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FD2	1 of 21	56%

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AN APPARATUS FOR PRODUCING ALGAE ✓1

Technical field

The invention relates to an apparatus for producing algae, and in particular to an apparatus comprising a photo-reactor bag for containing a mixture of algae, water and nutrients in which algae can grow. ✓1

Background

There are many different types of algae that grow naturally in water (e.g. in rivers and lakes), as well as in damp soil and on the surfaces of rocks and trees. Algae need light, water and nutrients to grow, but when the conditions are right, they can grow very quickly and form large colonies, sometimes even covering the entire surface of lakes. Some types of algae can also be processed to produce biofuels and other useful products, and it has been known to grow algae on an industrial scale for many years, for example using a so-called `bioreactor' that artificially replicates the optimum conditions needed for algae growth. In recent years, flexible plastic photo-reactor bags have started to be used instead of the more traditional concrete bioreactor tanks.

As shown in Figures 1-3, such a photo-reactor bag 10 contains a mixture of algae, water and nutrients 14, and has inflatable ribs 12 running along its length so that it floats on the surface of a body of water 20 such as a lake. The upper surface of the bag 16 must be transparent enough to visible light so that algae within the bag are exposed to natural light. Although the mixture is sealed within

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the bag 16, it is in thermal contact with the water 20 on which it floats, thereby regulating the temperature of the mixture within the bag 16. Inlet 22 and outlet pipes 24 are connected to the bag 10 allow the mixture to be continually pumped to an external fluid processing system 26 that adds nutrients and extracts algae in the form of a sludge that can be further processed to produce biofuel. Wastewater has been used previously in known bioreactors to provide the nutrients required for algae growth. However, the fluid pumping and external processing system is energy intensive, and making it prohibitively expensive for use in industrial biofuel production.

The present invention is aimed at alleviating one or more problems associated with the prior art. ✓2

Summary of Invention

In one aspect, the present invention provides an apparatus according to claim 1. Advantageously, the present invention uses a selectively permeable membrane to passively exchange water or nutrients with the water outside the photo-reactor bag, therefore, no pumps or external fluid processing systems are needed to facilitate exchange the water or nutrients, which minimises energy consumption. ✓1 In addition, the passive nature of this process means the photo-reactor bag can be left floating in the sea, with the algae sludge being pumped out periodically. ✓1

In an embodiment, [claim 2]. In this way, FO membrane allows water to pass from the fresh water (i.e. of the wastewater) within the bag to the (saltier) sea water outside the bag. It would also work with seawater inside the bag if the bag was floating on brine; the water outside the bag just needs to be saltier than the water inside the bag. Advantageously, it is only water and not any of the algae or

nutrients in the wastewater that will pass out of the bag through the FO membrane and into the sea. This provides an added environmental benefit that only water is discharged into the sea, and not any of the nutrients present in the photo-reactor bag, which is particularly advantageous when the photo-reactor bag is connected to a source of wastewater which would otherwise be discharged into the water. In addition, the loss of water from the bag through the FO membrane means that the nutrients in the wastewater are retained and concentrated within the bag for consumption by the algae, further aiding the growth of the algae to ensure efficient algae production. ✓1

In another embodiment, [claim 3]. Advantageously, the nutrient permeable membrane allows nutrients (e.g. nitrates) to pass from the sea water outside the bag (where they are present in high concentrations) to the fresh water retained inside the bag (where the nutrient concentration is lower), whilst retaining the algae inside the bag and preventing water from entering or leaving the bag. n use, the algae will consume the nutrients, thereby lowering the nutrient concentration in the bag, which in turn means more nutrients will enter the photo-reactor bag through the nutrient permeable membrane. There will thus be a net inflow of nutrients into the bag for consumption by the algae, thereby extracting unwanted nutrients from the sea. ✓1

In an embodiment, [claim 4]. Advantageously, a nitrate permeable membrane can be used to reduce nitrate concentrations in certain regions of the sea which are already uninhabitable for most marine life due to the build-up of large amounts of nitrates following the extensive release of wastewater.

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In an embodiment, [claim 5]. In this way, the photo-reactor bag can be attached by ropes to one or more floats, for example buoys. The term buoy may be understood as a floats that is anchored to the seabed. This is advantageous to allow securing of the photo-reactor bag to the seabed and stop it drifting off with the tide. Such buoys also help the bag to be seen, for example so it can be grabbed to allow attachment of the flexible hose for the pumping out procedure. ✓1

In an embodiment, [claim 6]. Advantageously, a loop may be stitched into the seams of the photo-reactor bag.

In an embodiment, [claim 7]. In this way, the photo-reactor bag may be kept afloat across its entire length, rather than having some regions submerged.

In an embodiment, [claim 8]. Advantageously, a plurality of ribs facilitates both sides of the photo-reactor bag being kept afloat. ✓½

In an embodiment, [claim 9]. In this way, the float may provide buoyancy, which allows the use of smaller inflatable ribs, or they could even be used instead of the air-filled ribs. The amount of buoyancy could also be adjusted to allow the bag to float just below (e.g. by 5-10cm) the surface of the sea. ✓½

In an embodiment, [claim 10].

In an embodiment, [claim 11]. Advantageously, attachment to a buoy stops the photo-reactor bag drifting off with the tide. Such buoys also help the bag to be seen, for example so it can be grabbed to allow attachment of the flexible hose for the pumping out procedure.

In an embodiment, [claim 12]. If the buoyancy of the bag is adjusted to allow the bag to float just below (e.g. by 5-10cm) the surface of the sea, patches of a

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transparent selectively permeable membrane can be included on the top surface of the bag, which, for example, would advantageously allow the surface area of the FO membrane to be increased for a given size bag.

In an embodiment, [claim 13]. Advantageously, this reinforces the photo-reactor bag to make it sufficiently robust for long-term use in the sea.

In an embodiment, [claim 14]. Advantageously, this reinforces the photo-reactor bag to make it sufficiently robust for long-term use in the sea. ✓½

In an embodiment, [claim 15]. Plastic is impermeable and cheap to use for manufacture.

In an embodiment, [claim 16]. Polyurethane is impermeable, strong and cheap to use for manufacture.

In an embodiment, [claim 17]. In this way, the accumulated sludge may be periodically pumped out (e.g. into a visiting barge) by attachment of a hose to the bag. ✓½

In an embodiment, [claim 18]. In this way, the bag is provided with a separate inlet port, which may be used to provide a continuous inflow of wastewater to the bag. The separate inlet obviates the need to disconnect the inlet hose when pumping out the bag (as there is a separate outlet port). ✓½

In another aspect, there is provided a kit of parts according to claim 19.

Brief Description of the Figures

The present invention is best understood with reference to the following figures, in which:

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Figure 1 is a section view of a prior art photo-reactor bag.

Figure 2 is a cross-section view of a prior art photo-reactor bag floating on water.

Figure 3 is a schematic of a prior art photo-reactor bag floating on water connected to a pumping/processing station on the shore.

Figure 4 is a schematic of a photo-reactor bag of the present invention forward osmosis membrane floating on water connected to a sewage treatment plant on the shore.

Figure 5 is a plan view of the bottom of a photo-reactor bag of the present invention with a forward osmosis membrane.

Figure 6 is a cross-section view of a photo-reactor bag of the present invention with a forward osmosis membrane.

Figure 7 is a schematic of a photo-reactor bag of the present invention with a nitrate-permeable membrane floating on water attached to a buoy.

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Figure 8 is a plan view of the bottom of a photo-reactor bag of the present invention with a nitrate-permeable membrane.

Figure 9 is a cross-section view of a photo-reactor bag of the present invention with a nitrate-permeable membrane.

✓1

Like features are denoted by like reference numerals in the attached figures.

Specific Description

An exemplary apparatus according to the present invention is shown in Figure 4. The photo-reactor bag 30 floats on the surface of the sea 20. In use, the forward osmosis membrane (FO membrane) allows water to pass from the fresh water

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(i.e. of the wastewater) within the bag to the (saltier) sea water outside the bag. It would also work with seawater inside the bag if the bag was floating on brine; the water outside the bag just needs to be saltier than the water inside the bag. Importantly, it is only water and not any of the algae or nutrients in the wastewater that will pass out of the bag through the FO membrane 32 and into the sea. In use, a flow of wastewater enters an inlet at one end of the bag, for example via a flexible pipe 41 connected to a sub-sea sewage outfall pipe 40. The flow of wastewater into the bag and the loss of water from the bag through the FO membrane 32 means that the nutrients in the wastewater are retained and concentrated within the bag for consumption by the algae. The temperature of the bag's contents is regulated by the sea water 20, the wave motion agitates the mixture, and the algae is exposed to natural daylight passing through the transparent upper surface of the bag. No pumps or external fluid processing systems are needed, which minimises energy consumption. There is also the added environmental benefit that only water is discharged into the sea, and not any of the nutrients present in the wastewater. A loop 46 is provided which is stitched into the seams of the bag 30.

An exemplary photo-reactor bag 30 is shown in Figures 5 and 6. The photo-reactor bag 30 has upper 50 and lower surfaces 52 joined by inflatable ribs 12 running along its length so that it floats on the surface of a body of water, such as a lake or sea. The upper surface 50 is transparent to visible light so that algae within the bag are exposed to natural light. The lower surface 52 includes forward osmosis membranes 32. To make the photo-reactor bag 30 sufficiently robust for long-term use in the sea 20, multiple patches of FO membrane

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material 32 are surrounded and supported by regions of stronger, thicker polyurethane plastic material 49. Alternative impermeable plastic materials may be used. Further robustness was added to the bag by the inclusion of reinforcement strips 44 that run along and across the bag between the FO membrane patches 32.

Figures 7-9 show a different embodiment of the invention which includes a nitrate permeable membrane 54 instead of the FO membrane 32, but otherwise has a very similar structure as indicated by the like reference numerals. Whilst the nitrate permeable membrane 54 is still not as strong as the impermeable plastic 49 it is much more robust than the FO membrane material, which allows a large, single piece of such material to be used.

It will be appreciated that the amount of reinforcement necessary may vary depending on the specific semi-permeable membrane material or materials used for each different type of photo-reactor bag.

✓6

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Intro + Descrptn

19½

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6

Claims

1. An apparatus for producing algae, comprising:

a photo-reactor bag for containing a mixture of algae, water and nutrients; and

a buoyancy means coupled to the photo-reactor bag, for keeping the photo-reactor bag afloat in water;

wherein the photo-reactor bag comprises a transparent upper surface for exposing the mixture to light, and a selectively permeable membrane for allowing the exchange of water or nutrients between the inside of the photo-reactor bag and the water outside the photo-reactor bag in use.

✓19

2. An apparatus according to claim 1, wherein the selectively permeable membrane is a forward osmosis membrane for allowing water to pass from the inside of the photo-reactor bag to the water outside the photo-reactor bag along a salt concentration gradient, and for preventing algae and nutrients from entering or leaving the photo-reactor bag through the forward osmosis membrane.

✓2

3. An apparatus according to claim 1, wherein the selectively permeable membrane is a nutrient permeable membrane for allowing nutrients to pass from the water outside the photo-reactor bag to the inside of the bag along a nutrient concentration gradient, and for preventing algae and water from entering or leaving the photo-reactor bag through the nutrient permeable membrane.

✓3

4. An apparatus according to claim 3, wherein the nutrient permeable membrane is a nitrate permeable membrane for allowing nitrates to pass from

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the water outside the photo-reactor bag to the inside of the bag along a nitrate concentration gradient, and for preventing algae and water from entering or leaving the photo-reactor bag through the nitrate permeable membrane.

5. An apparatus according to any one of the preceding claims, wherein the photo-reactor bag comprises an attachment means for attaching the photo-reactor bag to a float.

6. An apparatus according to claim 5, wherein the attachment means is a loop. ✓1

7. An apparatus according to any one of the preceding claims, wherein the buoyancy means comprises an inflatable rib.

8. An apparatus according to claim 5, wherein the buoyancy means comprises a plurality of inflatable ribs. ✓½

9. An apparatus according to any one of the preceding claims, wherein the buoyancy means comprises a float. ✓1

10. An apparatus according to claim 9, wherein the buoyancy means comprises a foam float.

11. An apparatus according to claim 9 or 10, wherein the buoyancy means comprises a buoy.

12. An apparatus according to any one of the preceding claims, wherein the transparent upper surface comprises a transparent selectively permeable membrane. ✓1

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13. An apparatus according to any one of the preceding claims, wherein the photo-reactor bag comprises multiple patches of selectively permeable membrane material surrounded by material thicker than the selectively permeable membrane material for reinforcement. ✓½

14. An apparatus according to any one of the preceding claims, wherein the photo-reactor bag comprises strips of impermeable material thicker than the selectively permeable membrane for reinforcement. ✓1

15. The apparatus according to claim 13 or claim 14, wherein the impermeable material is plastic.

16. The apparatus according to claim 15, wherein the plastic is polyurethane.

17. The apparatus according to any one of the preceding claims, wherein the photo-reactor bag comprises a sealable fluid port for connection to a hose to empty the bag. ✓1

18. The apparatus according to claim 17, wherein the photo-reactor bag further comprises a fluid inlet port for connection to an inlet pipe. ✓1

19. A kit of parts, comprising the apparatus of any one of the preceding claims, and algae. ✓1

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Claims

33

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Abstract

✓½

AN APPARATUS FOR PRODUCING ALGAE

The invention relates to an apparatus for producing algae, and a kit of parts comprising the same. The apparatus includes a photo-reactor bag 30 for containing a mixture of algae, water and nutrients 14, a buoyancy means 12 coupled to the photo-reactor bag, for keeping the photo-reactor bag afloat in water 20, a transparent upper surface 50 for exposing the mixture to light, and a selectively permeable membrane 32 for allowing the exchange of water or nutrients between the inside of the photo-reactor bag 12 and the water outside the photo-reactor bag 20. The apparatus may be used to produce algae for use in biofuels.

✓2½

✓½

[Figure 6]

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Abstract

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Figures

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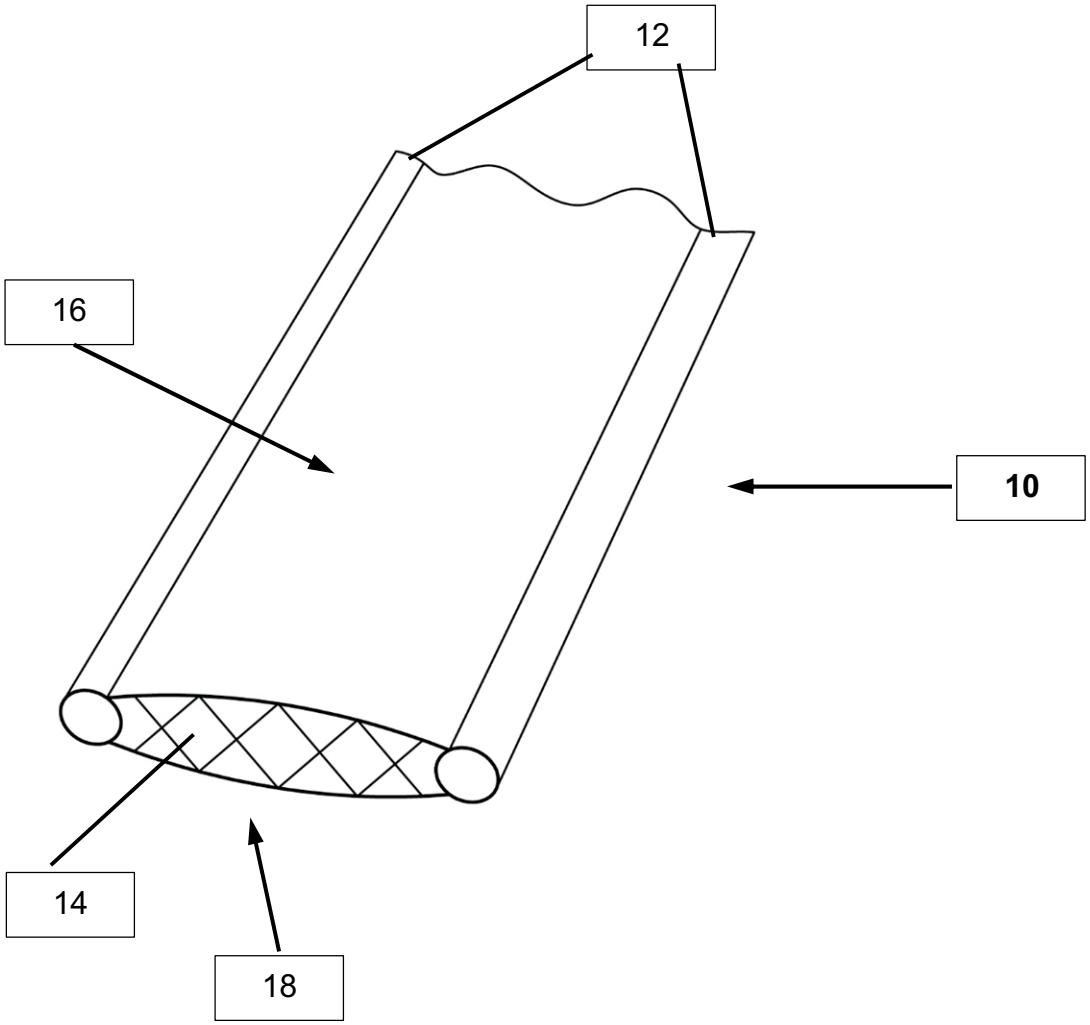
PRIOR ART



✓½

Figure 1

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PRIOR ART

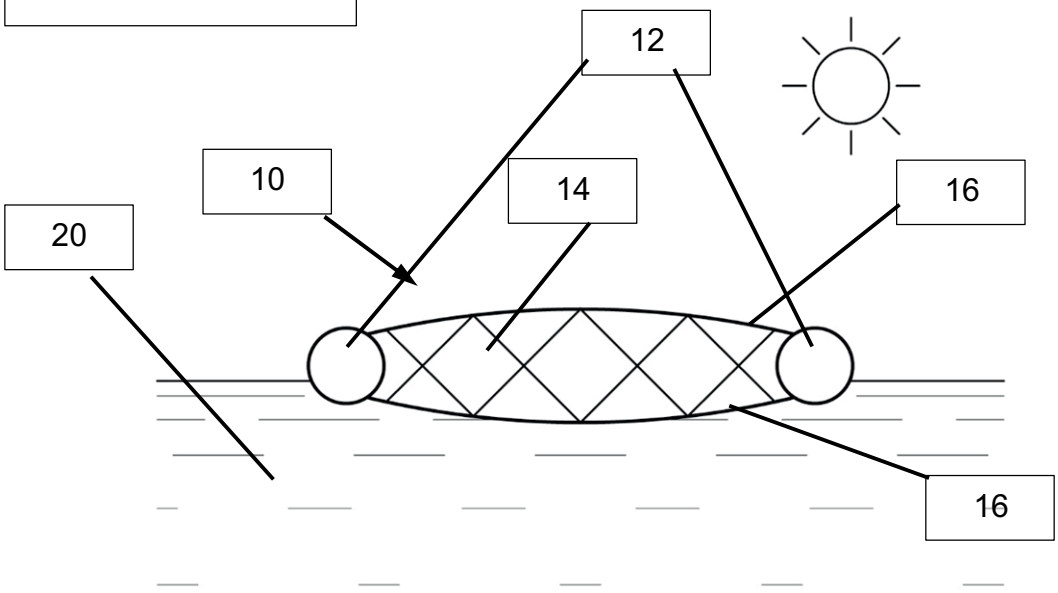

Figure 2

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Doc A - Client drawings

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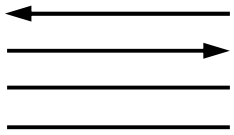

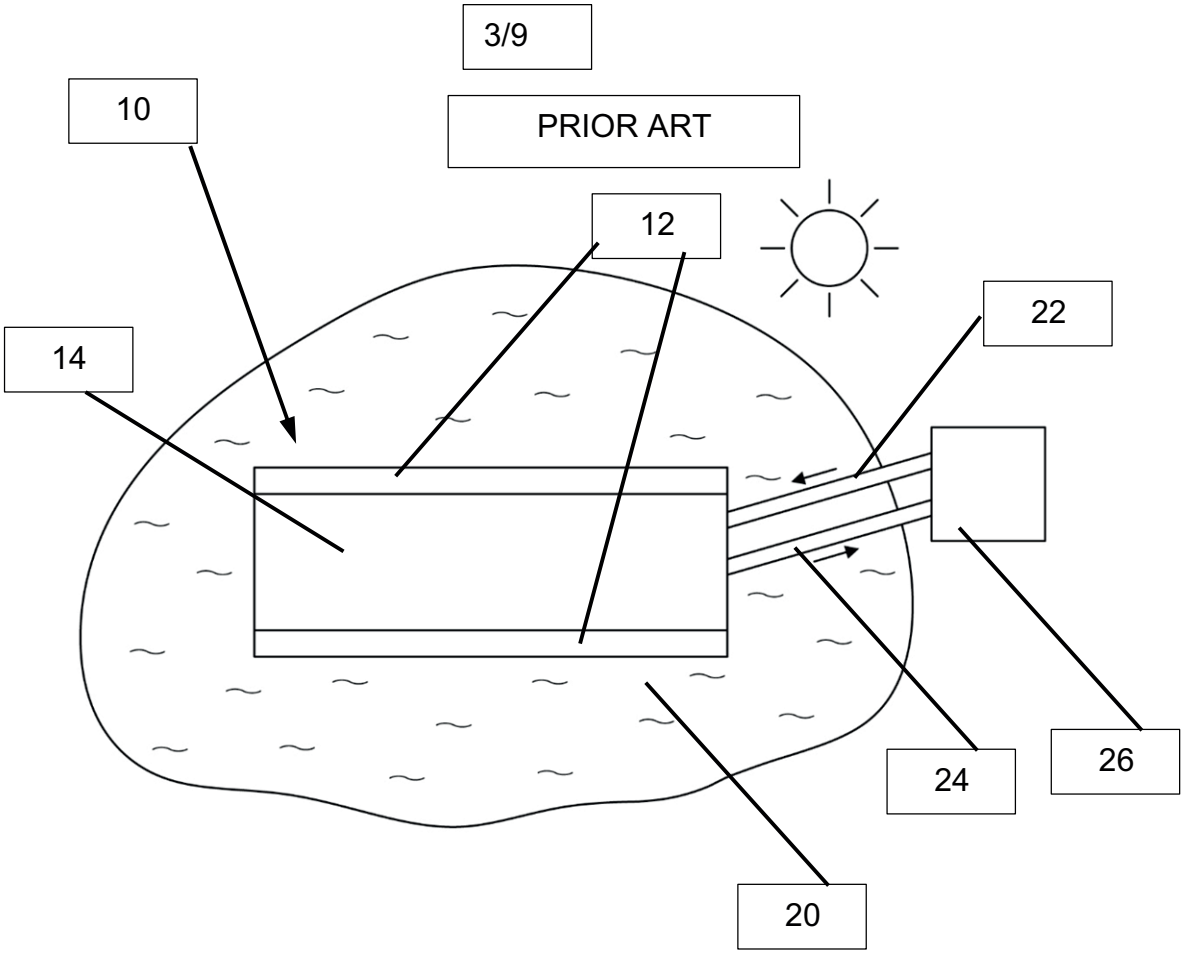

Figure 3

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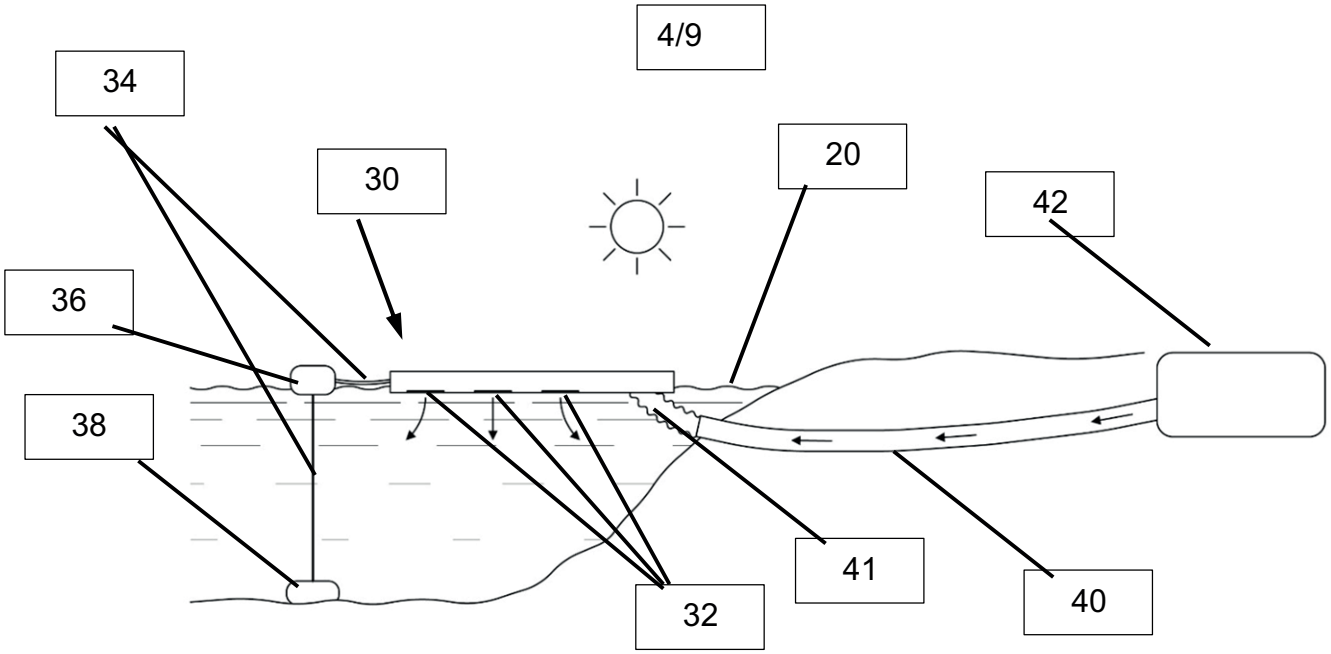

Figure 4

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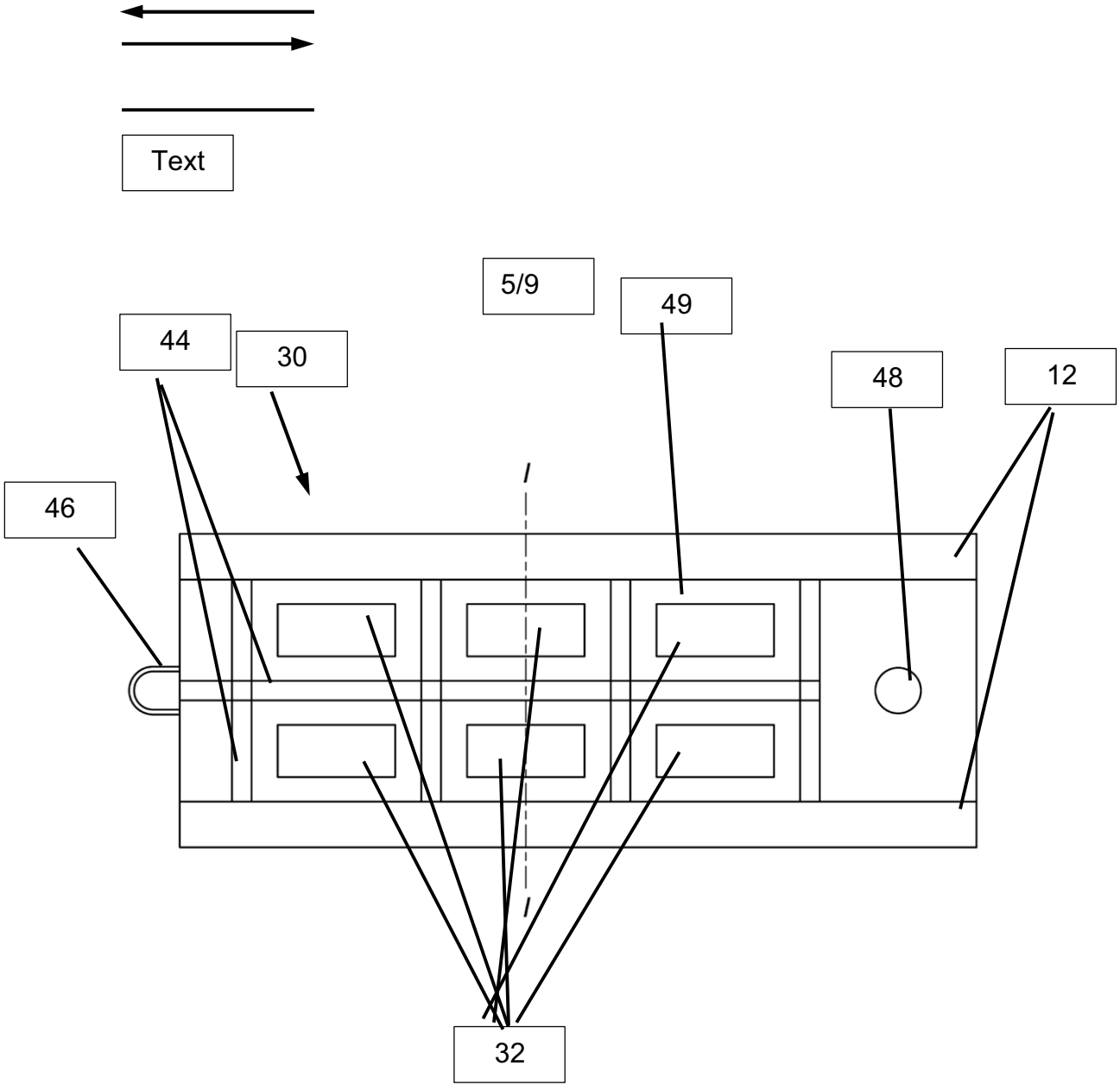

Figure 5

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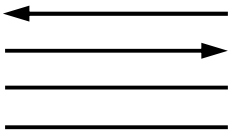

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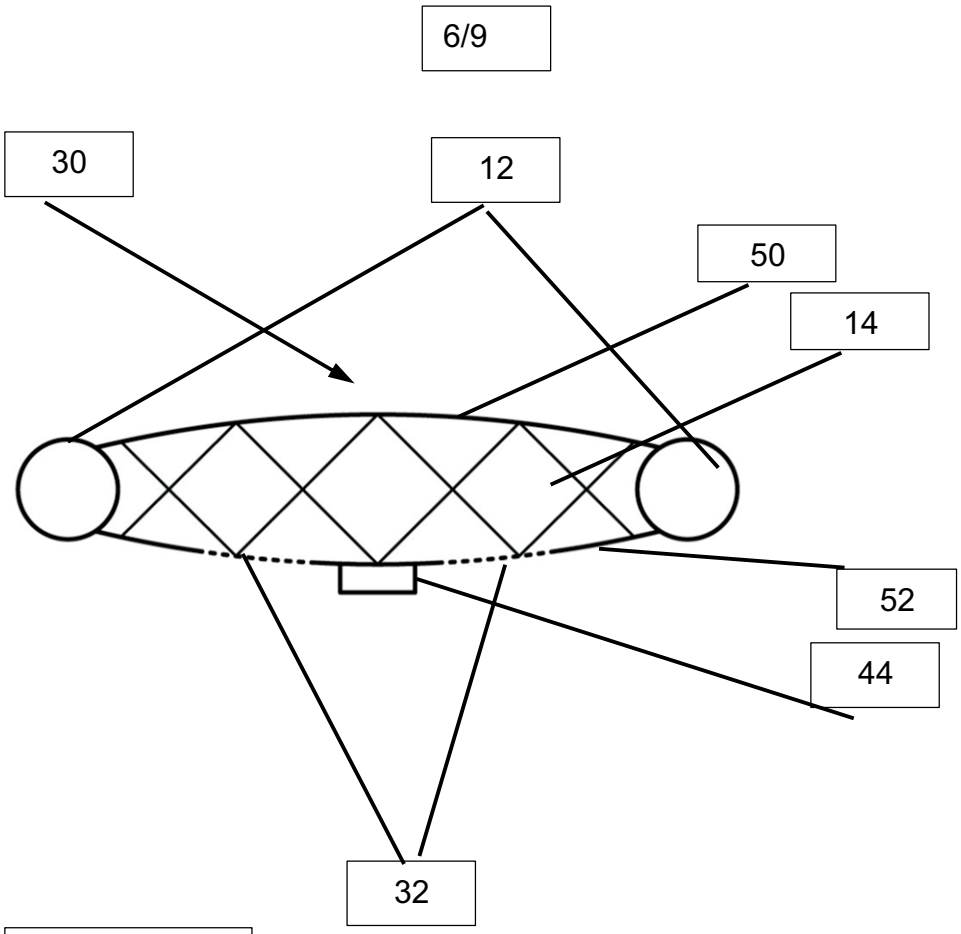

Figure 6

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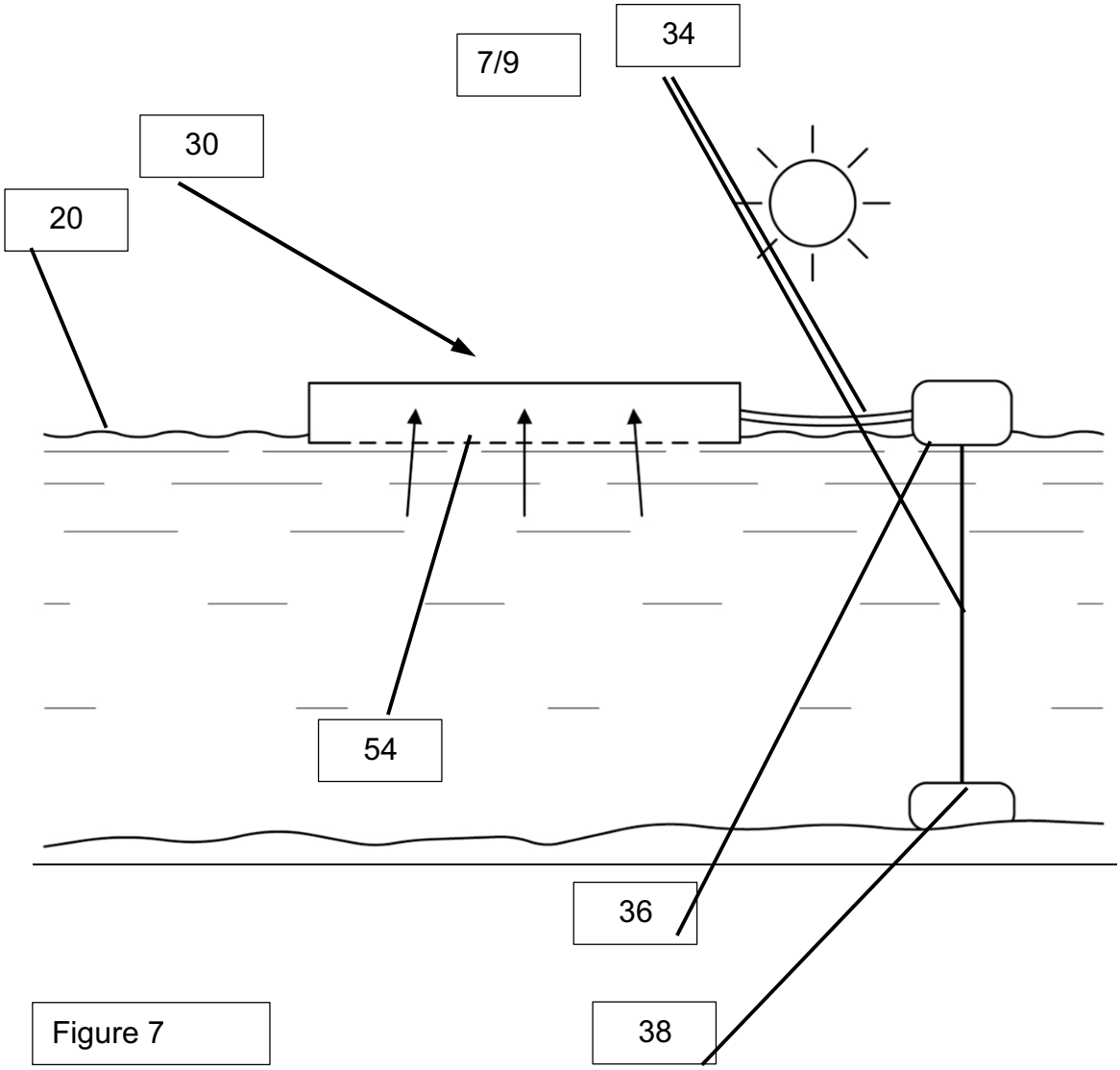

Figure 7

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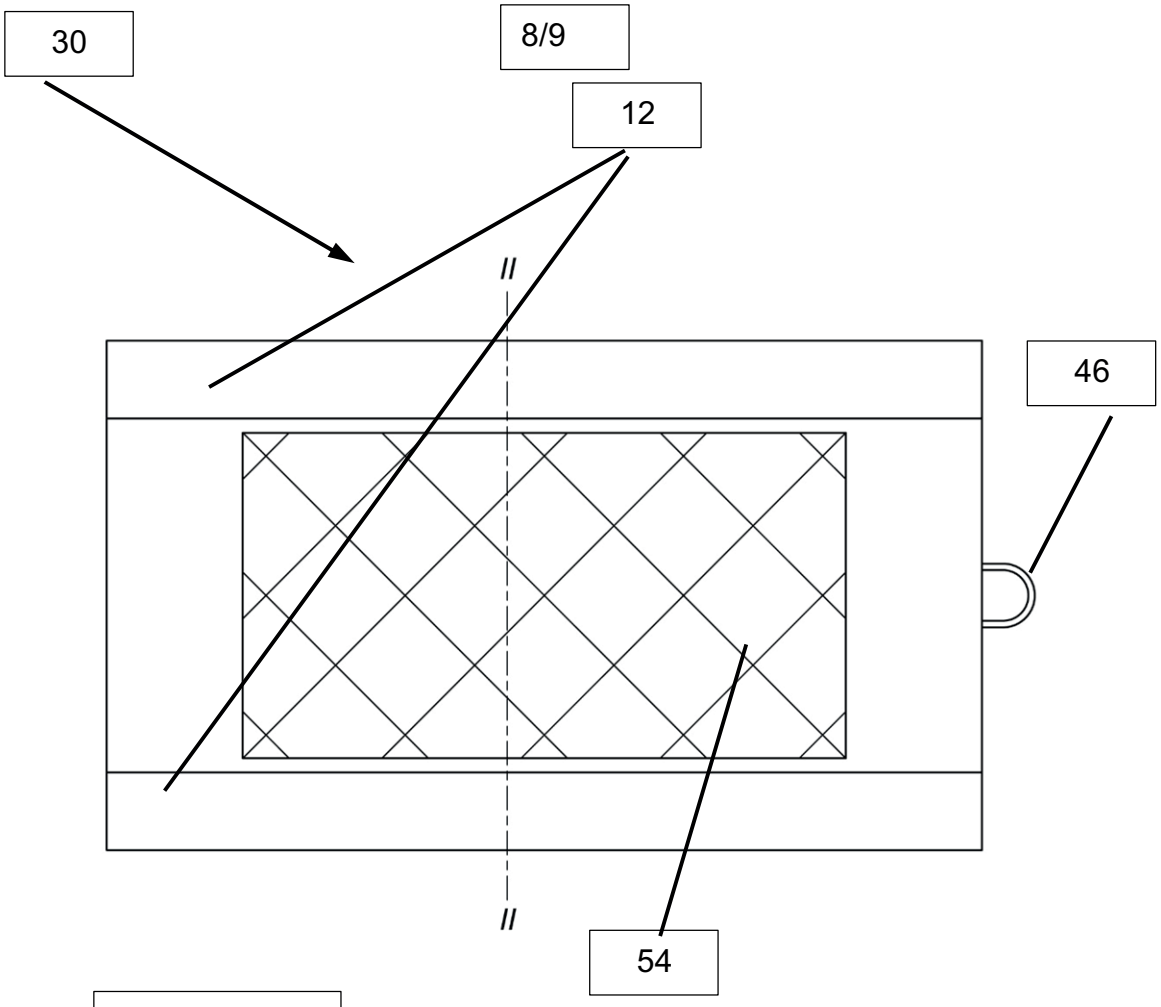

Figure 8

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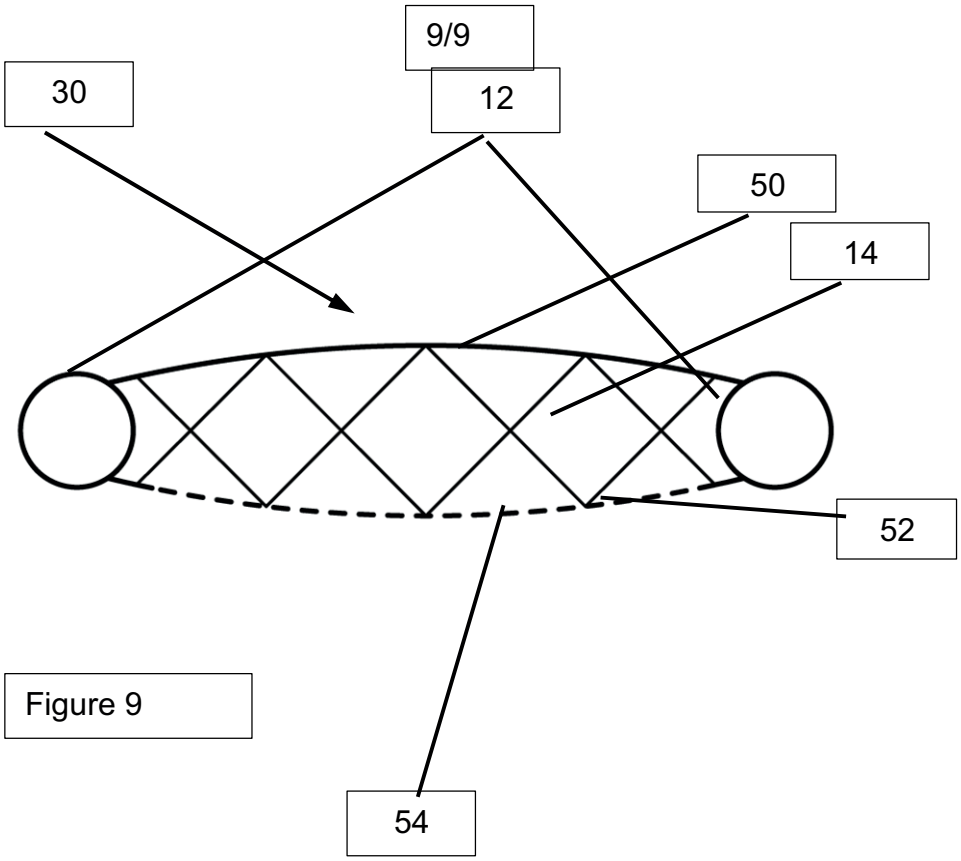

Figure 9

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