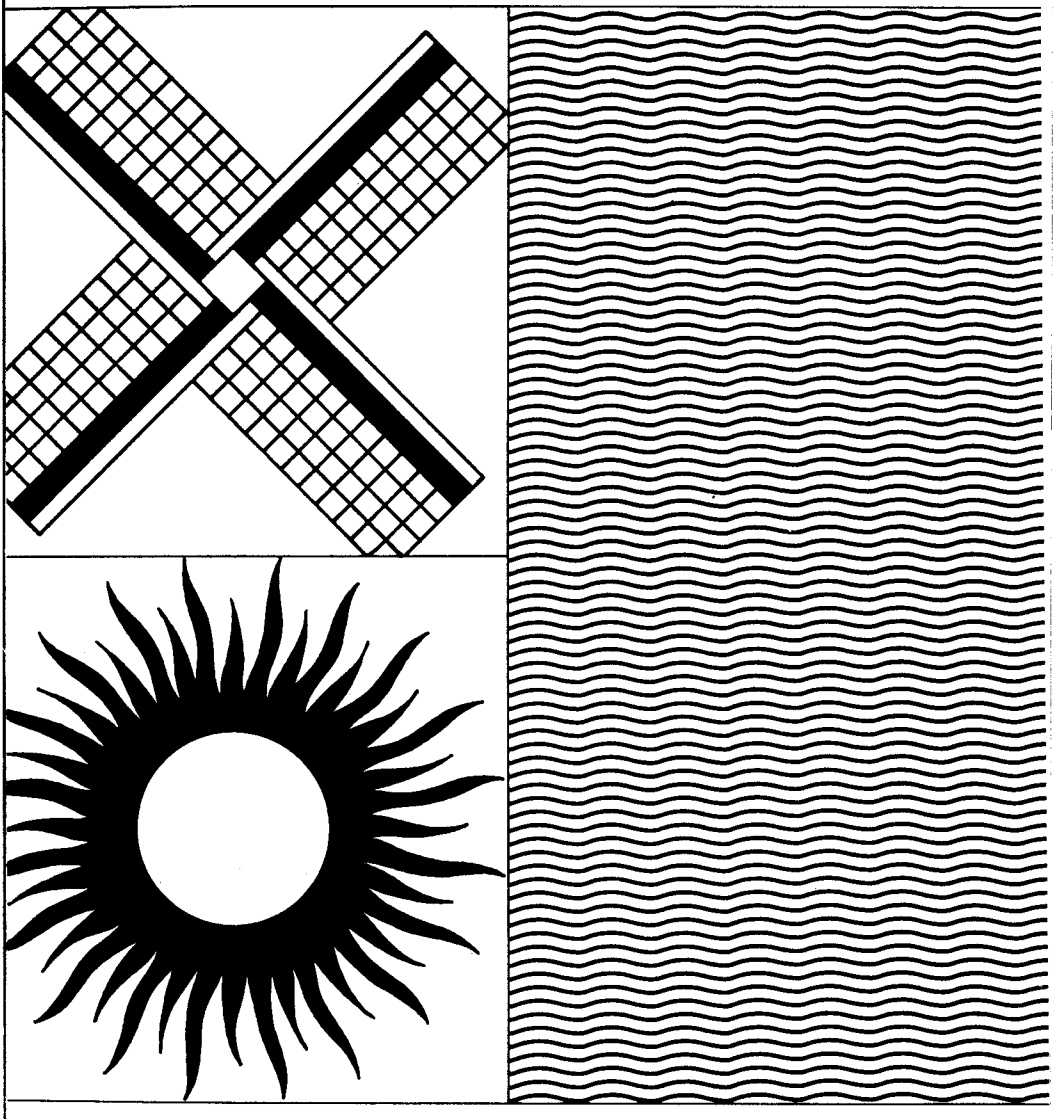
Appropriate Technologies for Semiarid Areas: Wind and Solar Energy for Water Supply



German Foundation
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APPROPRIATE TECHNOLOGIES FOR SEMIARID AREAS: WIND AND SOLAR ENERGY FOR WATER SUPPLY

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CONFERENCE REPORT

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FLAPPING-VANE WIND MACHINE

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1. Patent Specification

1.1 Introduction

The following specification describes the invention of a flapping-vane wind machine to produce a force effect with an up-and-down movement from the energy of the wind.

Wind machines heretofore known and used provide energy by way of a rotational movement. The classical windmill and the "American wind motor" are probably the best known examples of this method of energy conversion.

However, a number of machines, such as the reciprocating pump, must receive their energy by way of an up-and-down movement. To drive such machines, therefore, the rotational movement of the classical wind machines must be converted to an up-and-down movement by means of gearing and lever mechanisms.

The wind apparatus by Melzer[1/] and the oscillating vane as described by Vadot[2/] do provide a force effect with an up-and-down movement, but owing to the complexity of the mechanical guiding of the vane, which simultaneously moves up and down and swings from one angular position to the other, practical application has not yet been found.

1.2 The invention and its mode of action

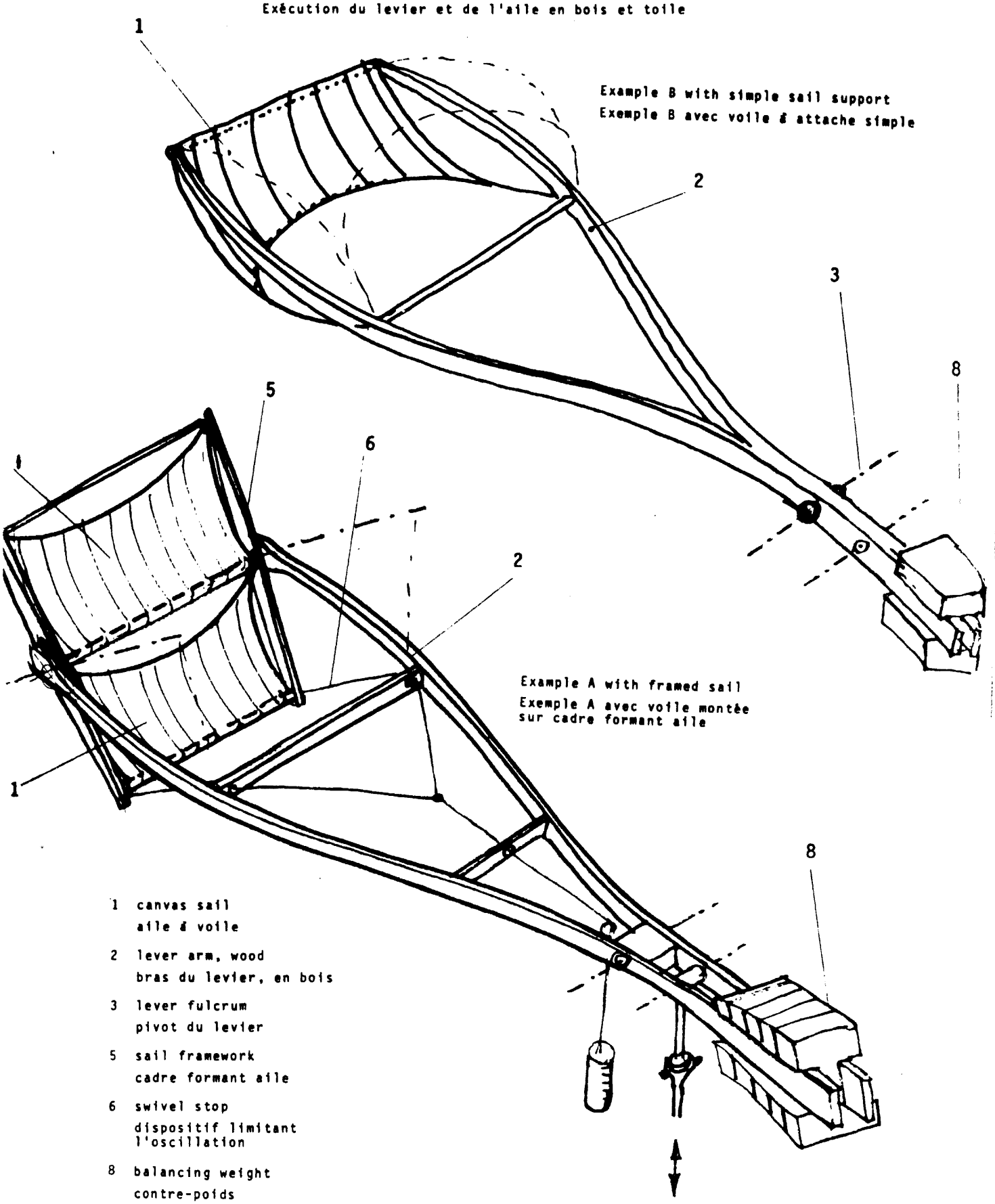
The flapping-vane wind machine proposed here produces a force with periodic up-and-down movement from the effect of the force of the wind on one vane or several vanes arranged in lattice form above each other, without complicated guiding of the vane, solely from the motion of the vane relative to the direction of approach of the wind.

1/ Heys, J. W. van: Wind und Windkraftanlagen, Berlin 1947

2/ Vadot, L.: La Houille Blanche, No 2, Mars/Avril 1957

Figure 7: FLAPPING-VANE PUMP
Arrangement of lever and sail in wood and canvas

Figure 7: POMPE A AILE BATTANTE
Exécution du levier et de l'aile en bois et toile



1 canvas sail
aile à voile

2 lever arm, wood
bras du levier, en bois

3 lever fulcrum
pivot du levier

5 sail framework
cadre formant aile

6 swivel stop
dispositif limitant l'oscillation

8 balancing weight
contre-poids

One (or several) vanes (2) are rotatably mounted on the end of a long swinging lever (1) so that they can swivel freely about their horizontal axis transversely to the axis of the swinging lever (1) between two stops (4). In this way, a vane symmetrical about its generatrix can assume the angular position α or $-\alpha$ relative to the axis of the swinging lever.

The horizontal axis of the vane (2) lies behind the resultant of the vane lifting force F_W seen in the direction of the wind, so that with a change in the direction of force F_W as a result of a change in the effective vane incidence angle γ, the vane will be swivelled from one angle α to the other.

Swinging lever (1) is rotatably mounted in a fulcrum (3) at a distance R_0 from the swivelling axis of the vane, so that the swinging lever can move up and down about this point. The angle between the axis of the swinging lever and the horizontal is β. As a result of the up-and-down movement of the swinging lever, the incidence angle of the vane γ will change at the same time dependent on angle β between the axis of the swinging lever and the horizontal (Fig. 1).

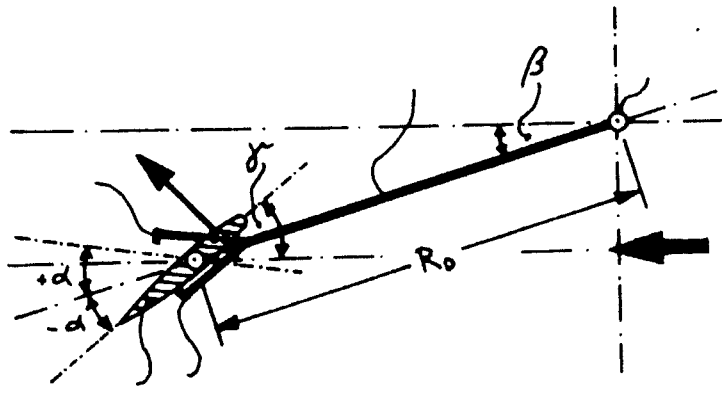


FIG. 1

As angle β changes as a result of the up-and-down movement of the swinging lever, the effective incidence angle of the vane γ receives an additional angular component $\gamma(t) = \frac{R_0}{U} \cdot \frac{d\beta}{dt}$ where U is the wind velocity (Fig. 2).

The effective time-dependent vane incidence angle γ is there-

fore expressed as follows:

$$\gamma_{(t)} = \alpha + \beta_{(t)} - R_o \cdot \frac{d\beta}{dt} \cdot \frac{1}{U} \qquad \text{(Eq. 1)}$$

In the extreme positions of angle β of the axis of the swinging lever at

$$|\alpha| - |\beta| = R_o \cdot \frac{d\beta}{dt} \cdot \frac{1}{U} \qquad \text{(Eq. 2)}$$

the effective incidence angle of the vane γ undergoes a change of sign, the vane swings from one angular position to the other, and as a result of the now very large opposite vane force, the direction of movement of the swinging lever is reversed and the swinging lever is forced into the other extreme position.

Owing to the coupling of angle α of the vane with the angle β of the swinging lever, the latter executes up-and-down movements as a result of the periodically changing direction of the vane force F_w.

The fulcrum (3) of the swinging lever is supported in a bearing pedestal (7) which is arranged on a mast (8) in such a way that it can rotate about the vertical. The height of the mast should be such that the vane does not touch the ground at the maximum angular position and can always work in an undisturbed wind current.

At a distance R_a from the fulcrum (3) is the point of engagement of a connecting rod (10), which acts on a thrust rod (6) through a universal joint (11). With this arrangement the movements of the swinging lever deriving from the vane forces F_w are transmitted to the machine with the lever ratio R_o/R_a.

With the periodically changing incidence angle of the vane, the vane stream experiences a periodically changing circulation and hence a periodic, very stable boundary layer. This prevents interruption of the flow at large vane incidence angles γ in the extreme positions for β, and high vane surface loadings permit a good utilization of the vane

surface, which is kept as small as possible for constructional and economic reasons.

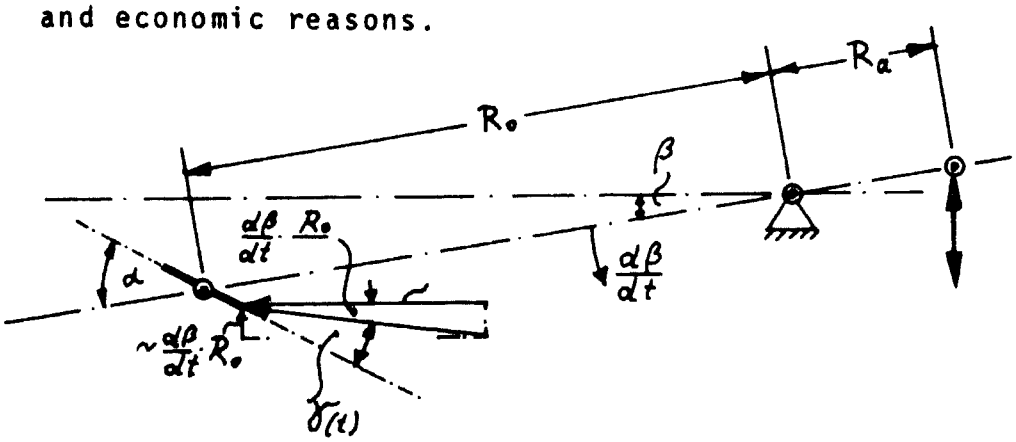


FIG. 2

Equation 1 shows how the motion quantities depend on the wind velocity U, such that with an increasing U the value dß/dt increases faster than the wind velocity itself. Also, the frequency of the up-and-down motion increases but the amplitude becomes smaller, so that the system is self-regulating with respect to output.

In order to protect the vane bearings from excessive shock loading when the vane flaps, the angular stops (4) are fitted with shock absorbers.

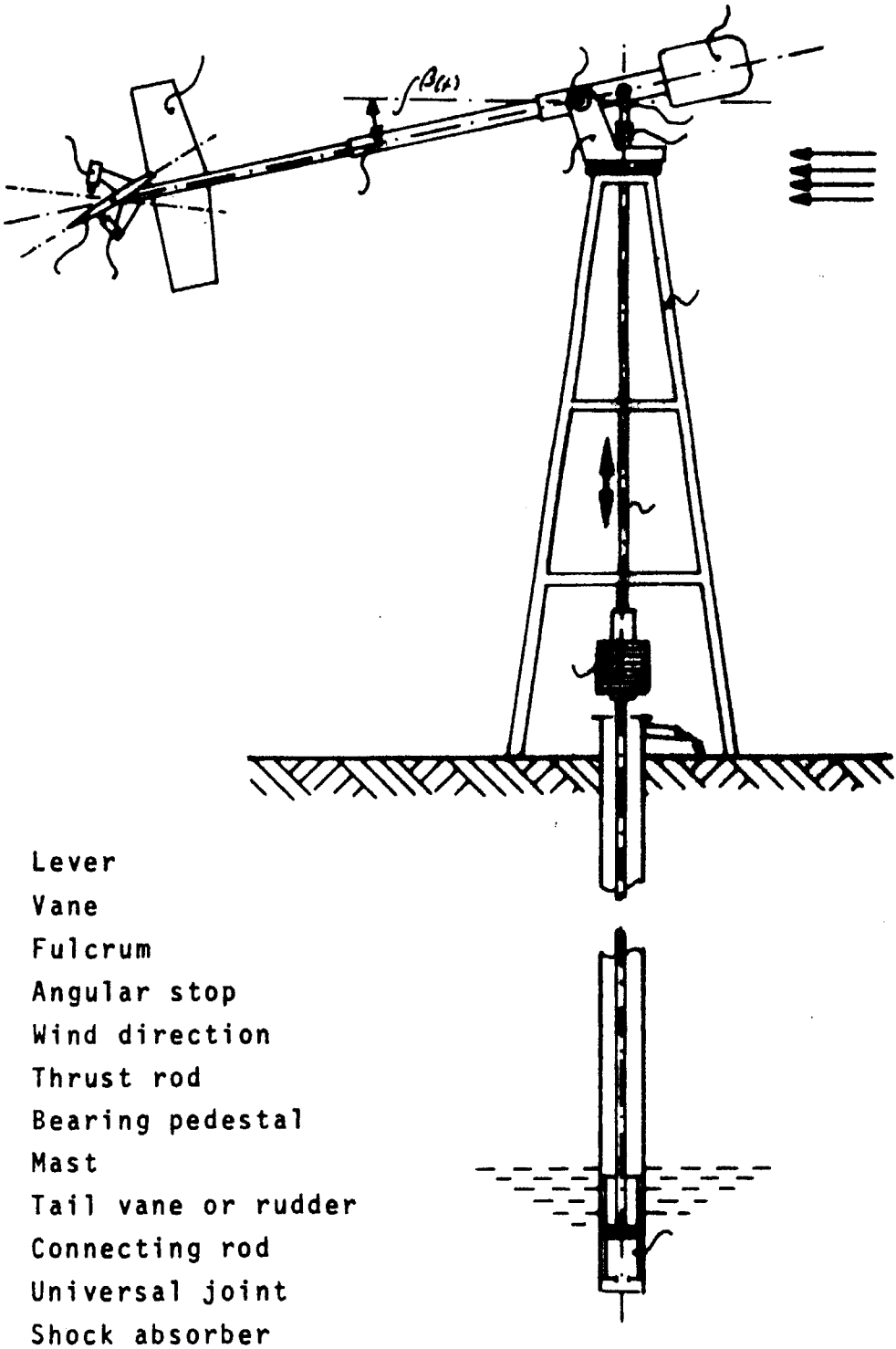
Weights (13) attached to the lever arm at the end remote from the vane serve to keep the system in static equilibrium.

The flapping-vane wind machine to which this invention relates will, owing to the back-and-forth and up-and-down force action provided specially by it, find application on such machines for which this moving force action is characteristic.

The invention is therefore specially useful in conjunction with a reciprocating pump (14) for pumping liquids from great depths. Both single-acting and double-acting pumps can be used.

Use as prime mover for the production of electricity by means of linear or immersed-coil generators is also possible, likewise a combination of pump and generator as energy supply station for use in remote areas, since the construction, servicing, and maintenance of such an installation will be extremely simple.

Fig. 3 shows the arrangement of a flapping-vane wind machine installation in diagrammtic form.



1. Lever
2. Vane
3. Fulcrum
4. Angular stop
5. Wind direction
6. Thrust rod
7. Bearing pedestal
8. Mast
9. Tail vane or rudder
10. Connecting rod
11. Universal joint
12. Shock absorber
13. Balancing weight
14. Reciprocating pump
15. Linear generator

FIG. 3

2. Patent Claims

2.1 A flapping-vane wind machine, characterized in that one or several vanes (2) capable of swivelling about their horizontal axis between an upper and a lower angular stop (4) are mounted on a free end of a swinging lever (1), and the horizontal swivelling axis of the vane (2) lies in the direction of wind flow behind the point of application of the resultant of the lifting force F_w of the vane.

2.2 A flapping-vane wind machine according to Claim 2.1, characterized in that the swinging lever (1) can move up and down in a pedestal (7) through the angle $\pm \beta$ about the fulcrum (3), which is at a distance R_o from the swivelling axis of vane (2) and acts with a shorter lever distance R_a through a connecting rod (10) and a universal joint (11) to move a thrust rod up and down, through which machines are driven.

2.3 A flapping-vane wind machine according to Claims 2.1 and 2.2, characterized in that the pedestal (7) is mounted on a mast (8) so that it can rotate about the vertical in such a way that the rotational axis of the pedestal (7) is in alignment with the axis of the thrust rod (6).

2.4 A flapping-vane wind machine according to Claims 2.1, 2.2 and 2.3, characterized in that the thrust rod (6) moving up and down is directly connected with a linear generator and a reciprocating pump.

2.5 A flapping-vane wind machine according to Claims 2.1, 2.2, 2.3 and 2.4, characterized in that the angular stops (4) are equipped with shock absorbers for damping of the swivelling motion of the vane or vanes (2) from one angular position α to the other.

are the Chinese type (figure 16) and the Turks and Caicos Islands type (figure 17). These rotors may be particularly adaptable to Persian wheel and bucket types of water lifts in addition to continued traditional use with square-wooden-pallet chain pumps.

(a) The rotors used in the Turks and Caicos Islands, British West Indies, for pumping salt water to evaporating ponds consist of six triangular cloth jib sails supported along their long edge by a vertical pole, and held by a rope tied from the loose corner to the adjacent vertical pole. Each vertical pole is supported by two horizontal wooden poles which radiate out from the central vertical main shaft. A similar jib-sail rotor utilizing eight sails has been proposed for use in Thailand (figure 18).

(b) The Savonius rotor (figure 19) has been well documented (reference W 25). Its use for practical water pumping and electricity generation has met with limited success only.

(c) The Darrieus rotor (figure 20) consists of two or three constant-chord aerofoil blades bent into a catenary curve and fixed at each end to a vertical axis which is supported by guy wires at the top and connected to a power utilization device at the base (reference W 42). The advantages of this rotor are that, unlike other vertical-axis rotors, a minimal support structure is required, the proportion of materials to total swept area is very low (solidity about 5 per cent), and efficiency is high. The main disadvantage is that it is not self-starting, and construction of the blades from fibreglass reinforced plastics or extruded aluminium is quite expensive. Although it has only recently been developed for electricity generation (reference W 43), it may have some potential for water pumping. Experimental work with a Darrieus rotor powered water pump has recently been undertaken at the National Aeronautical Laboratory in India.

(d) The gyro vertical-axis rotor (figure 21 and reference W 44) is similar to the Darrieus rotor in that it has a high efficiency of about 60 per cent, a very low solidity factor and minimal support structure requirements. This rotor consists of two or three straight symmetrical aerofoil blades supported vertically from horizontal support arms fixed to a vertical central power shaft. Orientation of the blades is reversed twice during each rotation so that maximum lift is achieved. High-speed small-diameter designs have considerable vibration. Further development of this rotor is currently in progress at the Cranfield College of Technology, United Kingdom.

3. Three novel concepts

Three novel concepts for utilizing wind power for water pumping have recently been proposed. Although these ideas have not yet been given full-scale demonstration, their simplicity of operation and low-cost construction makes them worthy of further consideration.

(a) The flapping-vane wind pump (figure 22 and reference W 45) has beeen designed for use with deep well piston-type water pumps, although it may be adapted to diaphragm pumps,or to a crankshaft flywheel to produce rotary motion. This device consists of a long lever arm with a cloth vane mounted on a horizontal axis at the outer end and a vertical reciprocating power rod at the fulcrum end. The vane can swing freely about its axis within the range of an upper and lower angular stop. Action of the wind on the vane alternatively depresses and lifts the lever arm with resultant power applied to the reciprocating rod. The lever fulcrum is mounted on a pedestal which can rotate on top of the tower in order to allow the vane to automatically orient itself to the direction of the wind. This device is expected to pump 100 m^3 per day from a depth of 40 m with a wind velocity of 16 km/h when the vane area is 29 m^2 and the lever arm is 20 m long. With increasing wind velocity, the amplitude of the up and down motion of the lever arm decreases and the frequency increases, so that the system is self-regulating.

(b) A tree pump has been proposed that converts the horizontal motion of a tree trunk swaying in the wind to reciprocating vertical motion of a piston pump, via cables and pulleys. In this device, the only cost is for the power transfer mechanism and pump. This method is limited to sites with tall unsheltered trees.

(c) A parachute pump (figure 23) has been proposed as a low-cost method of supplying power to traditional animal-powered bucket pumps. This system comprises a large parachute whose circumference ropes are tied to the lift rope. The force of the wind on the parachute pulls the bucket to the top of the well, at which point a rope attached to the centre of the parachute becomes tightened and collapses the parachute so that it may be returned to the starting point by the operator, and the bucket can return down to the base of the well. The parachute is then again allowed to fill with wind to begin another lifting cycle. With this system the only expense is the wind collection device (parachute). The pump and transfer mechanism exist and there is no need for a support structure.

D. *CLASSIFICATION OF WATER PUMPS*

A comprehensive international classification of all types of small pumps used for water pumping is urgently needed. Such a classification could include the following information regarding each type of pump; typical schematic diagram, normal range of suction and discharge heads, normal range of output, construction materials and skills required, usual mode of power supply, efficiency, range of operating speed and torque.

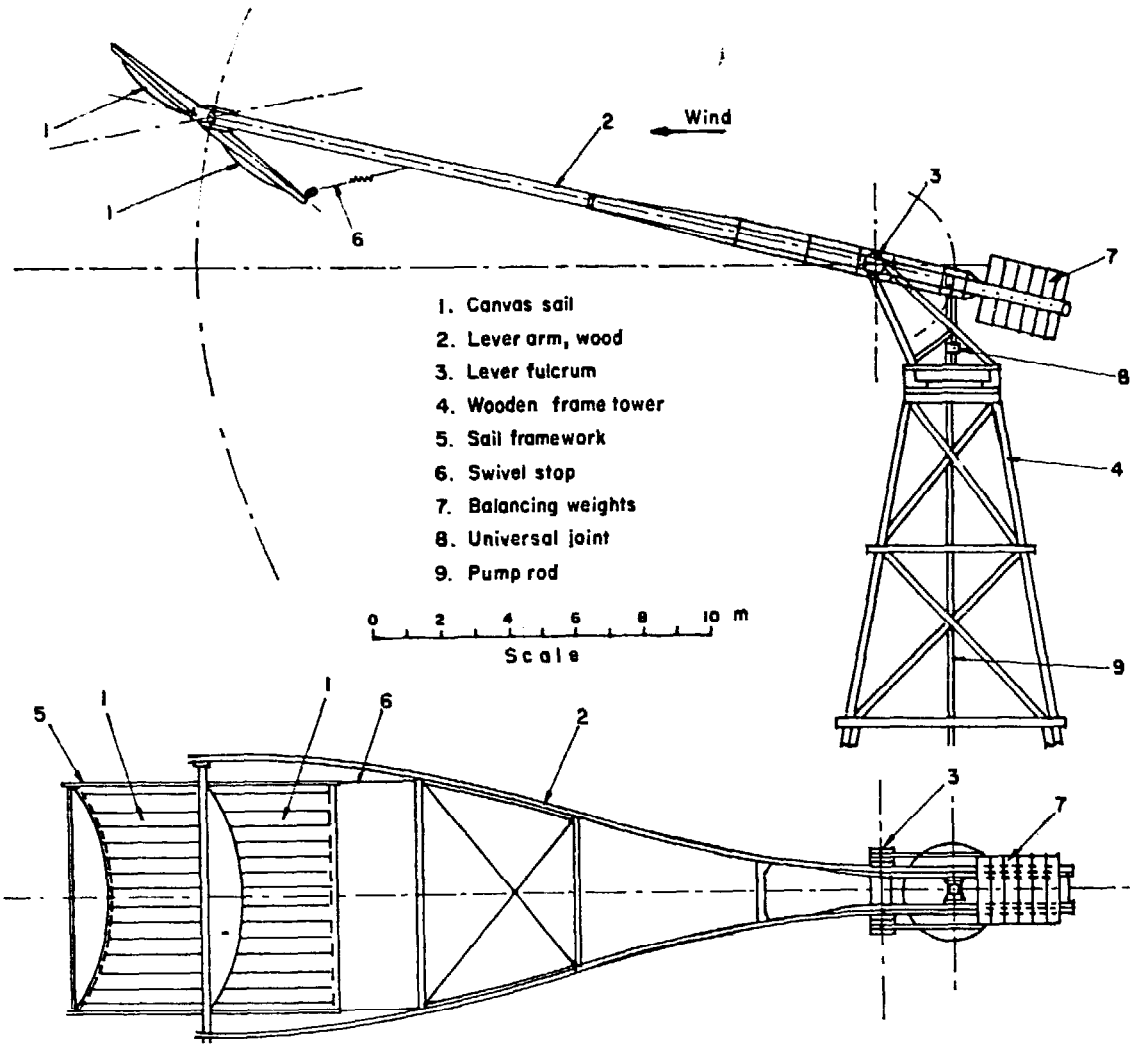


Figure 22. Flapping-vane rotor water pump

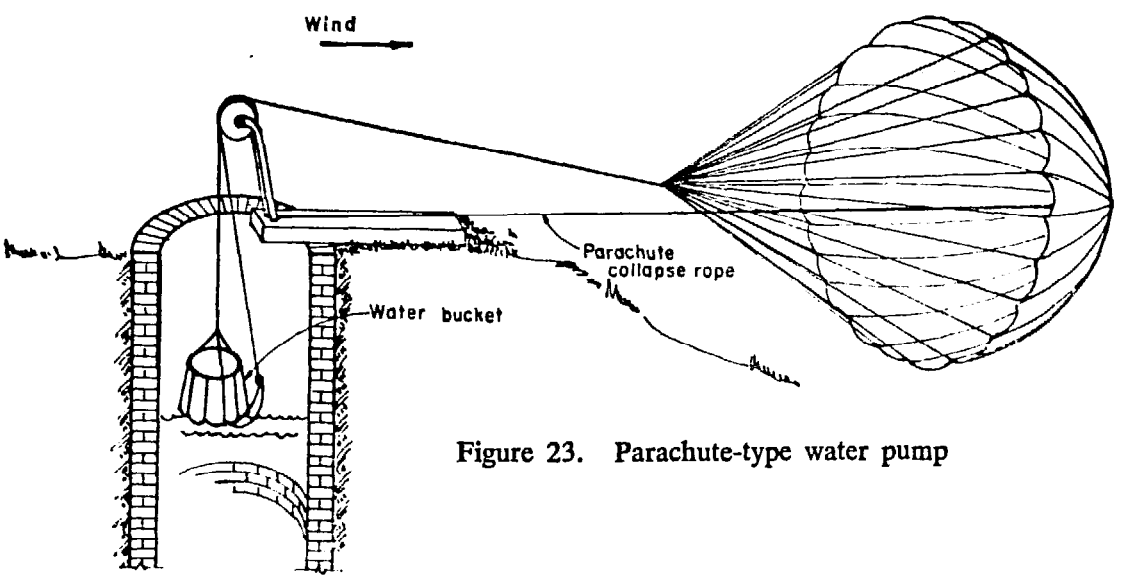


Figure 23. Parachute-type water pump