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(54) **Titre : AGENCEMENT DE CAPTEURS POUR GENERATEUR DE MAREE**
(54) **Title: A SENSOR ARRANGEMENT FOR A TIDAL GENERATOR**

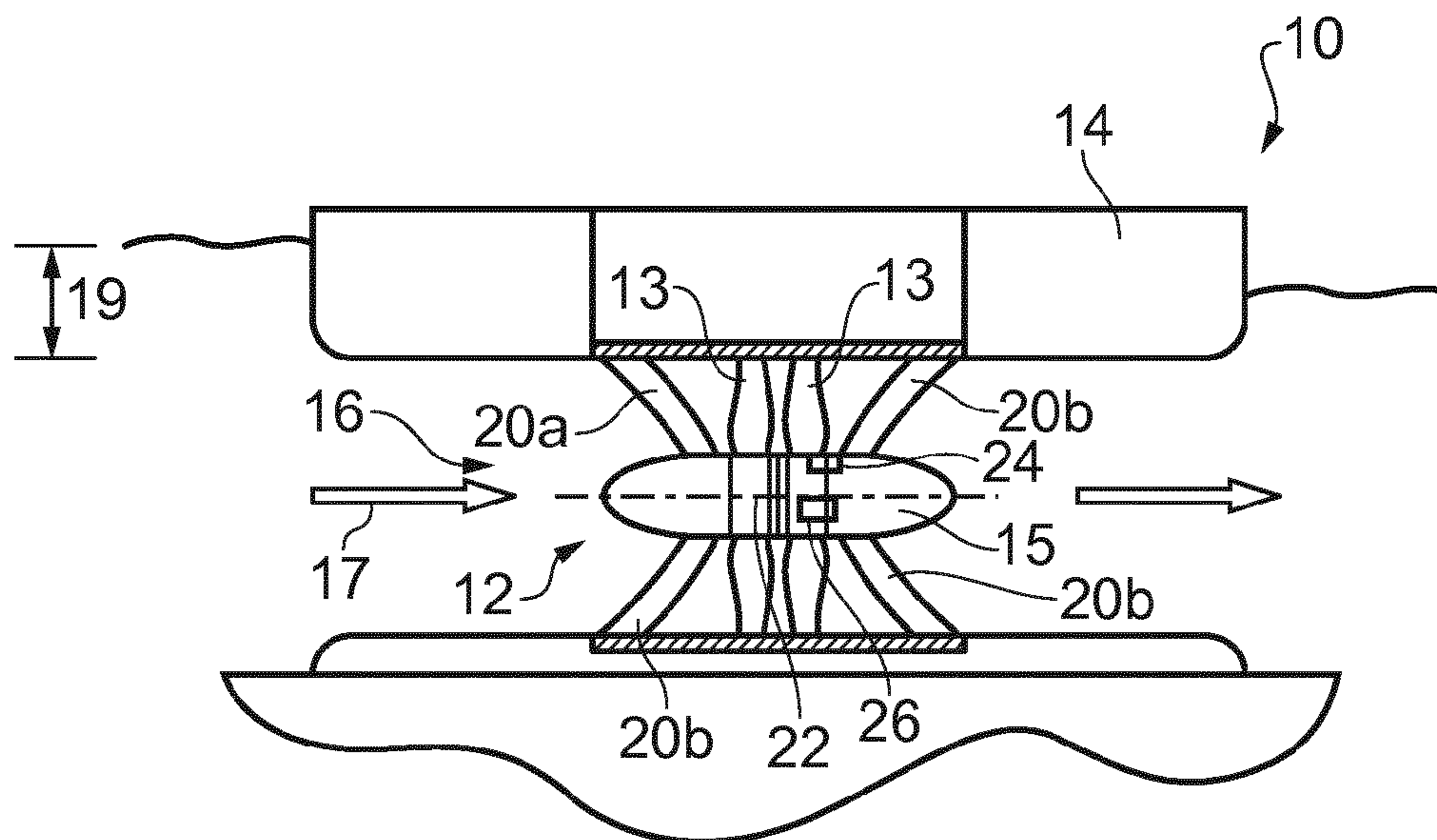


FIG. 1

(57) **Abrégé/Abstract:**

This invention relates to a generator arrangement (10), comprising: a generator (12) located within a flow passage (16) wherein the flow passage (16) has an inlet and an outlet, and the generator (12) includes at least one contra-rotating blade arrangement (13) which is configured to be rotated about a principle axis (22) of the generator (12) by a flow of liquid (17) in the flow passage, and wherein the at least one blade (13) has an adjustable pitch; an array of sensors (222-228) located downstream of the blade arrangement for detecting the outlet flow conditions; a controller (26) for determining the outlet flow conditions on the basis of conditions sensed by the sensor array; and, a pitch control system (24) for adjusting the pitch of the at least one blade so as to affect the flow conditions at the outlet of the flow passage.



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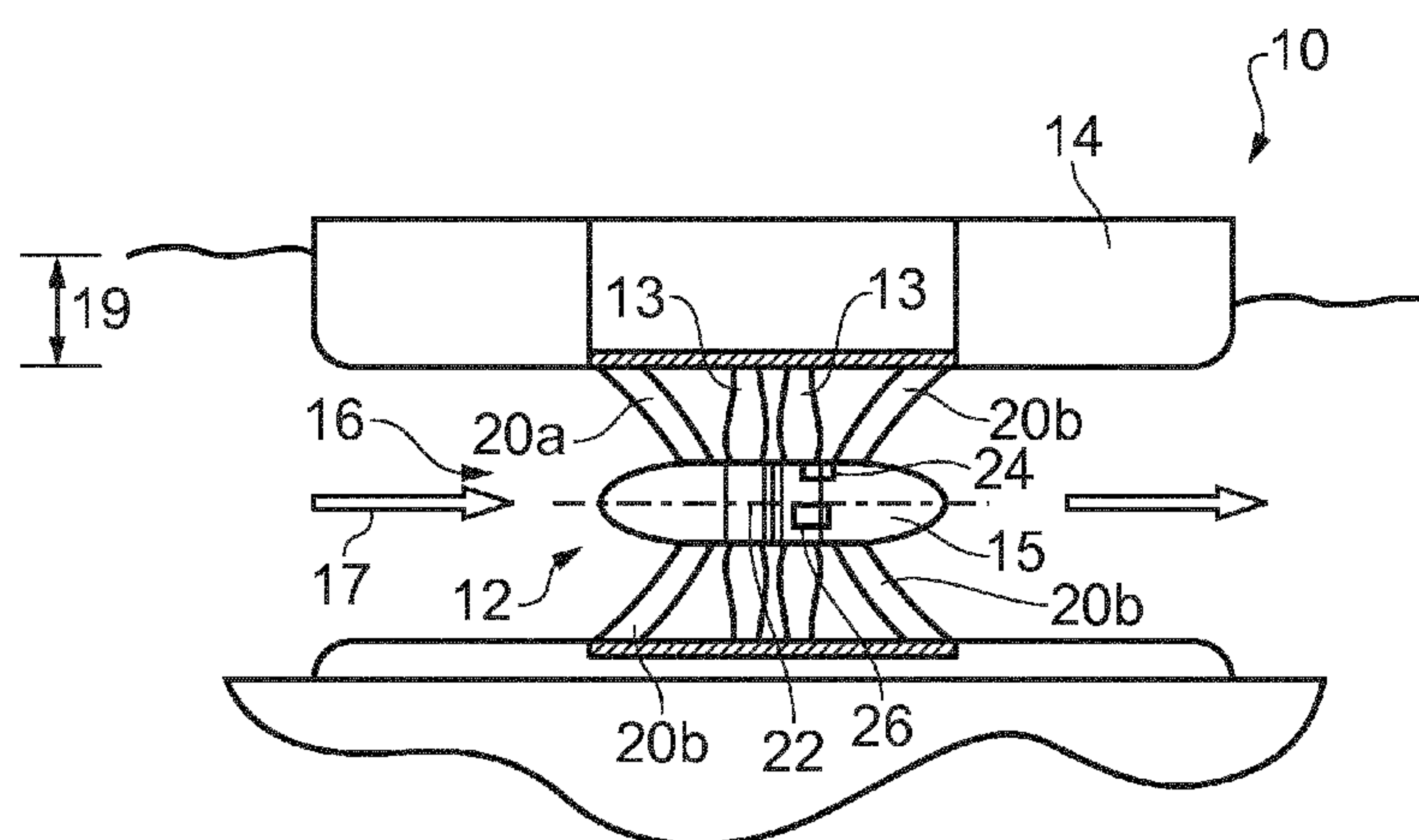


FIG. 1

(57) Abstract: This invention relates to a generator arrangement (10), comprising: a generator (12) located within a flow passage (16) wherein the flow passage (16) has an inlet and an outlet, and the generator (12) includes at least one contra-rotating blade arrangement (13) which is configured to be rotated about a principle axis (22) of the generator (12) by a flow of liquid (17) in the flow passage, and wherein the at least one blade (13) has an adjustable pitch; an array of sensors (222-228) located downstream of the blade arrangement for detecting the outlet flow conditions; a controller (26) for determining the outlet flow conditions on the basis of conditions sensed by the sensor array; and, a pitch control system (24) for adjusting the pitch of the at least one blade so as to affect the flow conditions at the outlet of the flow passage.

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A Sensor Arrangement for a Tidal Generator

This invention relates to a sensor arrangement for monitoring the flow conditions experienced by a tidal generator. In particular, invention relates to an apparatus for
5 controlling the exit swirl from the generator so as to maximise efficiency.

Tidal barrage schemes are known in the art. An example of a tidal barrage scheme is the one at La Rance in France. This scheme uses 24-off 10 MW low head bulb turbines to capture energy from an eight metre tidal range using a 22.5 km² basin.

10

It is known that for all types of turbine that optimum efficiency is obtained when the exit swirl velocity from the turbine is zero as the losses in the outlet flow are minimised. Typically, variable pitch rotor and stator vanes are used to provide the desired output flow across a range of operating conditions. These systems are used in accordance with
15 predetermined parameters derived from measurements. However, it is very difficult to account for a uniform inlet flow in this way.

The present invention seeks to provide a monitoring apparatus and method which accounts for a wide variety of flow conditions.

20

In a first aspect, the present invention provides a generator arrangement, comprising: a generator located within a flow passage wherein the flow passage has an inlet and an outlet, and the generator includes at least one contra-rotating blade arrangement which is configured to be rotated about a principle axis of the generator by a flow of
25 liquid in the flow passage, and wherein the at least one blade has an adjustable pitch; an array of sensors located downstream of the blade arrangement for detecting the outlet flow conditions;
a controller for determining the outlet flow conditions on the basis of conditions sensed by the sensor array and a pitch control system for adjusting the pitch of the at least one
30 blade so as to affect the flow conditions at the outlet of the flow passage.

The arrangement of the present invention allows the flow conditions exiting the outlet of a flow passage to be monitored and the pitch of the generator blades to be adjusted.

In doing so, it is possible to reduce the exit swirl velocity of the generator flow passage and thereby increase the efficiency of the rotating blades.

The generator arrangement may be part of a barrage tidal scheme. As such the generator arrangement may be located within a dam or barrage. The dam or barrage
5 may be across an estuary or lagoon. The barrage or dam may include a plurality of generator arrangements. The flow passage may be a passage through the dam or barrage. Alternatively, the generator arrangement may be for use in an open flow. In an open flow arrangement the flow passage would be defined in relation to the rotational path of the blade arrangement.

10

The blade arrangement may include contra-rotating blades.

The at least one sensor array may be located on a support member. The support member may be located within the flow passage. The support member may be
15 mounted the dam or barrage. The support member may be attached to a hub of the generator. The support member may be a generator blade. In the case where the generator has a contra-rotating blade arrangement, the support member may be located between the contra-rotating blades. The support member may be a strut for supporting the electrical generator within the flow passage.

20

The sensor array may include three upstream sensors. The sensor array may include one downstream sensor. The sensors may be pressure sensors. The pressure sensors may be of a diaphragm type.

25 The sensors may be located within a cavity of the support member. The cavity may have a longitudinal axis extending from the surface of the support member. The cavity being sized and shaped so as to expose the sensor to a predetermined angle of the flow velocity along the longitudinal axis of the cavity. The cavity may be a bore or slot within the support member. The bore or slot may be elongate having a longitudinal axis. The
30 longitudinal axis may be orthogonal to the sensor.

The sensor array may include at least one upstream sensor and one downstream sensor along a common axis. The common axis may run in a direction parallel to the principle axis of the generator. The sensor array may be included at least two lateral sensors

arranged equidistantly from the common axis. The upstream sensor may be located at a mid-point between the two lateral sensors.

The sensor arrays may be mounted on a curved support member. For example, the
5 cross section of the support member may be circular or oval. The cross section of the support member may be elliptical. The longitudinal axis of the cavities of the lateral sensors may be separated by an included angle of approximately 60 degrees.

The embodiments of invention will now be described here file for this in which:
10

Figure 1 shows a cross section of a generator according to the present invention.

Figure 2 shows a cross section of a strut having a sensor arrangement according to one embodiment of the present invention.

15

The tidal barrage generator arrangement 10 shown in Figure 1 includes a contra-rotating generator 12 located within a dam or barrage structure 14. The generator includes contra rotating blades 13 which are rotatably mounted to a hub 15 which is held in a stationary position during use. The generator 12 includes a pitch adjustment
20 system 24 within the hub which is operable to adjust the pitch of the blade, and thus the area of the blades 13 exposed to the inlet flow and the generated torque. Such pitch adjustment systems are known and typically used to control the power generated at any given instance.

25 Typically, the barrage 14 would extend across a tidal estuary or lagoon and include several electrical generators 12. The generator 12 sits within a flow passage in the form of a cylindrical passageway 16 having an inlet and an outlet. In use water flows 17 through the passageway 16 when a head 19 is created on one side of the barrage 14, i.e. when there is tidal movement. The generator 12 is configured such that the blades
30 13 contra-rotate when the tidal flow passes from one side of the barrage 14 to the other, thereby generating electricity for export to a grid or the like.

The tidal barrage structure 14 includes support members in the form of inlet struts 20a and outlet struts 20b which locate the generator body within the flow channel. The

struts 20a, 20b are arranged to transfer the mass of the generator hub 15, the axial thrust created by the tidal flow, and to react the torque from the drive train. It will be appreciated that there may be a plurality of struts 20a, 20b circumferentially spaced around the flow passage 16 as required.

5

In the described embodiment one of the downstream struts 20b includes sensors which are arranged to detect the exit swirl flow conditions as the water leaves the generator 12. This information can then be used by a controller 26 to determine the angle of the rotor blades (and stators if they are used) to adjust the exit swirl flow, thereby

10 minimising it and maximising the efficiency of the generator.

Figure 2 shows a cross section of one of the supporting struts 20b containing an array of sensors. The strut 20b is elliptical in cross-section and includes four flow sensors 222, 224, 226, 228. In this embodiment, the major axis 230 of the strut 20b is aligned so as
15 to run parallel to the principle axis 22 of the contra-rotating blades of the generator 12 and thus in line with an axial tidal flow 17. Two of the flow sensors 224, 228 are positioned on the major axis 230 of the strut 20b, one on the upstream facing surface of the strut (the upstream sensor 224), and one on the downstream facing surface of the strut (the downstream sensor 228). Two further lateral sensors 222, 226 are arranged
20 on the upstream facing surface, equidistantly on either side of the upstream sensor 224.

The sensors 222 - 228 are all mounted within a cavity in the respective surface of the strut 20b. In the embodiment, the cavities are in the form of bores 222a - 228a having a
25 longitudinal axis which extends from the surface of the strut 20b. The longitudinal axes of the upstream and downstream sensor bores 224a, 228a are coaxial with each other and the major axis 230 of the strut 20b. The longitudinal axes of the lateral sensor bores 222a, 226a are inclined at an angle of β . The magnitude of β can be any required by the particular arrangement of the strut 20b and by the flow, but is approximately 60
30 degrees in the described embodiment. The sensors 222 - 228 are located at the terminal end of each of the bores 222a - 228a and so only experience the component of flow in the direction which corresponds to the longitudinal axis of the bore. The skilled person will appreciate that to obtain an accurate reading of dynamic pressure it may be

necessary to provide a cavity in the form of channel through which the sea water can flow, rather than a closed bore.

The sensors used in this arrangement can be pressure sensors in the form of diaphragm
5 sensors or the like.

The sensors 222-228 detect the exit swirl of the flow through the turbine at any head and flow condition. This information may then be fed to the turbine control system which is in communication with the pitch control system housed within the hub. Thus,
10 the turbine control system may vary the pitch of the upstream and downstream rotor blades to minimise exit swirl at all head and flow conditions accordingly. The turbine control system may be housed within the hub or remotely and will typically include some form of data processing hardware operating under the influence of one or more algorithms to carry out the necessary operations. For example, the controller may also
15 monitor the effective pitch of the rotor blades by sensors on the blades.

The location of the sensors 222 - 228 in the described arrangement allow the flow rate to be measured using a pressure from the three upstream facing sensors 222, 224, 226 and the static pressure from the downstream sensor 228. Specifically, if the flow 232
20 approaches the strut at angle α (as shown in Figure 2), then the total pressure experienced by the forward facing sensor 224 will be given by: $p_0 + \frac{1}{2}\rho U_0^2 \cos^2 \alpha_0$, and the total pressure apparent to lateral sensor 226 is $p_0 + \frac{1}{2}\rho U_0^2 \cos^2(\beta/2 - \alpha_0)$.

The two remaining sensors 222 and 228 have no inlet normal to the direction of flow
25 given the flow condition shown in Figure 2 and so only detect the static pressure p_0 of the inlet flow. The static pressure p_0 is the pressure head resultant from the column of water from the free surface to the sensor depth. The dynamic head at the flow facing sensors 224, 226 is determined by subtraction of the static pressure measurement at non-flow facing sensors 222, 228.

30

Using the above sensor relationships, the inlet swirl angle α_0 and flow velocity U_0 may be determined by solving the resulting simultaneous equations to provide a figure for the dynamic head at each sensor $h_{224} = \frac{1}{2}\rho U_0^2 \cos^2 \alpha_0$ and $h_{226} = \frac{1}{2}\rho U_0^2 \cos^2(\beta/2 - \alpha_0)$

where h_{224} , h_{226} , ρ , and β are known. The inlet axial velocity U_{x0} through the turbine may also then be determined with knowledge of α_0 and U_0 .

In addition, the downstream sensor 228 sees the total head $p_3 + \frac{1}{2}\rho U_3^2 \cos^2 \alpha_3$ and as
5 mass continuity requires that U_{x0} and U_{x3} are equal, the angle of exit swirl α_3 may be determined as $\arccos(U_3/U_{x0})$. $p_3 - p_0$ is the static pressure reduction resulting from work transfer to the turbine rotor.

In use, the tidal water passes through the flow passage, thereby rotating the contra-
10 rotating blades of the generator and generating power. The sensors detect the flow conditions and exit swirl produced by the rotating blades and sends corresponding signals to the control system. There the controller calculates the exit swirl conditions and a desired pitch for the blades so as to reduce exit swirl and maximise the efficiency of the generator. Once calculated, the controller provides the pitch control system with
15 an appropriate signal and the pitch is adjusted. This is an iterative process which is carried out as required so as to maintain the maximum output of the generator.

Claims:

1. A generator arrangement, comprising:
a generator located within a flow passage wherein the flow passage has an inlet
5 and an outlet, and the generator includes at least one contra-rotating blade
arrangement which is configured to be rotated about a principle axis of the generator
by a flow of liquid in the flow passage, and wherein at least one of the contra-rotating
blades has an adjustable pitch;
an array of sensors located downstream of the blade arrangement for detecting
10 the outlet flow conditions;
a controller for determining the outlet flow conditions on the basis of conditions
sensed by the sensor array; and,
a pitch control system for adjusting the pitch of the at least one blade so as to
affect the flow conditions at the outlet of the flow passage.
15
2. A generator arrangement as claimed in claim 1 wherein the at least one sensor
array is located on a support member.
3. A generator arrangement as claimed in claim 2 wherein the support member is a
20 strut for supporting the electrical generator within the flow passage.
4. A generator arrangement as claimed in any preceding claim wherein the sensor
array includes three upstream sensors and one downstream sensor.
- 25 5. A generator arrangement as claimed in any preceding claim wherein the sensors
are pressure sensors.
6. A generator arrangement as claimed in any of claims 2 to 5 wherein the sensors
are located within a cavity which has a longitudinal axis extending from the surface of
30 the support member, the cavity being sized and shaped so as to expose the sensor to a
predetermined angle of the flow velocity along the longitudinal axis of the cavity.
7. A generator arrangement as claimed in any preceding claim wherein the sensor
array includes at least two lateral sensors arranged equidistantly from a common axis.

8. A generator arrangement as claimed in any preceding claim wherein the sensor array includes at least one upstream sensor and one downstream sensor along the common axis.

5

9. A generator arrangement as claimed in any of claims 6 to 8 wherein the support member is rounded and the longitudinal axes of the cavities of the lateral sensors are separated by an included angle of approximately 60 degrees.

10 10. A generator arrangement as claimed in any preceding claim further comprising a second sensor array which is arranged to detect the flow conditions in the direction of flow is opposite to that for which the first sensor array is configured to detect.

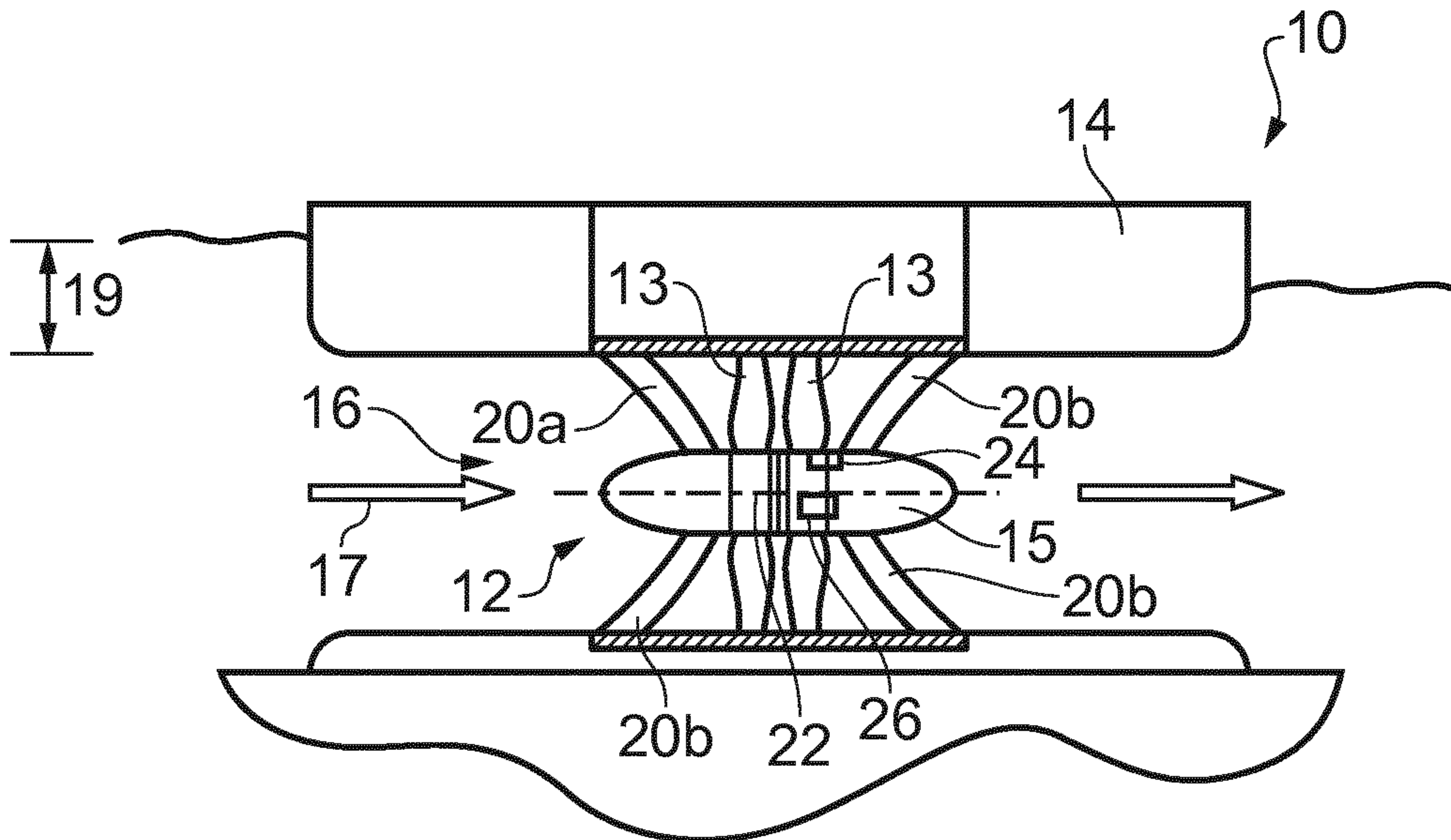


FIG. 1