PROCESS AND DEVICE FOR CONVERTING HYDRAULIC ENERGY INTO MECHANICAL ENERGY

A process and a device for converting the energy of a water stream into pneumatic energy of an air stream which, in turn, is converted into mechanical energy.
PROCESS AND DEVICE FOR CONVERTING HYDRAULIC ENERGY INTO MECHANICAL ENERGY

DESCRIPTION

It is an aim of the inventor to propose a process and a method for making it easier and cheaper to convert hydraulic energy into mechanical, especially from those water streams that are characterised by very low head drop values, and by rather large and/or very large flow rates.

Water streams with very low head drops (e.g. 2-5 metres) and large flow rates (e.g., 10-100 cubic metres per second), require hydraulic turbines that are much slower than those usually working on high-head streams, and, in the very general case where one wishes to obtain the energy in the form of electricity, the electric generators that are available for direct coupling with slow motors are complicated, heavy and expensive.

Even gearing up entails drawbacks in terms of greater weight and cost and lesser reliability.

This problem has already been solved in part by using, instead of a water turbine, a device for obtaining an air stream from the water stream and using said air stream for feeding a pneumatic motor coupled with an electric generator.

One thus obtains the advantage of using, for an equal power, a much faster, lighter and cheaper motor for operating the electric generator.

For transferring energy from a water stream to an air stream, at least two methods have been used so far: namely, the “hydraulic air compressor” and the “oscillating water column”, or OWC for short; both will be better described in the following.

Water streams characterised as above are often available in the nature and the energy
they contain is not negligible.

Rivers and brooks offer very many examples, that are presently the object of very careful scrutiny for their capacity of yielding power at an acceptable cost.

They all belong to the class of renewable energies defined as Small Hydroelectric Power (SHP), a theme on which the European Union has set up a Network of Excellence, or research community.

However, for the reasons stated above, the cost of hydroelectric power plant is considered to be excessive in those cases where the available drop is too low, typically if less than 3 metres. Even plants between 3 and 4 metres drop are considered borderline, and their construction suffers a lot of hesitation and delay.

The hydraulic air compressor has been used in a few instances to exploit inland water streams, especially where a direct use for compressed air as such was at hand.

The sea offers many examples of low-drop streams, both in the form of the well known tidal currents, and as currents produced by wave motion or that can be derived from it.

Another Network of Excellence, also set up by the European Union, has given rise to many diverse proposals for obtaining from wave motion at least a fraction of the huge amount of energy it is continually throwing on our coasts.

Some of these proposals are presently at the pilot plant stage, and they mostly follow any of three lines: (1) direct use of the water current through hydraulic turbines connected with special electric generators, (2) conversion of the wave energy into a stream of hydraulic oil under high pressure, by means of floats acting on special piston pumps, (3) conversion of the wave energy into an air stream, by the OWC method.

The "hydraulic air compressor" has also been proposed in connection with wave motion, but no plants based on this method are known to have been built so far.

The hydraulic air compressor has been known for quite some time.

In principle, this device connects a forebay and a discharge basin or receiving pool. Water in the latter has a lower level than in the former, and the level difference is the motive head drop one wants to use. Water leaves the forebay through a pipe.

On entering said pipe, it is caused to entrain some air from the atmosphere, and the
pipe leads the air-water mixture to a chamber or vessel placed at a much greater depth than the level of the discharge basin.
Within said chamber or vessel, air and water separate from each other, the water is withdrawn from its bottom through another pipe that connects it with the discharge basin, while the air can be withdrawn under pressure by means of a third pipe from the ceiling of the separator.
To avoid the cost of building deep underground chambers, in some instances use has been made of exhausted mine sites.
A recent proposal features the use of dismissed oil tankers as separator vessels, that would be sunk and laid on the sea floor.
This proposal envisages the capture of wave energy, the forebay being divided from the sea by a dam higher than the mean sea level, but lower than a significant fraction of the waves that can be expected at the site.
All waves that top the dam will throw water into the forebay, so its level can stay higher than the mean sea level. The hydraulic air compressor will then connect the forebay with the sunken ship, and compressed air can be withdrawn from the latter, while water flows from its bottom directly into the surrounding sea.
Examples of such method are shown in the documents JP 2002-021699 and JP 2002-021800.
Drawbacks of this method are that of the cost and inconvenience of building or installing large underground or submarine structures and that, if the purpose is to drive a motor, this receives a mist that can cause considerable damage to machinery in the long run.
While the above proposal has not been tried out yet, at least two pilot plants are using the OWC principle.
This relies on the fact that, although wave motion in the open seas is mostly oscillatory and has an important component in the vertical direction, near the coast, and in general at shallow sites, the waves give rise to strong, albeit alternating, horizontal streams.
Waves are captured by means of a chamber placed across the mean level of the sea, so that its lower part is below said level, while its higher part is above it. Said
chamber has no opening but one that is below sea level all the time, through which the water flows periodically in and out, so to produce an oscillating water column (OWC), that either compresses or expands the air in the space above it.

From the ceiling of said chamber to the atmosphere, a duct leads the air through a special turbine, so designed as to turn always in the same sense, whichever sense takes the air motion, i.e. both when the air flows into the chamber and out of it. And the turbine drives a fast electric generator, that is a lightweight one, based on a design that is rather commonplace and cheap.

Although the air stream has the same volume or, more exactly, an equal volume flow rate as the incoming water stream, and if the air pressure drop effectively driving the turbine equals the available water head, air can flow at much higher speeds than water, owing to its much smaller density, and this causes the pneumatic turbine to turn much faster than the hydraulic one.

However seemingly complicated, the OWC solution is favoured by many designers in view of its robustness, comprising machines not difficult to build and that are sheltered, to some extent, from damage by the sea. But the civil works it requires are huge indeed, since the chamber must swallow the full volume of each wave, amounting to thousands of cubic metres, and so imply a high construction cost, visual impact, maintenance charges.

Furthermore, the OWC system produces an air stream with a pressure that periodically oscillates between values above and below the atmospheric pressure.

Scope of the present invention is to avoid the drawbacks of the prior art devices and processes.

This is obtained by a method according to claim 1 and by a device according to claim 5.

Further advantages can be achieved by means of the additional features of the dependent claims.

It has now been found that advantages equal to those of the hydraulic air compressors or OWC systems can be obtained at lesser cost and with fewer drawbacks, by using a different means for converting water energy into pneumatic energy different from those of the present art; i.e., how it will better clarified in the
following, using the energy of an air stream aspirating ambient air in a duct by means of a suction produced by a water stream in said duct and using the energy of said air stream to move a pneumatic machine before this air is aspirated into the duct.

This can be obtained, according to the present invention, by means of the suction that can be created within a zone of a Venturi tube or within a zone of a siphon or, better, in general, within a duct so shaped as to be able to act both as a Venturi tube and as a siphon (namely the Venturi tube, or Venturi for short). While the OWC system produces an air stream with a pressure that periodically oscillates between values above and below the atmospheric pressure, the Venturi will maintain a continuous suction and an air stream that is constantly at a pressure below atmospheric.

When compared to the hydraulic air compressor, the Venturi offers the advantage of avoiding the cost and inconvenience of building or installing large underground or submarine structures; moreover, if the purpose is to drive a motor, this receives clean air instead of a mist that can cause considerable damage to machinery in the long run.

The Venturi tube, or Venturi for short, is a very simple device, basically comprising a main convergent-divergent duct, with an intermediate point or stretch where its section is at the narrowest, and another duct or secondary duct, that ends into said intermediate point or stretch having the narrowest section.

A first fluid, or driving fluid, flows in the main duct. In its initial, convergent length, the fluid is forced to increase its velocity, because the duct section area diminishes continuously.

The fluid velocity will remain constantly high in the intermediate stretch with a uniformly narrow section, that is named the throat of the Venturi, then it will slow down in the divergent length, that is often named diffuser or diffusor.

As stated by Bernoulli’s theorem, the pressure of the fluid will change in a sense opposed to that of velocity changes: it will diminish in the convergent length, then remain at a minimum all along the throat, and it will increase in the diffusor.

These phenomena are put to use for sucking into the throat any second fluid that arrives there by means of the secondary duct.
This second fluid will mix with the first, or driving fluid, and be driven or entrained by the latter into the diffusor, at the outlet of which there will arrive a mixture of both, driving fluid and driven fluid.

A more detailed theoretical explanation is given below.

The natures of the driving fluid and driven fluid can be the same or different: in the three centuries since Venturi’s invention, its principle has got numberless applications and as many practical configurations.

For example, either driving fluid and/or driven fluid can be a gas, a vapour, a liquid or a mixture; the section of the main duct can be round or not round, or it can change its shape along its path.

The duct axis can be horizontal, vertical, inclined or even curved.

The connection between main duct and secondary duct can take any of many shapes; in particular, their axes can be at an angle, even at a right angle, or at least either can curve at its end near the throat until it becomes parallel with the other, or even sometimes enter it and become concentric with it, or become subdivided into a number of parallel nozzles: all these devices have the common purpose of causing an intimate mixture of both driving and driven fluids to form within the throat.

Many applications of the Venturi take advantage of its simplicity, that affords a cheap construction and a steady operation.

Other applications, however, are thwarted by its low efficiency as an energy converter. This is in part a consequence of the losses involved in recovering in the form of pressure the energy that has been converted into dynamic energy, but also of the losses due to the action principle, the transfer of momentum from a fluid to another fluid, which losses are as much the bigger as the driven fluid is the denser.

A lucky circumstance has been found however in the particular case of our interest, where energy and momentum must be transferred from water to air: this latter kind of losses become almost nil because of the very low density of air, as compared with that of the driving water: the ratio is about 1 to 1000.

Moreover, a device has been found, that will be better described in the following, by virtue of which one can limit considerably the share of the energy that must be converted twice, i.e. from potential to dynamic and backwards: this reduces the
losses bound with this conversion and improves the overall efficiency.

A look at theory is in order here: Bernoulli’s theorem states that the total head $H$ of a given stream is constant over its course, but for losses $L$ and useful work $D$. A natural stream flowing from a place where its head is $H$ to another place with a lower head $H'$ incurs losses $L$ or, in formula, $H-H' = L$. If a device is introduced to extract energy (or, more exactly, power, that is energy per unit time), care must be taken to reduce losses to a lower value $I$, so that $H-H' = I + D$, where $D$ is the useful motive head drop.

In turn, the expression for $H$ contains three terms: $H = P + Z + \frac{v^2}{2g}$, where $P$ is pressure, $Z$ is the geometric height or elevation over a convenient reference point, such as the sea level, $v$ is the water velocity (m/s), and $g$ is the gravity constant or $9.8$ (m/s$^2$).

The expression $\frac{v^2}{2g}$ is known as the velocity head, and is usually measured in metres of water column (w.c.). It is convenient to use the same units for $L$, $H$, $P$, $Z$, $I$ and $D$ as well.

One should recall that the ordinary atmospheric pressure at sea level amounts almost exactly to 10 metres w.c.

In the usual practice, $P$ and $Z$ are often lumped together, and the sum $P+Z$ is named static head, which is then measured starting from the same reference level as $Z$. The static head is an expression of the potential power of the stream, while the velocity head expresses its dynamic power.

Let us now consider a Venturi tube and give a sub-index 1 to all the above terms, as measured at its inlet or mouth, a sub-index 2 to the same as measured at the throat, and a sub-index 3 to those measured at the outlet or exit. One can state, after Bernoulli:

$$H_1 = H_2 + l_{1,2} \quad H_2 = H_3 + l_{2,3} + D$$

$l_{1,2}$ and $l_{2,3}$ are the losses incurred in , respectively, the first or convergent stretch and in the second stretch or diffuser of the Venturi. Both increase as a function of the stream velocity. The drop $D$ is indeed used to compress the air that has been sucked into the throat, from the reduced pressure prevailing there up to the ordinary atmospheric pressure, and this process takes place in the diffuser only.
The power $N$ (in kW) that one can extract from the stream is given by $N = g * Q * D$, where $Q$ is the water flow rate ($m^3/s$).

This power is used to compress the air from the throat pressure $P_2$ to the atmospheric pressure that it will meet at the outlet, $P_3 = P_1$, so $N = g * Q * P_2 * \ln(P_2/P_1)$, where $\ln$ is the natural logarithm and $Q$ is the volume air flow rate at the conditions (reduced pressure) prevailing in the throat.

The reason for this formula is that the air compression is an isothermal process, since the heat capacity of the water largely exceeds that of the air.

When developed, the full expression of Bernoulli’s theorem for the convergent stretch becomes:

$$P_1 + Z_1 + v_1^2 / 2g = P_2 + Z_2 + v_2^2 / 2g + l_{1,2}$$

While $P_1$ is the atmospheric pressure, $P_2$ must be lower than atmospheric, in order to suck the air that starts from the atmosphere, then drives a pneumatic motor, and finally reaches the throat. This can be done in either of two ways, or both:

- by increasing the elevation of the throat over the mouth, or $Z_2 > Z_1$
- by increasing the velocity, and, as a result, the velocity head at the throat, or $v_2 > v_1$

In the latter case, use is made of the Venturi effect, while in the former a siphon effect is involved.

According to the invention, as already said, the suction of air can be obtained by a combination of both Venturi and siphon effect, although, in some cases, just the first or the second effect could be used.

A preferred version of the device that has been found able to produce the air suction is a Venturi whose main duct axis, that is the line that ideally joins the barycentres of the successive duct sections, is not in the form of a straight line, but rather of a downward concave curve or broken line, i.e. one bulging upward.

This makes it possible to place the Venturi throat in the position where its axis reaches its highest elevation in order to have $Z_2$ as high as possible.

One will indeed recognise that the shape suggested for such a Venturi makes it similar to some extent to another device, that is well known in hydraulics under the name of siphon.
However, the former differs from the latter because of its characteristic convergent-divergent pattern, that results in the creation of a significant velocity head within the throat.

One will also recall that a siphon usually cannot start to operate by itself, but instead requires a previous priming.

Also, the priming can be lost and the siphon operation stopped if air accidentally enters it. In order to prevent this, one must make sure that both inlet and outlet of the siphon are permanently under water during their operation.

The whole inlet mouth and particularly its upper rim must be kept below the water level in the forebay, while the outlet must stay below the level in the receiving pool.

Self priming is possible if the forebay level is, or becomes at least temporarily, higher than the maximum elevation or summit of the Venturi or siphon.

Two different embodiments are shown in the enclosed figures, both pertaining to the finding of this invention: Fig. 1 shows a Venturi whose summit is just below the level of the forebay, so that all the suction it produces relies substantially on the Venturi effect, while in Fig. 2 the Venturi summit is decidedly above said level, so that the siphon effect is responsible for the larger part of the total suction.

Both embodiments are efficient, but their fields of application are different: the embodiment of Fig. 1 can get primed by itself, whenever hit by a billow, and requires little or no attendance, even if driven by so irregular a water source as wave motion causing a frequent loss of priming.

On the other hand, the embodiment of Fig. 2 can afford a better efficiency, provided it is fed by a steady water stream.

In contrast with the former, it requires priming by a separate suction pump at the start, and an appropriate control system, especially for preventing loss of priming in the course of operation.

Instead of a suction pump, any other priming means can be envisaged. Of particular advantage is a combination whereby a Venturi of the self-starting variety, as described by Fig. 1, is used to provide suction for priming a second duct of the variety that cannot start by itself, as described by Fig. 2. Once started, and if required, especially in the case where the installation includes a number of Venturis to cope
with a large stream, the second Venturi can in turn provide suction for priming still another, or even many other such devices, until all of them become operative.

It is well possible, of course, to design a device wherein all the energy conversion relies on the siphon effect, while reducing to zero the Venturi effect, although this scheme could be possible, it could be expected to require an excessive amount of control for a regular operation.

The Venturi can work even without valves, but if automatic priming is required, this will be made easier by providing a vent, from the throat ceiling or summit to the atmosphere, through an automatic check valve, so oriented as to allow air to get out, but not into the throat.

Whenever some air enters the Venturi as a result of an excessively low level of the incoming water, this check valve will let it out, as soon as the level rises again and water fills the Venturi.

If there is air in the Venturi, its action stops and it will no longer suck the air stream which is supposed to receive the energy being transferred. It is expedient to provide a second check valve, directed contrary to the first one, in the secondary duct.

This second check valve will allow the air from the secondary duct to enter the throat, but not to flow back from it, and it will be most useful in the case, that one can expect to meet often, where a number of Venturis are connected in parallel via a manifold to the pneumatic motor or motors: thanks to their check valves, some Venturis can keep working, while others are momentarily out of priming and/or out of service.

The Venturi can be installed and operate on an appropriate fixed structure such as a dam, especially if rivers or brooks are to be used as a source of hydraulic energy.

Alternatively, especially when wave energy on the sea surface is to be used, one can provide instead a carrier that is at least partly mobile or deformable, in order for it to best use the properties of the water current available.

A first type of motion is yaw, or rotation around a vertical axis, that will help to best collect a current derived from wave motion, where the direction of the latter is subject to varying from time to time.

A second type of motion is pitch, or lengthwise inclination: this can allow the
Venturi to make the best use of water currents whose motive head drop, that is the free-level difference between the Venturi inlet and outlet, can vary over time, as this will become clearer on considering the first example described in the following.

Finally, a third type of motion is simple upward or downward translation, causing the Venturi to keep staying parallel to its former position, while moving to different levels: this can be useful on sites where the tidal range is considerable.

A scheme of installation that will allow these motions involves placing the Venturi on board of a floating pontoon, that is possibly retained on the sea floor by appropriate moorings.

Thanks to this installation, it will easily follow the oscillations of the sea level and optimise the approach between throat elevation and incoming water level.

Moreover, if the Venturi is on board a floating pontoon, one can also allow or even cause the latter to change its attitude, either by a pitch motion, in order to make the best use of the level drop available between incoming and outgoing water, according to the sea condition at hand, or by a yaw motion, in order to best face the current.

These details become apparent on considering the following non limiting examples, that refer to the enclosed figures.

Said figures represent in a schematic way lengthwise sections of two Venturis of the types so far described. Numbers identify the elements of the figures that will be recalled in the following description.

Let us first look at Fig. 1.

The Venturi is firstly characterised by having an axis (0), that is not straight, but rather concave downward (i.e., bulging upward).

The points identified along the axis show the limits of the parts comprised in the Venturi: the convergent length, from (1) to (2); the throat, from (2) to (3); the divergent length or diffusor, from (3) to (4).

Then, (5) is the vent duct joining the throat, (51) the check valve that allows air to vent while priming takes place, (52) the vent open to the atmosphere, (6) is the secondary duct that conveys the air being sucked toward the throat, (61) the check valve that allows air to move only toward the throat and not backwards, (63) the outside duct that joins the air wheel or turbine, (not shown in the figure) and sucks
from the latter the air that has just passed it.
The air wheel or turbine can be coupled, in turn, with an electric generator (not shown).
By operating an air wheel or turbine with sucked air the risk of malfunctions is reduced because the air flow is not charged with moisture or mist.
The ducts (5) and (6) can even merge into just a single duct, in the length between the Venturi and the valves; in this case they should branch out before they join the valves (51) and (61).
The body or hull (7) of the Venturi surrounds the axis and its section can have any shape.
For the sake of simplicity, but by no means limiting, one can assume a round section all along the axis, in this case the diameter will change from point to point.
The level of the incoming water is (81), that of the receiving pool is (82).
As mentioned above, level (81) not only tops the inlet rim (11), but also the throat summit (25); level (82) in turn tops the outlet rim (41).
In order to appreciate the effect of changing the attitude of the Venturi and of the pontoon (not shown in the figure) that supports it, one should imagine rotating the whole figure clockwise, so as to bring the dashed lines (91) and (92) to the horizontal position, where they will represent the new levels of respectively incoming and outgoing water.
The difference (90) between these new levels is much greater than the previous one (80), and this shows how easily one can adapt the Venturi to the instantly available motive head, even if this involves a few additional losses, because of the increased distance between the new level (91) and the throat summit (25).
Let us now turn to Fig. 2.
The numbers here refer to the same elements already seen in Fig. 1, with the following exceptions:
- (26), the level of the Venturi summit, is considerably higher than level (81);
- instead of vent (52), a duct (53) leads to the priming pump (not shown);
- a dam or wall (100) separates the forebay, where the water level is (81), from the discharge basin, where the water level is (82). The motive drop is (80), as
in Fig. 1.

The purpose of this Fig. 2, as already mentioned, is to show an example where the Venturi effect and siphon effect are both present and work in cooperation.

Still on the basis of the above non limiting examples, a few data can give a better idea of the scope of the invention.

Let us assume, for the sake of simplicity and of an easier comparison, that in both examples there is available a steady water stream with an inlet velocity of 1 metre per second and a useful drop (80) of 2 metres. Let us also neglect the losses $l_{1,2}$ and $l_{2,3}$.

For both designs, a reasonable value for the working suction is 3 to 4 metres of water column.

Since the atmospheric pressure is roughly equivalent to 10 metres water column (w.c.), the previous statement means that the absolute pressure at the Venturi throat, in both examples, should be between 7 and 6 metres w.c., or, respectively, between 0.7 and 0.6 atmospheres.

In the first example, all the suction is produced by the Venturi effect, and it amounts to the increase in velocity heads between the Venturi inlet and its throat. Since the velocity head is $v^2/2g$, as explained before, a slow inlet velocity of 1 metre per second only amounts to 5 centimetres water column.

The suction required at the throat implies that the velocity head increase by 3 to 4 metres, and it will result in a total velocity head of between 3.05 and 4.05 metres w.c.

In the second example, instead, the suction is shared between Venturi effect and siphon effect.

Let us assume that level (26) is 2 metres higher than level (81). In order to get a total suction of 3 metres w.c., an increase in velocity head of just 1 metre w.c. is enough; if, instead, the total suction required is 4 metres w.c., the velocity head must increase by 2 metres w.c.

The velocity head at the throat should then be 1.05 metres w.c. in the former case, 2.05 metres w.c. in the latter.

Calculation gives: for velocity heads of, respectively, 0.05 1.05 2.05 3.05 4.05 metres water column,
these water velocities: 1.0 4.54 6.34 7.73 8.91 metres per second.
As stated before, a higher water velocity causes increased energy losses, especially in
the diffusor, so the advantage of sharing the suction between Venturi effect and
siphon effect is clearly shown by the comparison of these examples.

No mention of water flow rates has been made in these examples.

They will fit any flow rate, provided the section areas are calculated on the basis of
the velocities that characterise each point along the path of the Venturi.
For example, if the flow rate is 1 cubic metre per second, and the inlet velocity is 1
metre per second, the section area required for the inlet mouth is 1 square metre.

The same flow rate of 1 cubic metre per second at the throat velocity of 8.91 metres
per second requires a section area of just 0.1122 square metres.

The reader skilled in the art will appreciate that the above disclosed device require
very small structures and minimise the visual impact.

It is also evident how the simplicity of the device according to the invention can be
useful not only for electricity production but even for local simple needs such as
irrigation, just for example: for this purpose, the pneumatic machine could be
directly connected to a pump for pumping water to levels higher than those of the
river or brook whose hydraulic energy is being exploited.
CLAIMS

Claim 1. A process for the exploitation of hydraulic energy, said process comprising the following steps:
   a. causing a water stream to flow inside a duct;
   b. causing, by means of said water stream, a suction to form within a suction zone in said duct;
   c. converting the hydraulic energy of said water stream inside said duct into pneumatic energy of an air stream sucked by said water stream;
   d. converting said pneumatic energy into mechanical energy in a pneumatic machine before that said air stream is sucked by said water stream;

Claim 2. A process, according to claim 1 wherein the suction is caused by means of Venturi effect and/or siphon effect.

Claim 3. A process, according to claim 1 or 2, wherein the conversion of said pneumatic energy into mechanical energy is achieved by means of an air turbine.

Claim 4. A process, according to any claim from 1 to 3, wherein the mechanical energy is converted into electric energy.

Claim 5. A device for the exploitation of hydraulic energy comprising:
   a. a duct for a water stream, said duct having an inlet under the waterline of the forebay and an outlet under the waterline of the discharging basin, said duct being so shaped that the water stream creates a suction inside a suction zone in said duct;
   b. a pneumatic machine for converting the pneumatic energy of an air stream into mechanical energy, said pneumatic machine having an inlet for sucking air from the atmosphere and having an outlet connected to said suction zone of said duct;

Claim 6. A device, according to claim 5, wherein said pneumatic machine is an air turbine.

Claim 7. A device, according to claim 5 or 6, characterised in that it further comprises an electric generator mechanically connected to said
pneumatic machine.

Claim 8. A device, according to any one of the previous claims from 5 to 7, characterised in that said suction zone is connected to said pneumatic machine by means of a check valve preventing the air to be blown back toward the pneumatic machine.

Claim 9. A device, according at least with claim 5 wherein said suction zone of said duct is above the water level of the forebay, and wherein means are provided for priming so that said suction can be achieved by, or also by, siphon effect.

Claim 10. A device, according at least with claim 5, wherein the duct comprises, from the inlet to the outlet, a portion characterised by a decreasing cross section followed by a portion with a constant cross section, said suction zone being located in said portion with constant cross section, so that said suction can be achieved by, or also by, a Venturi effect.

Claim 11. A device, according to claim 10, wherein all the duct body is under the water level of the forebay.

Claim 12. A device, according to claim 11, wherein the axis of said duct is concave downward.

Claim 13. A device according to any of the previous claims, wherein a venting pipe is provided for said suction zone.

Claim 14. A device according to claim 13, wherein said venting pipe is connected to priming means.

Claim 15. A device, according to claim 14, wherein said priming means are a Venturi device.

Claim 16. A device according to any one of the previous claims, characterised in that it is mounted on a floating pontoon.
### INTERNATIONAL SEARCH REPORT

#### A. CLASSIFICATION OF SUBJECT MATTER

| IPC | 7  | F03B13/24 | F03B17/06 |

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):

| IPC | 7  | 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 practical, search terms used):

EPO-Internal, PAJ

#### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>US 5 377 485 A (BELLAMY ET AL) 3 January 1995 (1995-01-03) column 9, line 43 - column 10, line 59 column 12, lines 49-58 figures 12-15</td>
<td>1-7,9, 10,12-15</td>
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<tr>
<td>X</td>
<td>FR 761 818 A (MM. AUBERGER M ET AL.) 28 March 1934 (1934-03-28) page 2, lines 70-102 figures 1,2</td>
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Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
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Authorized officer: Giorgini, G.
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