14 and the support 11. The advantage of this arrangement is that the support can automatically (or with assistance) return to a slightly inclined condition, for example less than 10° to the vertical, from which a variation in buoyancy will assure resumption of the maintenance condition.

An alternative or additional means of adjusting the upright position of the frame for engagement of a latch such as pin 24, is to arrange for ballast chambers, for instance

fore and aft of a vertical divider 77. Ballast water filling up the stern chamber (right-hand as viewed) of the frame will cause it to rotate clockwise and the bow chamber (left hand as viewed), anti-clockwise.

For trimming of the frame in positions other than the vertical, ballast chambers may be disposed along the length of the frame so as to allow trimming of the balanced position of the frame when at an angle between the upright operating condition and the horizontal maintenance condition.

The tether 14 includes an auxiliary arm 22 which extends above the pivot 18 and has a straight or cranked end 23 engageable with an abutment of the support 11 when in the operating condition. The abutment may include a compliant buffer or the like to prevent shock loading. Once in the condition of Fig. 4 a lock or latch is engaged to prevent further relative movement of the support and tether 14 beyond a defined range, typically no more than ±10° about the mean position.

As will be observed from Fig. 4, the support is arranged to pierce the surface of the water so as to give an indication of the position thereof. A suitable warning light may be provided. In the operating condition, the turbines 12,13 are wholly submerged, and adapted to generate electrical power, which may be transmitted in any appropriate manner, for example via a cable of the tether 14 and an underwater power collector of any suitable kind.

It will be appreciated that should maintenance or repair of the turbines be required, the assembly may be moved from the operating condition (Fig. 4) to the maintenance condition (Fig. 2) by unlatching the abutment lock, and increasing buoyancy of the support 11, which may be accomplished by pumping ballast water from the buoyancy chamber(s). The brake may be used to control the speed of relative movement about the pivot 18, to ensure smooth progressive transition.

A perspective view of an exemplar multi-turbine array is illustrated in Fig. 5, and comprises a support 11 consisting of twin buoyancy chambers 31 connected by substantially horizontal upper and lower cross arms 32,33, to which are attached an

array of six electricity generating turbines 34. The arrangement of Fig. 5 is illustrated in the operating condition. The support 11 comprises a generally cruciform frame which lies transverse to the stream flow direction in use, and is substantially co-planar with the surface of the water when in the maintenance condition.

A 'Y' shaped tether 35 has the apex connected to an underwater anchorage 36, which in this embodiment allows 360° rotation about a vertical axis at 37, and up and down motion about a horizontal axis at 38. The anchorage may also allow rolling of the structure from side to side, if desired.

Each arm 39 of the tether is pivoted to the support adjacent a connection between the lower cross arm 33 and a respective chamber 31, and further defines a respective auxiliary arm 40, having a cranked abutment end for engagement adjacent a connection between the upper cross arm 32 and a respective chamber 31. The arrangement is generally symmetrical, as illustrated in Fig. 5. The illustrated arrangement positions the tether 35 low in the water, and thus does not impede unduly the passage of shipping.

Fig. 6 illustrates an alternative embodiment in which the or each auxiliary arm comprises a rigid link 51 pivoted at one end to the tether 14, and sliding in a collar or trunnion 52 pivoted on the support 11. The arrangement is similar to the stay of an opening window. The link 51 has an abutment portion at the free end for engagement with a buffer of the support 11 and a suitable lock or latch to prevent relative movement when in the operating condition. The abutment portion maintains the support in a substantially vertical plane when in the operating condition. Upon movement to the maintenance condition, the link 51 slides through the trunnion, and may be braked so as to avoid abrupt changes of orientation of the support 11.

Figs. 7 and 8 illustrate a third embodiment in which the turbines 64 are mounted toward the bow or leading end of the support 61, and the support is allowed to sink bow-first (anti-clockwise) to the operating condition of Fig. 8. The tether 62 is cranked, for example at an angle greater than 60°, so as to have a greater draught in the deployment condition of Fig. 7, but as can be seen from Fig. 8 the tether lies close

to the underwater surface in the operating condition. A suitable abutment and latch may be provided at 63 to prevent relative movement of the tether 62 and support 61. In this arrangement the turbines 64 are on the leading side of the support 61, and thus unobstructed, as compared with the arrangement of Figs. 4 and 6.

Figs. 9-11 illustrate a fourth embodiment in which the tether 72 is straight from anchor end 73 to the frame pivot 74, and thus has a shallow draught in the deployment condition (Fig. 9). Fig. 10 illustrates the maintenance condition.

Fig. 11 shows the operating condition in which the support 71 has pivoted clockwise through 90°, a cranked end 75 of the tether constituting the abutment 76 for a trailing face of the support 71. The pivot 74 is at the lower portion of the support 71 (Fig. 11) and the abutment is approximately at the mid-point of the support. A buffer may be incorporated, as previously described.

In the drawings, the main frame spars 31 of Fig. 5 are illustrated as straight (and horizontal in the maintenance condition). In practice these spars may have a slight dog leg so as to be down in the middle in the maintenance condition. Such an arrangement may provide for enhanced sea-keeping and improved buoyancy balance when in the operating condition.

Fig. 12 shows a further example of an operating system arrangement where in the operating condition the tether 14 is connected further up the frame (adjacent the mid-point), with a lower auxiliary arm 22 providing a fixing against the stern, or lower part, of the frame (approximately midway between the main pivot 18 and the lower end).

Claims

1. An underwater turbine mounting comprising a buoyant elongate frame adapted to mount one or more stream flow turbines thereon, a rigid arm having a pivotal connection at one end to said frame, the other end of said arm being adapted for connection to an underwater anchorage, and means to vary the buoyancy of said frame whereby said frame is pivotable in use about said connection between a substantially horizontal maintenance position and a substantially upright operating position.

2. A mounting according to claim 1, wherein said frame comprises one or more buoyancy chambers adapted to be ballasted with water.

3. A mounting according to claim 2, and further including one or more valves operable to permit addition and/or removal of ballast water from said one or more chambers.

4. A mounting according to claim 2 or claim 3, wherein in the operating condition buoyancy chambers are provided fore and aft with respect to a stream flow direction to permit trimming of the upright orientation of the frame.

5. A mounting according to claim 4, wherein the fore and aft chambers are delimited in the operating condition by a substantially vertical divider of the frame.

6. A mounting according to any of claims 2-5, wherein in the maintenance condition buoyancy chambers are provided lengthwise of the frame, with respect to the stream flow direction, said chambers permitting trimming of the angle of the frame with respect to the arm when in transition between the maintenance and operating conditions.

7. A mounting according to claim 6, and further including a pump operable to add and/or remove ballast water from said one or more chambers.

8. A mounting according to any preceding claim, and having a floating deployment condition wherein said frame is in the maintenance position, and the other end of said arm is substantially horizontally aligned therewith.

9. A mounting according to claim 8, wherein the other end of said arm comprises a towing point for said frame.

10. A mounting according to claim 8 or claim 9, wherein said arm is latchable to said frame in the deployment condition to prevent relative pivoting thereof.

11. A mounting according to any of claims 8-10, wherein said arm is substantially straight.

12. A mounting according to any of claims 8-10, wherein said arm is cranked downwardly.

13. A mounting according to any preceding claim, wherein said connection is at a portion of said frame which is submerged in the operating position.

14. A mounting according to any preceding claim, and further including an abutment between said frame and arm to confine permissible relative pivoting thereof.

15. A mounting according to claim 14, wherein said abutment is engaged at the operating position.

16. A mounting according to claim 15, wherein said abutment comprises a complaint buffer.

17. A mounting according to any of claims 14-16, wherein said arm further includes a stay pivotable thereon at one end, and guided at the other end in a collar of said frame whereby said stay slides through said collar upon relative pivoting of the arm and frame.

18. A mounting according to any of claims 15-17, and further including a latch to maintain said arm and frame in the operating condition.

19. A mounting according to any preceding claim, and further including a brake operable to control relative pivoting between said arm and frame.

20. A mounting according to any preceding claim, wherein said frame is partially submerged in the operating position.

21. A mounting according to any preceding claim, and comprising a plurality of substantially parallel elongate frames linked by one or more cross members, wherein said arm is forked from an anchorage end for pivotal connection to two of said frames.

22. A mounting according to any preceding claim, and further including one or more stream flow turbines thereon.

23. A mounting according to claim 22, wherein said turbines are substantially above the waterline in the maintenance position.

24. A method of moving an underwater turbine mounting according to any preceding claim between a substantially horizontal maintenance position and a substantially upright operating position, the method comprising the steps of:

anchoring said arm to an underwater anchorage and varying the buoyancy of said frame.

25. A method according to claim 24, and including the step of adapting said frame to generate stream flow drag for enhancing said moving.

26. A method according to claim 24 or 25, wherein said frame includes one or more turbines thereon, and said method includes the steps of generating drag by turning of said turbines in a favourable direction for enhancing said moving.

27. A method according to claim 26, wherein said one or more turbines is permitted to auto-rotate in a stream flow.

28. A method according to claim 26, wherein said one or more turbines is driven.

29. A method according to claim 26, wherein one of a plurality of turbines is driven.

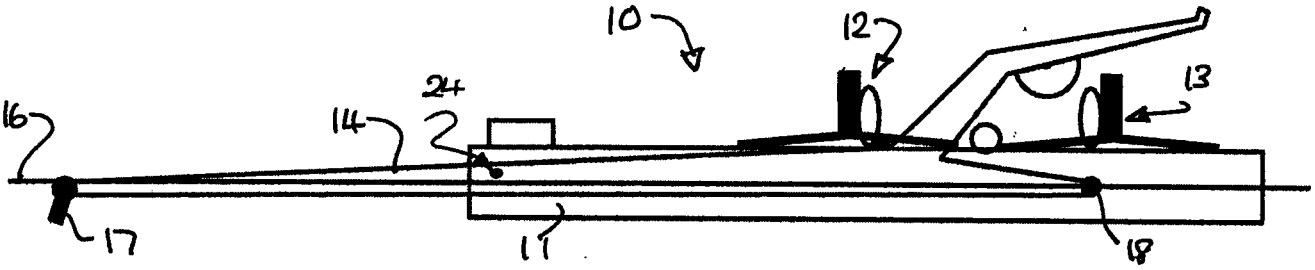


Fig1

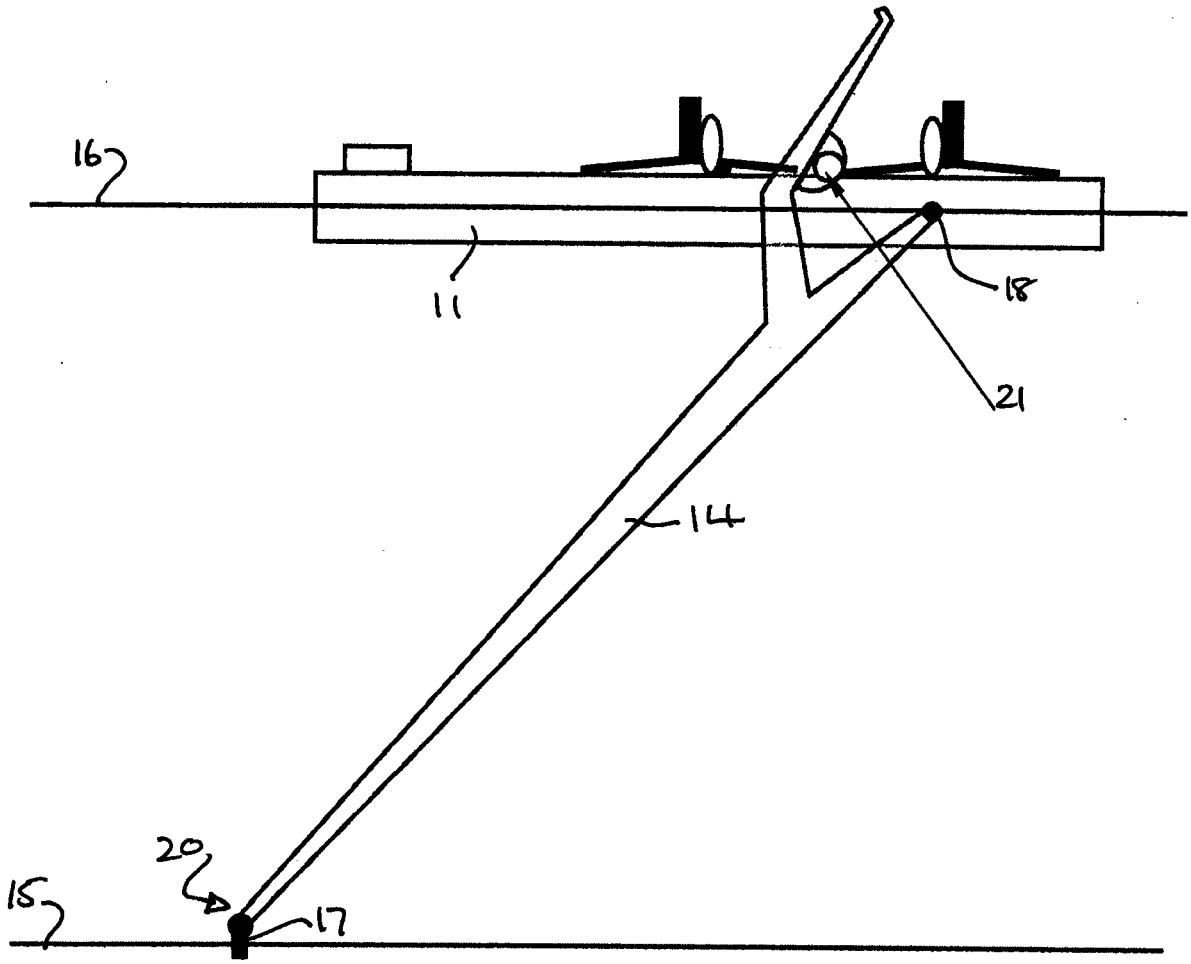


Fig2

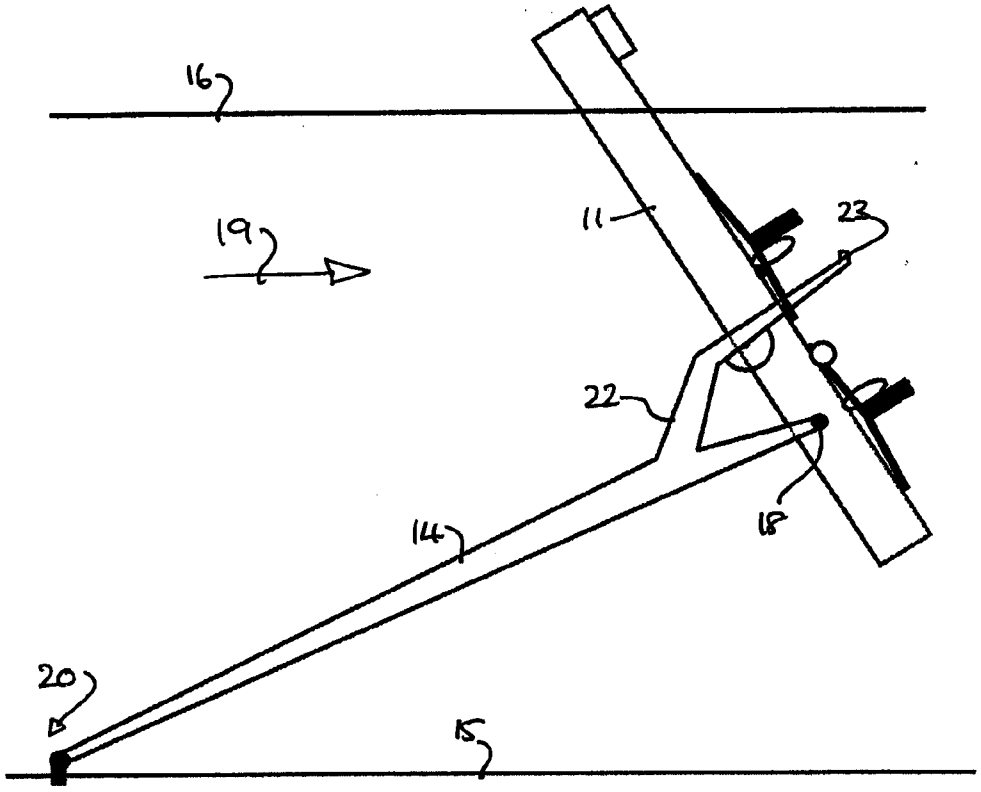


Fig 3

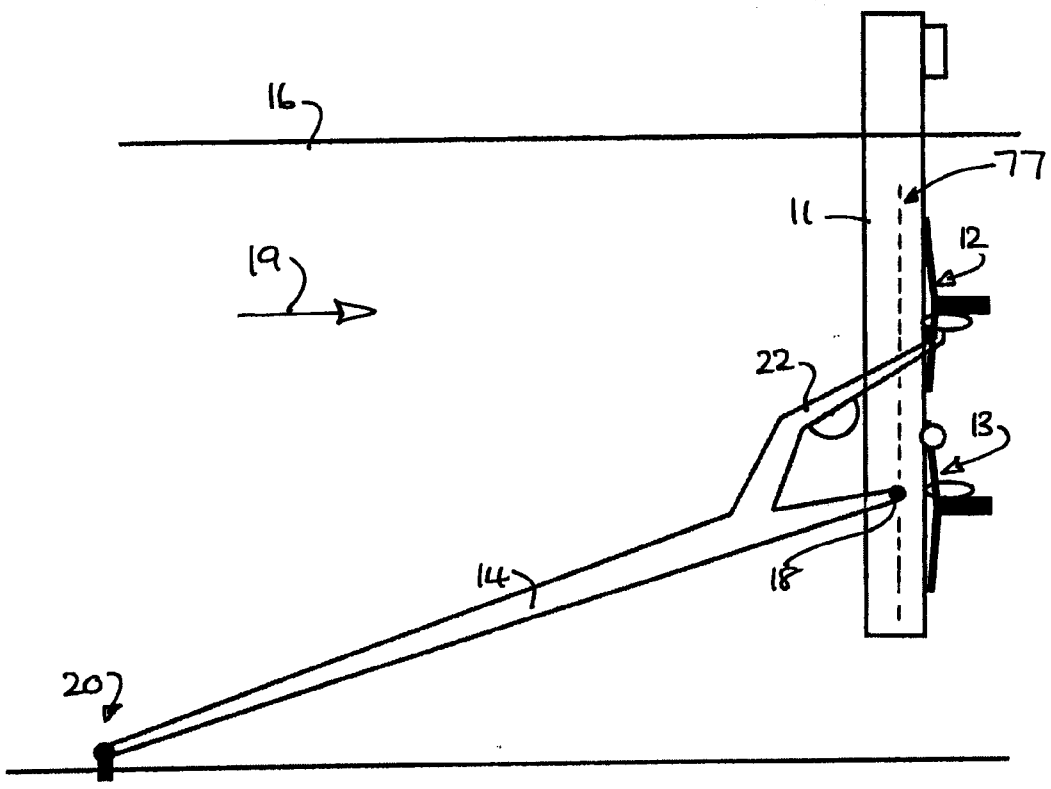
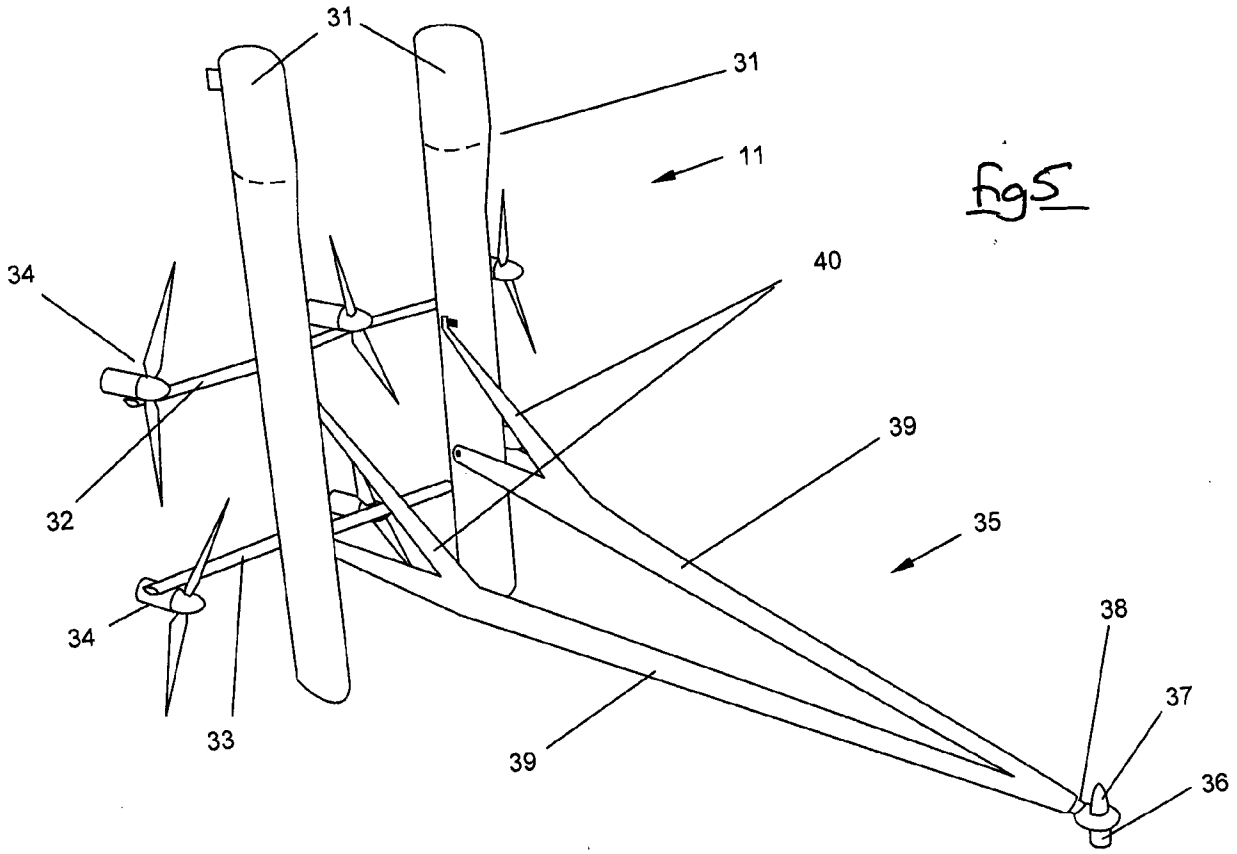
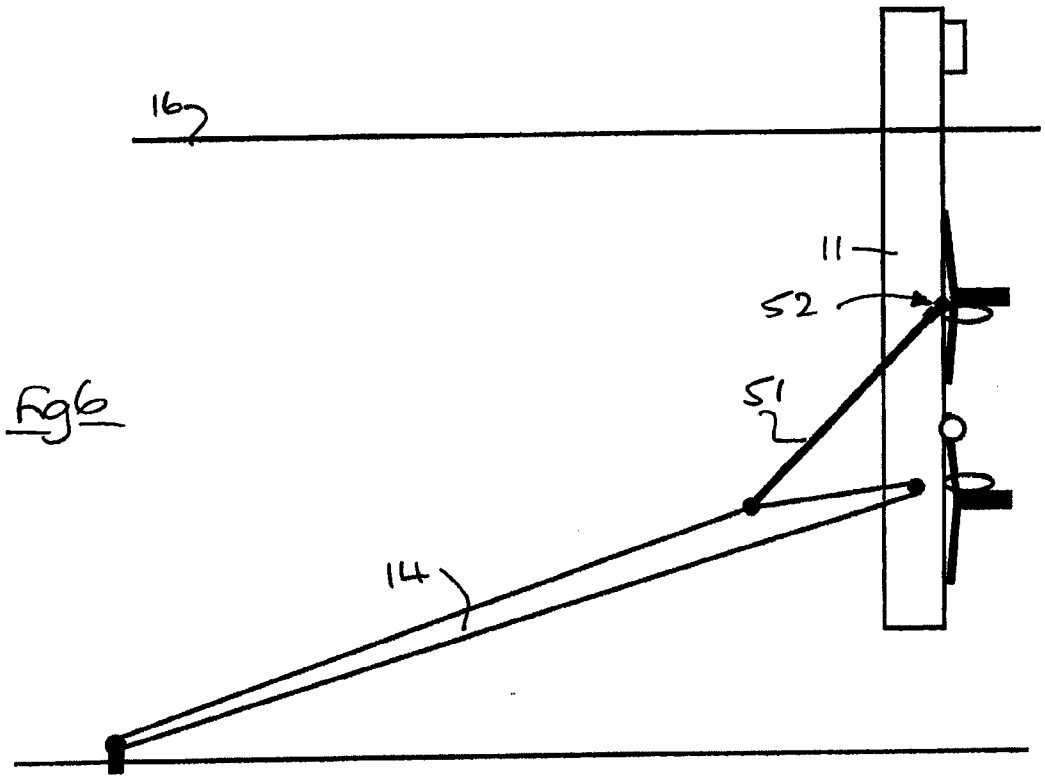


Fig 4



Fg5



Fg6

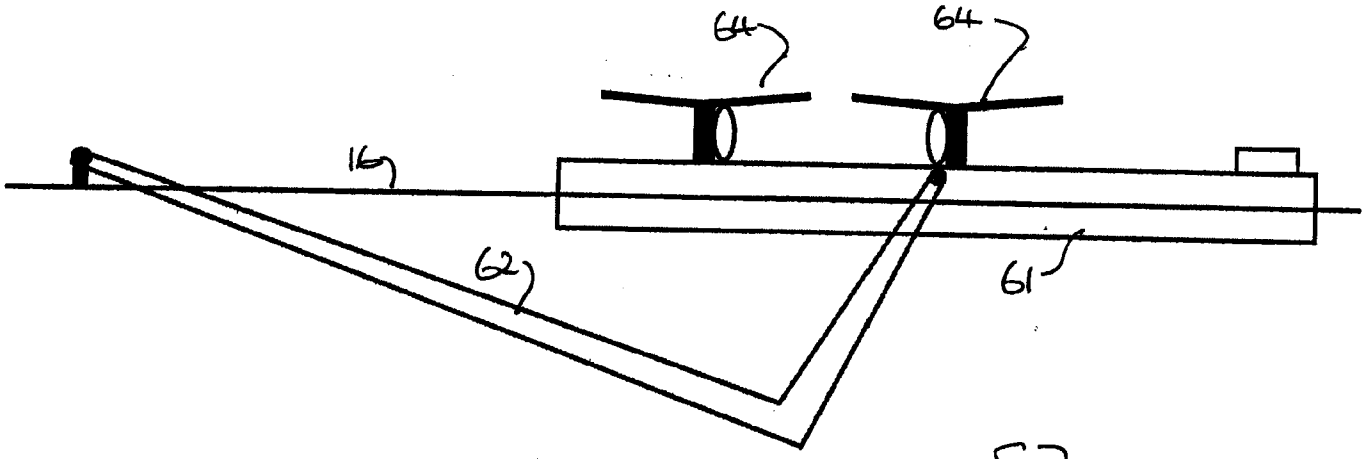


Fig7

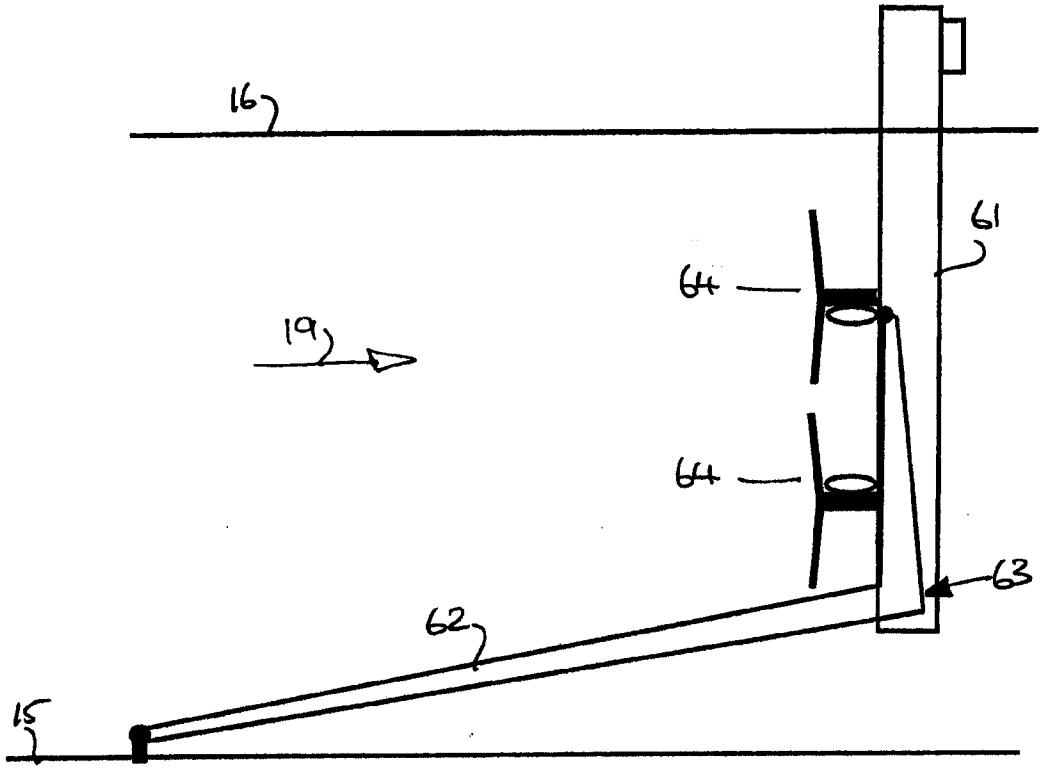


Fig8

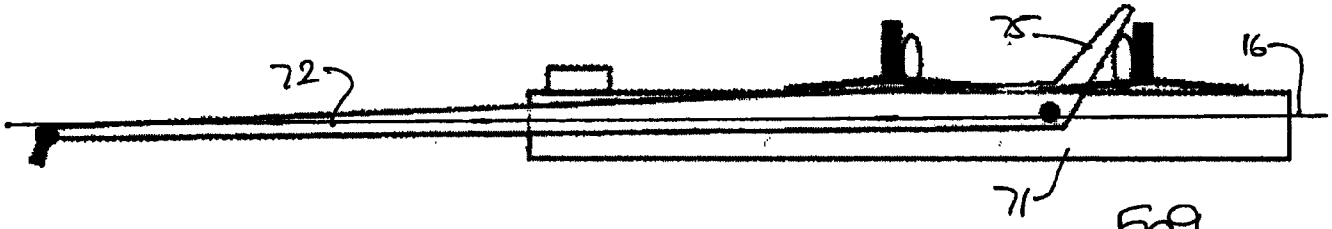


Fig9

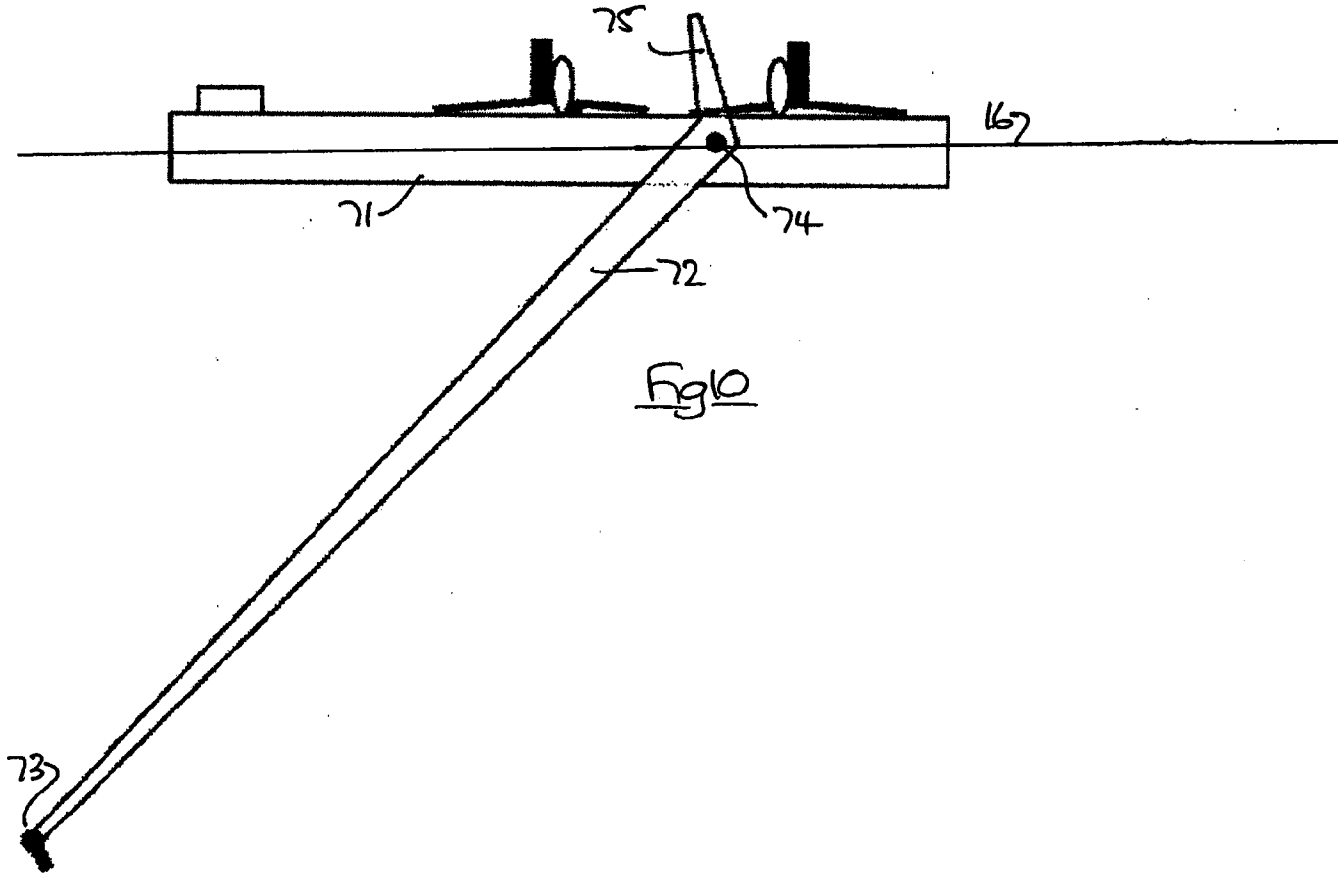


Fig10

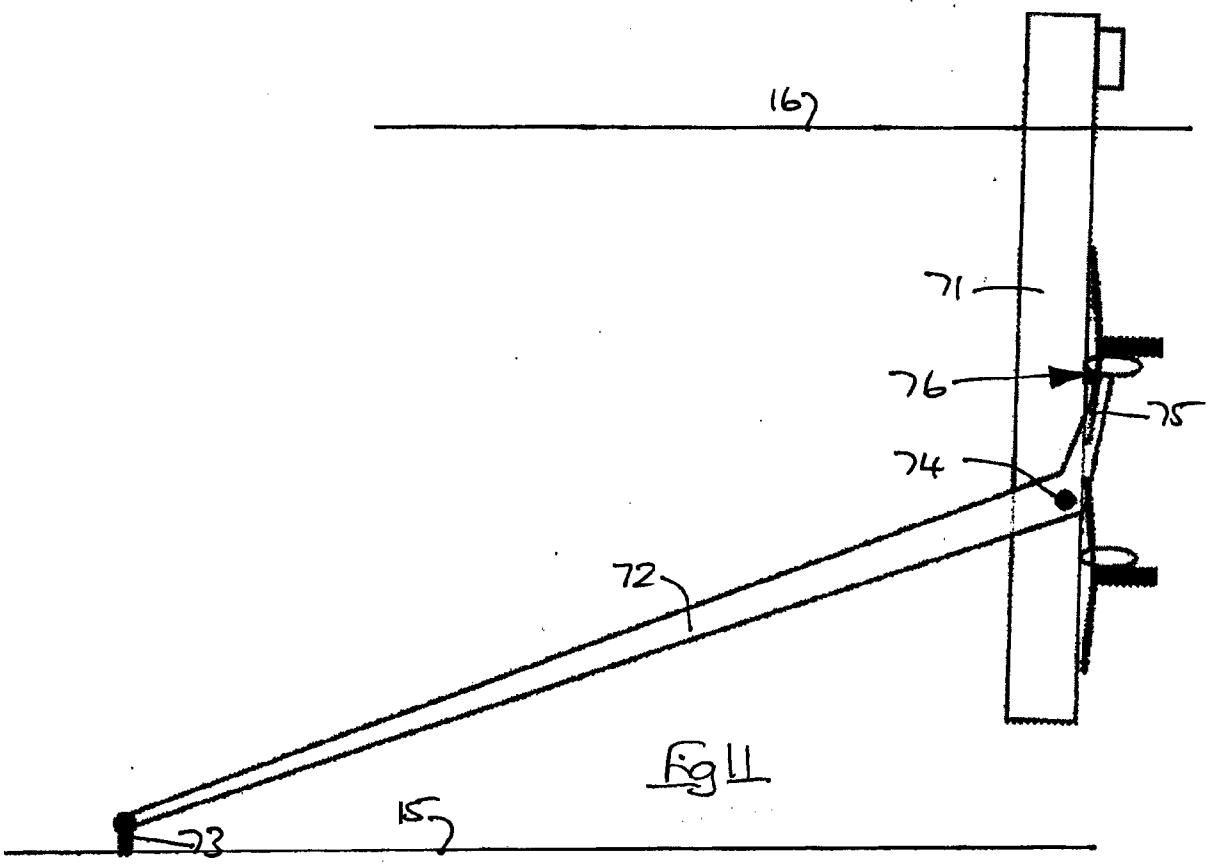


Fig 11

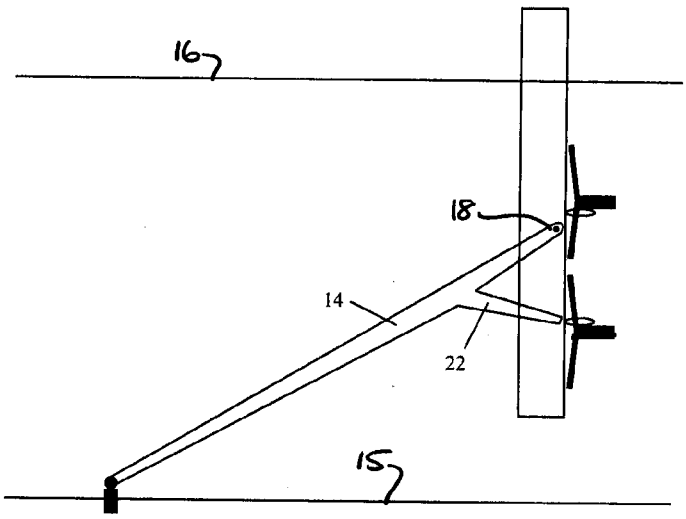


Fig 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2012/053026

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03B13/26 F03B17/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 450 624 A (ARMSTRONG JOHN RICHARD CAREW [GB] ; TODMAN MICHAEL TORR [GB] ARMSTRONG) 31 December 2008 (2008-12-31) page 2, lines 25-30; figures 1-13 page 3, lines 20-22 page 4, lines 1-12 page 7, lines 1-3 page 15, line 24 - page 16, line 2 -----	1-8, 10-16, 20-29
X	GB 2 441 822 A (TODMAN MICHAEL TORR [GB]) 19 March 2008 (2008-03-19) figures 1-5 -----	I-3,8,9 , II- 24, 28,29

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[X] Further documents are listed in the continuation of Box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
18 March 2013	25/03/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Biloen, David

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2012/053026

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 434 410 A (TODMAN MICHAEL TORR [GB]) 25 July 2007 (2007-07-25) cited in the application page 5, line 27 - page 6, line 12; figures 1-5 page 8, lines 13-17	1-3,8,9, 11,13-24
X	WO 2010/078903 A2 (ROLLS ROYCE PLC [GB]; SIMANWE TEZA [GB]; KINSON ALAN STUART [GB]; CHON) 15 July 2010 (2010-07-15) page 7, lines 1-17; figures 1,2	1,2
A	GB 2 473 354 A (KINGSTON WILLIAM [IE]) 9 March 2011 (2011-03-09) the whole document	1-29

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2012/053026

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