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(54) Wave and current energy converter

(57) A device for converting the energy of waves or currents of oceans, rivers or lakes into electricity, comprises a buoyant body which supports a bucket wheel or bucket chain when converting energy, wave the rise and fall of buoyant body 1 with the wave motion causes bucket wheel 9 or chain to rotate or circulate unidirectionally respectively. This movement is transmitted to a generator 33 or other energy conversion device on the buoyant body 1, and thence to shore. Where the energy is taken from under water currents, the bucket wheel 9 or bucket chain is supported by the buoyant body at a depth in the region of the under water currents, and where the currents are surface water currents a bucket wheel is fixedly secured to the buoyant body for circulation about horizontal axis disposed above the surface of the water or a bucket chain is mounted about the buoyant body. The buckets may be hingedly connected to the respective bucket carrying means.

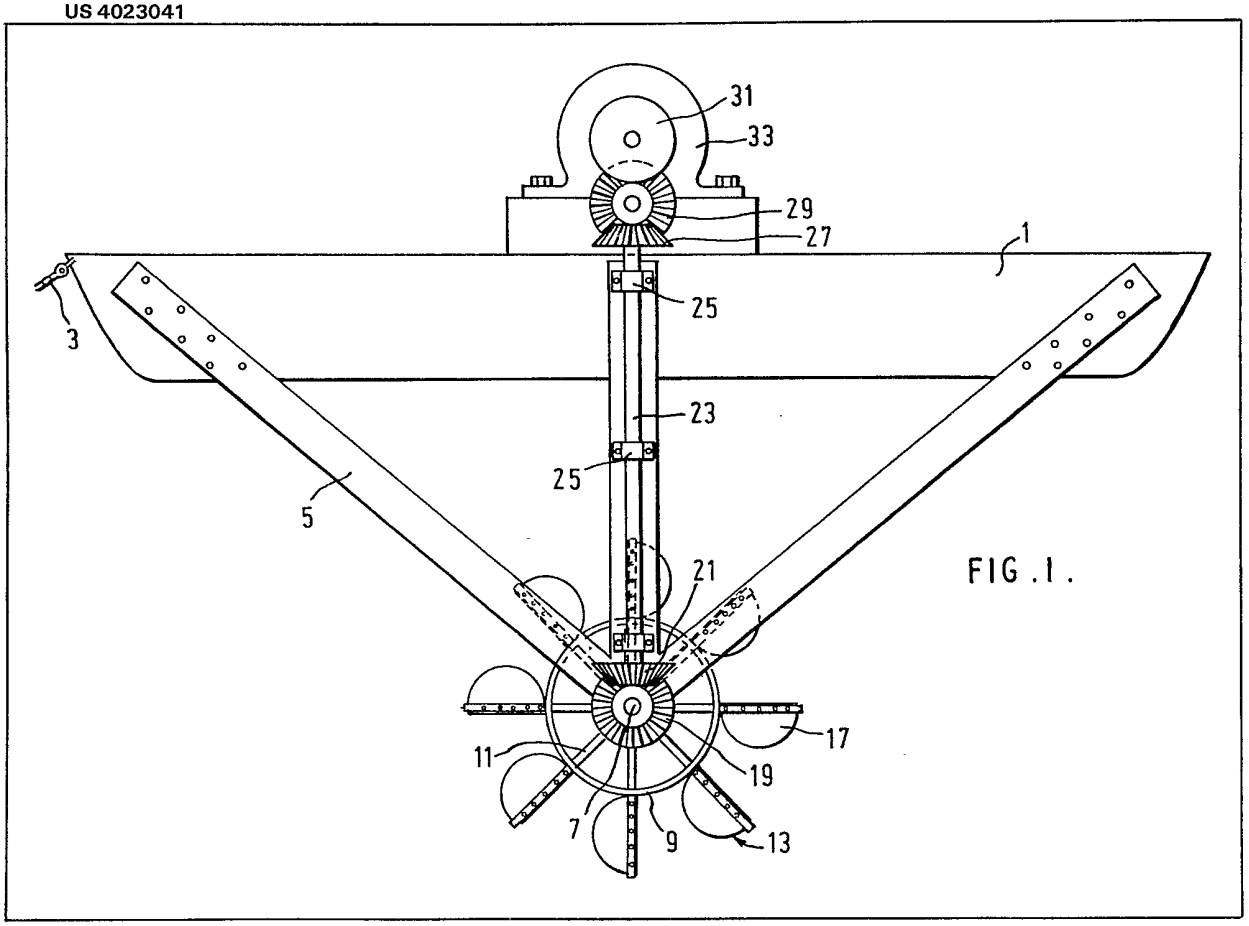

FIG. 1.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

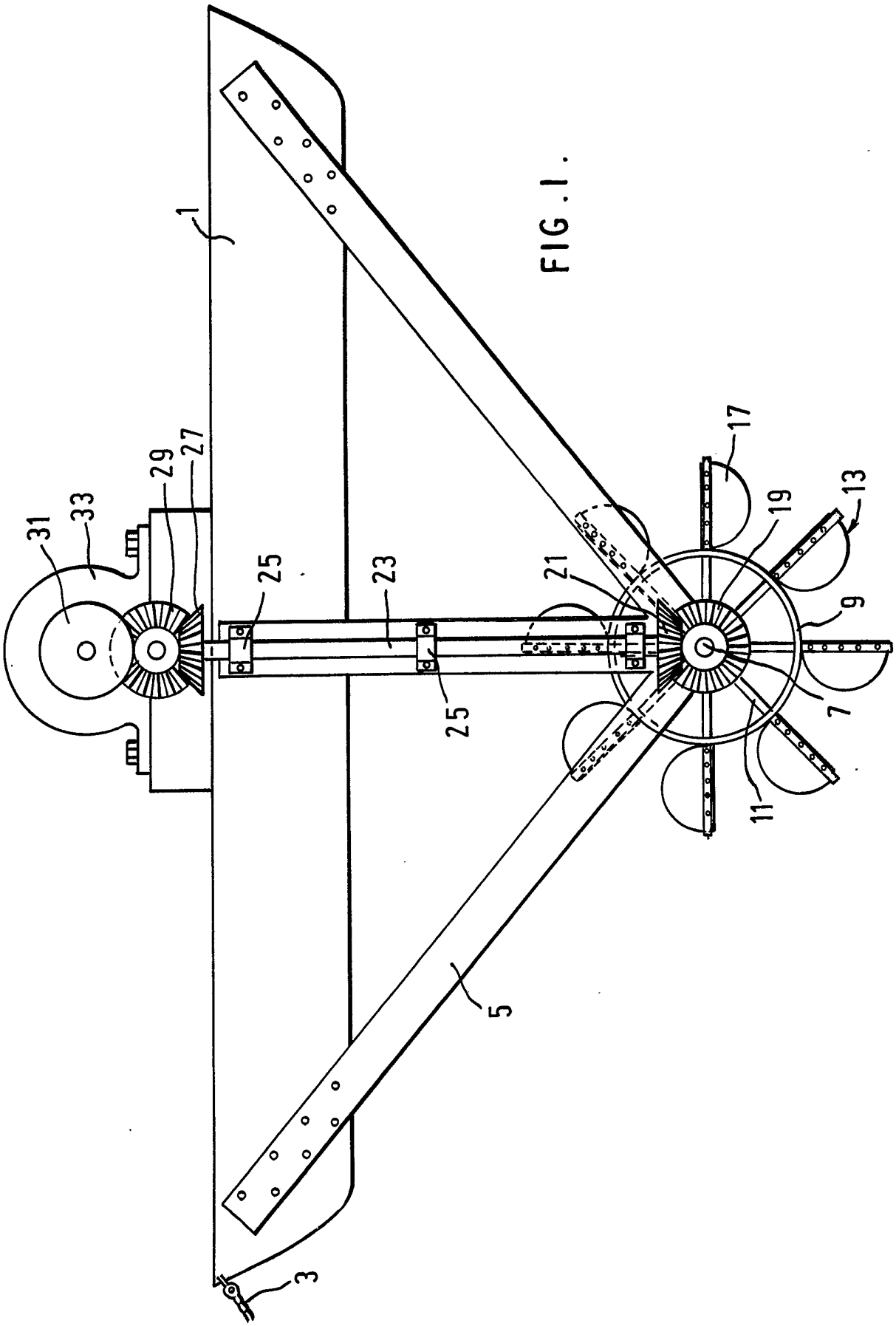

FIG. 1.

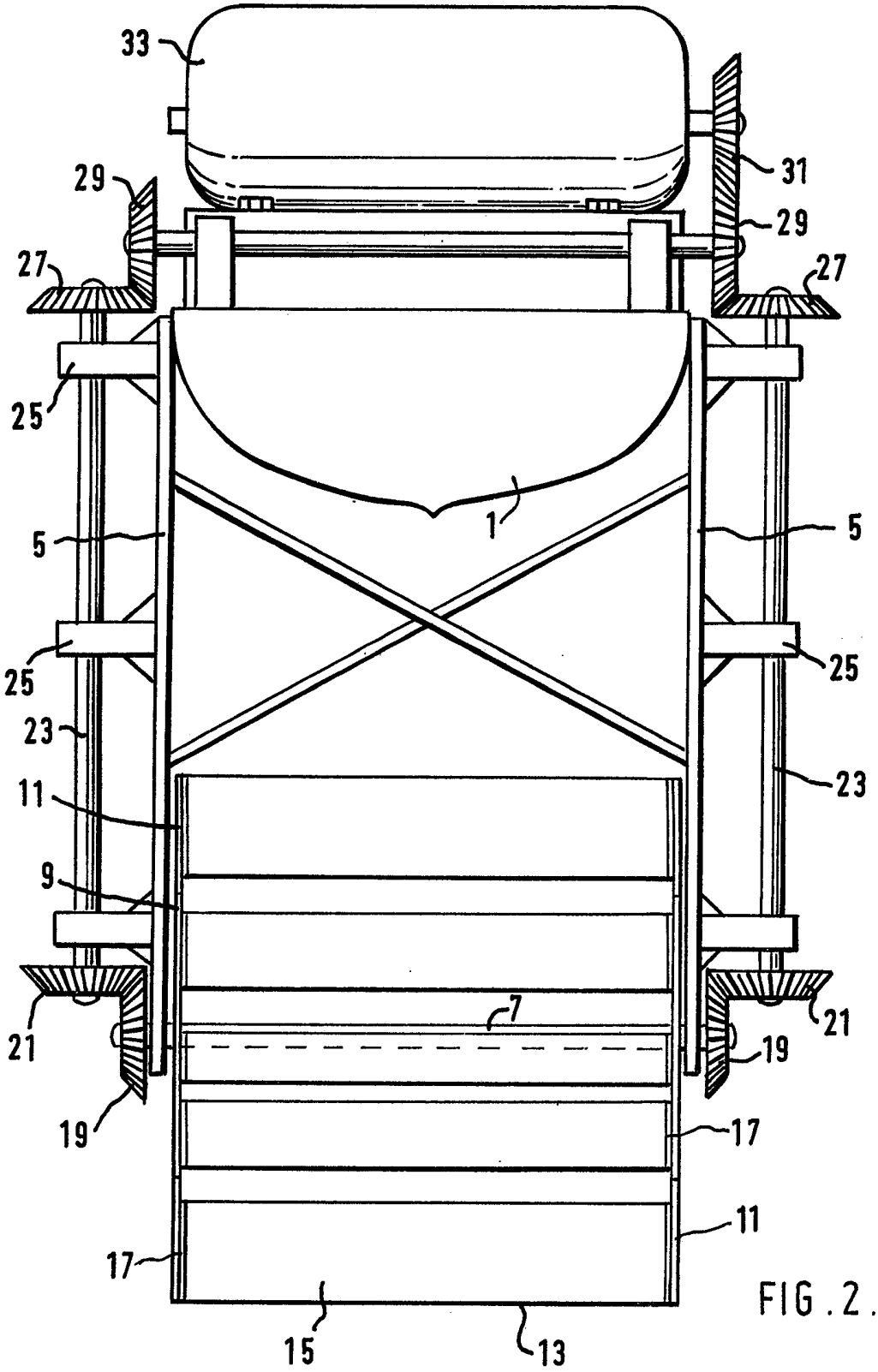

FIG. 2.

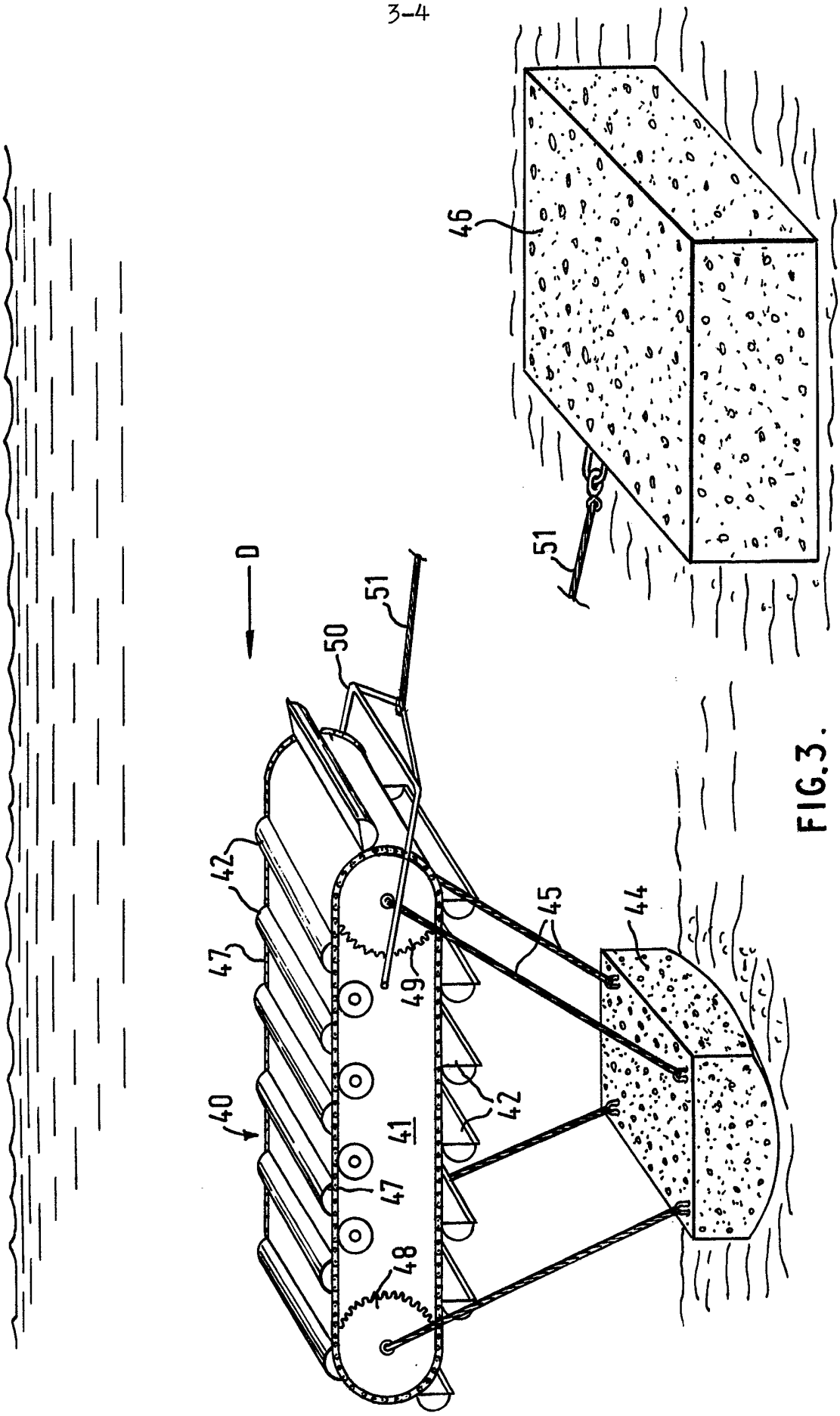

FIG.3.

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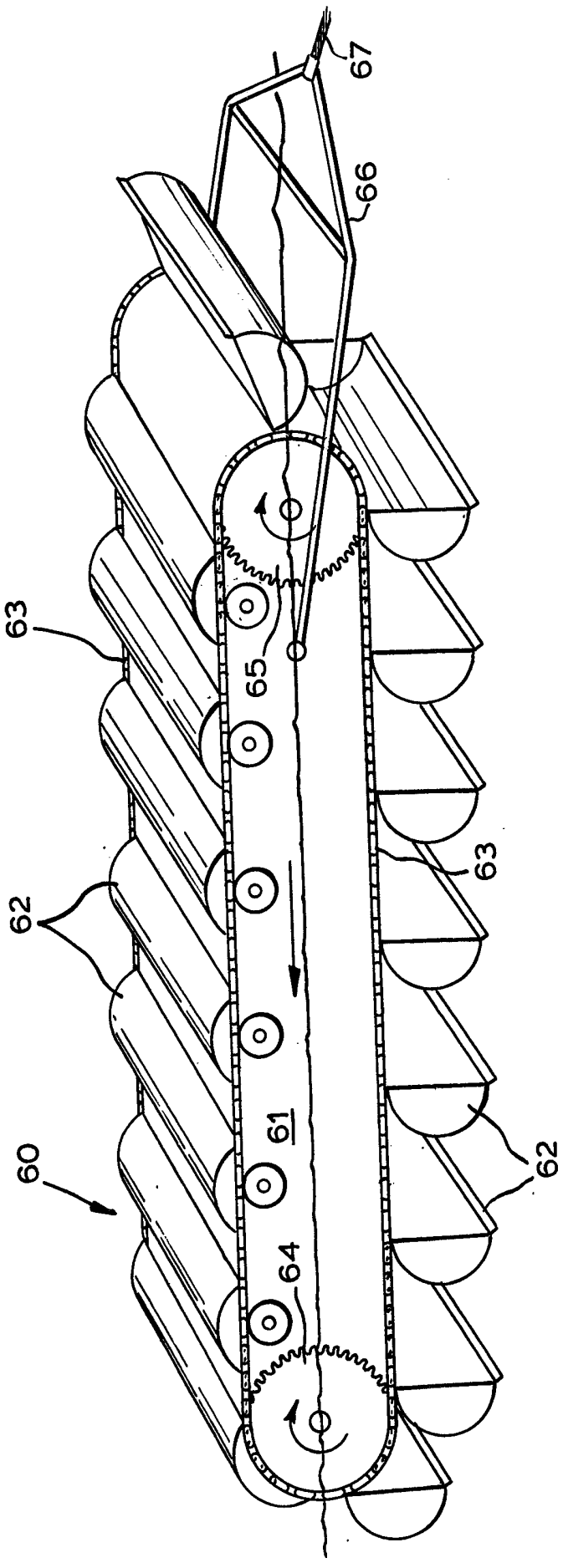

FIG. 4.

SPECIFICATION
Energy converter

The present invention relates to apparatus for converting the energy of waves, under water currents or surface currents into another form of energy, e.g. electricity.

The invention provides in its broadest aspect, an ocean energy converter comprising a buoyant body, bucket means disposed in a series in a closed path and supported by the buoyant body for circulation under the influence of wave action on the buoyant body or under the influence of water currents on the bucket means, and means to convert the kinetic energy of the circulation of the series of bucket means into another form of energy.

In a first narrower aspect the invention provides a wave energy converter, comprising a buoyant body, a framework fixedly secured to the buoyant body and extending to a depth substantially free from wave action, bucket means disposed in a series in a closed path and mounted on the lower portion of the framework for circulation in one direction,xthe bucket means offering greater resistance to the water upon movement through the water in one direction than in the other direction, the bucket means offering greater circulates in the same direction both when rising under the influence of wave action on the buoyant body and when falling under the influence of wave action on the buoyant body, and means to convert the kinetic energy of the circulation of the series of bucket means into another form of energy.

This latter aspect of the invention is based on the fact that waves e.g. ocean waves are of only finite depth, that is, the water surface may be in violent motion because of wave action, at the same time that the water at a certain depth will be relatively calm and takes advantage of this difference in kinetic energy of the water at the surface and the water at a substantial depth, by providing a buoyant member that moves with the surface water and imparts that same movement to the bucket means at a depth at which the water is relatively calm, The bucket means at that depth is mounted for circulation under the influence of the inertia of the calm water; and this circulation is converted into another form of energy, e.g. electricity.

In a second narrower aspect, the invention provides an under water current energy converter, comprising a buoyant body, bucket means disposed in a series in a closed path and supported by the buoyant body for circulation at a depth at which under water currents are present, the bucket means offering greater resistance to movement through the water in one direction than in the other direction whereby the series of bucket means is circulated by the action of under water currents on the bucket means, and means to convert the kinetic energy of the circulation of the series of bucket means into another form of energy.

In a third narrower aspect the invention provides a surface current energy converter, comprising a buoyant body, a framework fixedly secured to the buoyant body, bucket means disposed in a series in a closed path and mounted on the framework structure for circulation by the action of surface currents on the bucket means, and means to convert the kinetic energy of the circulation of the series of bucket means into another form of energy.

In a fourth narrower aspect the invention provides a surface current energy converter comprising a buoyant body, bucket means disposed in series in a closed path and mounted about the buoyant body for circulation by the action of surface currents on the bucket means, and means to convert the kinetic energy of the series of bucket means into another form of energy.

Preferably said series of bucket means comprises a bucket wheel or endless bucket chain to which said bucket means are secured.

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

Figure 1 is a side elevational view of a wave energy converter according to the present invention;

Figure 2 is an end elevational view thereof;

Figure 3 is a perspective view of an under water current energy converter according to the present invention;

Figure 4 is a perspective view of a surface current energy converter according to the present invention.

Referring now to the drawings, there is shown an ocean wave energy converter, comprising a buoyant body 1 such as a boat or the like, moored to an anchor by a line 3 so that it is free to float on the surface of the water and free to rise and fall with the wave action, and free to assume a position in the water in which its length extends perpendicular to the waves.

Fixedly secured to and depending downwardly from body 1 is a rigid framework 5 which at its lower end supports for rotation a horizontal shaft 7.

Fixedly mounted on shaft 7 for rotation about a horizontal axis, is a bucket wheel 9 comprised by a plurality of radially outwardly extending arms 11 disposed at each end of bucket wheel 9, each pair of arms 11 fixedly carrying between them an elongated bucket 13. Each bucket 13 has a semi-cylindrical wall 15 comprising the side and bottom walls of the bucket, and is closed at its ends by opposite end walls 17. Each bucket 13 is thus open at one side and closed on all the others.

All the buckets 13 open in the same direction, which is the counterclockwise direction as seen in Figure 1. It will therefore be appreciated that the buckets on one side of the wheel offer a different resistance to the water than the buckets on the other side of the wheel, depending on the direction in which the bucket wheel is moving through the water. Thus, with the buckets arranged as in Figure 1, it will be evident that, as

the bucket wheel moves downward through relatively calm water, the buckets on the left side of the wheel will offer greater resistance to the water than will the relatively streamlined buckets on the right side of the wheel, which present their rounded surfaces to the oncoming water. The result is that the wheel will rotate clockwise when it is forced down into calm water.

When the wheel is dragged back up through calm water, toward the surface, however, then the buckets on the right side of the wheel as seen in Figure 1 offer greater resistance to the water than to those on the left side of the wheel; so again, the wheel tends to turn clockwise.

In other words, with the buckets arranged as in Figure 1, both downward movement of the wheel and upward movement of the wheel tend to rotate the wheel clockwise as seen in Figure 1. This is a very important feature because it means that no energy is wasted overcoming the kinetic energy of a moving solid part of the mechanism so as to reverse its direction of rotation or circulation.

This continuous unidirectional rotary movement of the bucket wheel 13 is converted into another form of energy, e.g. electric, by a transmission train which, in the illustrated embodiment, extends above the surface of the water. Specifically, bevel gears 19 at each end of shaft 7 mesh with bevel gears 21 fixed to the lower ends of shaft 23 at each side of framework 5, the shafts 23 being mounted for rotation about their vertical axes in stanchions 25 on both sides of framework 5. Bevel gears 27 fixed to the upper ends of shaft 23 mesh with bevel gears 29, 31 mounted on buoyant body 1, to drive an electrical generator 33 supported by buoyant body 1. Electrical power from generator 33 is transmitted to shore by appropriate conductors (not shown) or is consumed onboard buoyant body 1.

Alternatively, of course, the bevel gearing 29, 31 could drive a pump or compressor or other device for storing energy hydraulically or pneumatically, for use as such or for subsequent conversion to electrical energy. Thus, for example, if the operation of generator 33 require a more constant rate of rotation than could be provided by bevel gearing 29, 31, it might in that case be desirable to interpose a compressor or the like between the bevel gearing and the generator.

In a modification (not shown), bucket wheel 9 can be replaced by an endless bucket chain whose length is preferably vertically disposed and whose buckets are caused to circulate unidirectionally and according to the same principle as in the case of bucket wheel 9.

In another modification (not shown), bevel gearing 19, 21 can be sealed in a housing to prevent corrosion or fouling.

The above described ocean wave energy converter can extract energy from ocean waves of any size, and in fact, the higher the better. The converter can be installed near the shore, and in fact in any location in which the depth of the ocean is at least twice the height of the highest wave. Moreover, it is well adapted to modular construction and is relatively simple and inexpensive to construct, easy and cheap to maintain, and rugged and durable in use.

In addition to wave energy, vast amounts of energy are stored in surface and under water ocean currents and modified versions of the above-described apparatus can be used to extract this energy.

In a first modification of the above-mentioned apparatus in order to extract energy from underwater ocean currents, the framework 5 is strengthened and extended at a depth at which underwater currents exist (usually at a depth of about 100—200 feet). The bucket wheel 9 is mounted on a shaft supported at the lower end of the framework. However, it is preferable that the shaft is supported for rotation about a vertical rather than a horizontal axis since this has the advantage that the buckets will be circulated by any under water currents to which they are subjected regardless of the direction of movement of the currents. Moreover, the energy extracted from the under water currents can be transmitted directly to the top of the buoyant body with the provision of only one pair of transmitting gears. In order to give it better stability, the buoyant body should, in this case, have a bottom which is of W-shaped or substantially W-shaped cross-section.

Figure 3 shows another ocean underwater current energy converter comprising a bucket chain drive 40 comprising a buoyant body 41 and a plurality of buckets 42 similar to the buckets 13 and mounted on the body 41. The bucket chain device is coupled to a weight 44 on the sea bed by cables 45. The buckets 42 are connected to two endless chains 47 which each extend about respective horizontally spaced sprocket wheels 48 and 49 carried by the buoyant body 41. The buckets are preferably hingedly connected to the chains for movement relative to the chains through an angle of 90°. The buoyant body 41 contains within it an electric generator (not shown) bucket chain device contains within it an electric generator (not shown) driven by the sprocket wheels 48 and/or the sprocket wheels 49 and for this reason the bucket chain device is sealed to prevent ingress of water to the generator. Electrical power from the generator is transmitted to shore by appropriate conductors or is consumed onboard the buoyant body 42. The bucket chain device is moored to the same anchor as the body 42 by a harness 50 and cable 51 and will together with the body 42 move about as the direction of the underwater currents changes. The orientation of the bucket chain device shown in Figure 3 is as a result of an underwater current in the direction of arrow D. The buckets 46 are hinged to the chains 47 so that the open ends of the buckets connected to the lower limbs of the chains are generally vertically orientated and face the oncoming flow of water and hence receive the full impact of the flow whereas the open ends of the buckets connected to the upper limbs of the chains are generally horizontally orientated and lie in the plane of the upper chain limbs. In this

position the buckets on the upper chain limbs present a minimal resistance to movement against the water currents and hence improve the efficiency of the device as compared with a device in which the buckets are rigidly connected to the chains. Again the buoyant body may have a bottom which is of W-shaped or

In a modification of the apparatus of Figure 1 in order to extract energy from surface water currents, the framework is designed so that the shaft of the or each bucket wheel is horizontal and above the surface of the water. Once again, the bottom of the buoyant body is preferably of W or substantially W-shaped cross-section to give it better stability and in this case it is advantageous to provide a single bucket wheel mounted at one end of the buoyant body, the lengthwise direction of the buoyant body being normal to the aforesaid cross-section, or two bucket wheels mounted on opposite sides of the buoyant body respectively.

Instead of the bucket wheel an endless bucket chain may be used. In this latter case, the endless chain will extend between two horizontally spaced wheels supported by the framework alongside the buoyant body. The two limbs of the chain will extend substantially horizontally with one above the other so that only the buckets secured to the lower limb are in the water. The wheel nearest to the front of the buoyant body may be connected to an electrical generator on the buoyant body *via* a transmission train.

Figure 4 shows another ocean surface current energy converter comprising a bucket chain device 60 in the form of a buoyant body 61, and a plurality of buckets 62 similar to the buckets 13 and 46 connected to two endless chains 63 extending about respective horizontally spaced sprocket wheels 64 and 65 which are carried by the buoyant body 61. The body 61 is sealed and contains within it an electric generator (not shown). The buckets 62 are hingedly connected to the chains 63 in the same way as the buckets 46 are connected to the chains 47. The body 61 is moored to an anchor by a harness 66 and cable 67 and floats on the surface of the water. The buckets connected to the lower chain limbs are below the water surface and the open ends of these buckets face the direction of the surface currents whereas the buckets connected to the upper chain limbs are above the water surface and the open ends of the buckets lie against the chains 63.

It is possible that the buckets of the bucket wheel may also be hingedly connected to the bucket wheel of Figures 1 and 2 and to a bucket chain used to extract energy from waves.

It is to be understood that when extracting energy from water currents or the waves, the buoyant body should be moored to an anchor at that end of the buoyant body which faces the currents or which faces the waves. When used to extract energy from under water currents which are at great depth, a second mooring line should be connected between the anchor and the lower end of the framework, the bucket wheel or bucket chain.

A big advantage of extracting energy from currents is that where they exist, they are normally constant and continuous day and night and the extraction of energy is not interrupted as in the case of extracting energy from ocean waves.

In the above description reference has been made to extracting energy from ocean waves or currents. However, the energy converters described above can be used to extract energy also from rivers and inland lakes and to exploit the energy stored in tidal flow. When used to extract the energy stored in the tidal flow the energy converter should be anchored at both ends.

CLAIMS

1. An energy converter comprising a buoyant body, bucket means disposed in a series in a closed path and supported by the buoyant body for circulation under the influence of wave action on the buoyant body or under the influence of currents on the bucket means, and means to convert the kinetic energy of the circulation of the series of bucket means into another form of energy.

2. A wave energy converter, comprising a buoyant body, a framework fixedly secured to the buoyant body and extending to a depth substantially free from wave action, bucket means disposed in a series in a closed path and mounted on the lower portion of the framework for circulation in one direction, the bucket means offering greater resistance to the water upon movement through the water in one direction than in the other direction whereby the series of bucket means circulates in the same direction both when rising under the influence of wave action on the buoyant body and when falling under the influence of wave action on the buoyant body, and means to convert the kinetic energy of the circulation of the series of bucket means into another form of energy.

3. A wave energy converter according to claim 2, wherein said series of bucket means are mounted for circulation about a horizontal shaft drivable in rotation by the bucket means and mechanical means are provided for converting the rotary motion of the shaft to rotary motion of a member located on the buoyant body.

4. A wave energy converter as claimed in claim 3, wherein at least one vertical shaft is mounted for rotation on said framework and has bevel gearing at its upper and lower ends, meshing with bevel gearing on said member and on said horizontal shaft, respectively.

5. An under water current energy converter, comprising a buoyant body, bucket means disposed in a series in a closed path and supported by the buoyant body for circulation at a depth at which under water currents are present, the bucket means offering greater resistance to movement through the water in one direction than in the other direction whereby the series of bucket means is circulated by the action of under water currents on the bucket means, and means to

convert the kinetic energy of the circulation of the series of bucket means into another form of energy.

6. An under water current energy converter according to claim 5, wherein the connecting means comprises a framework structure secured to the buoyant body and extending to a depth at which under water currents are present.

7. An under water current energy converter according to claim 6, wherein the series of bucket means are mounted for circulation about a vertical shaft driven in rotation by the bucket means.

8. An under water current energy converter according to claim 5, wherein the bucket means is mounted on the buoyant body and wherein the converter further comprises a weight attached thereto by one or more flexible elongate elements such that in use the buoyant body is held by the weight at a depth at which under water currents are present.

9. A surface current energy converter, comprising a buoyant body, a framework fixedly secured to the buoyant body, bucket means disposed in a series in a closed path and mounted on the framework structure for circulation by the action of surface currents on the bucket means, and means to convert the kinetic energy of the circulation of the series of bucket means into another form of energy.

10. A surface current energy converter according to claim 9, wherein said series of bucket means are mounted for circulation about a horizontal shaft drivable in rotation by the bucket means and supported by the framework so as to be above the surface of the water when the buoyant body is floating on the water.

11. A surface current energy converter comprising a buoyant body, bucket means disposed in series in a closed path and mounted about the buoyant body for circulation by the action of surface currents on the bucket means, and means to convert the kinetic energy of the series of bucket means into another form of energy.

12. A current energy converter according to any one of claims 5—7, 9 and 10, wherein the bottom of the buoyant body is of W-shaped or substantially W-shaped cross-section.

13. An energy converter as claimed in any one of claims 1—10 or claim 12, wherein said series of bucket means comprises a bucket wheel to which said bucket means are secured in a circular series.

14. An energy converter as claimed in any one of claims 1, 2, 5, 6, 8, 9 or 11, wherein said series of bucket means comprises an endless bucket chain to which said bucket means are secured.

15. An energy converter as claimed in any one of the preceding claims, wherein the bucket means are hingedly connected to respective bucket carrying means.

16. An energy converter according to claim 14 when dependent on claim 1 or 2, wherein the endless bucket chain is vertically disposed.

17. An energy converter according to claim 14 when dependent on claim 5, 6, 8, 9 or 11, wherein the endless bucket chain is horizontally disposed.

18. An energy converter according to any one of the preceding claims, wherein the bucket means comprises a plurality of elongate buckets having a semi-cylindrical or substantially semi-cylindrical wall closed at opposite ends.

19. A wave energy converter substantially as hereinbefore described with reference to and as shown in Figures 1 and 2 of the accompanying drawings.

20. An under water current energy converter substantially as hereinbefore described with reference to and as shown in Figure 3 of the accompanying drawings.

21. A surface current energy converter substantially as hereinbefore described with reference to and as shown in Figure 4 of the accompanying drawings.

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