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(54) Title: METHOD OF MANUFACTURING A REACTOR ELEMENT OF A PHOTO BIOREACTOR, A PHOTO BIOREACTOR AND A REACTOR ELEMENT THEREFOR

Fig 3a

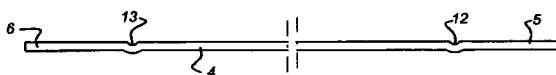


Fig 3b

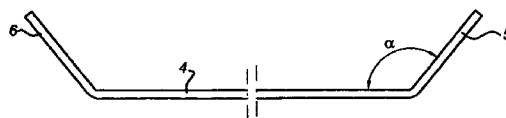
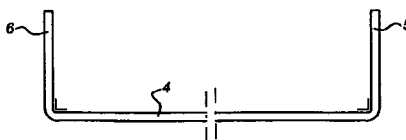


Fig 3c



(57) Abstract: The invention relates to a method of manufacturing a reactor element for receiving a mixture of liquid and phototropic organisms, comprising: providing a sheet of base material for the reactor element, the sheet having edge portions (5, 6) and a central portion (4) formed between the edge portions; - placing the sheet of base material on the surface of the site where the bioreactor is to be provided so that the central portion forms the bottom of the reactor element; - arranging the side portions of the sheet of base material in a substantially upright position, so that the side portions form the side walls of the reactor element. The invention also relates to a reactor element being made of a sheet of base material, the sheet comprising edge portions and a central portion formed between the edge portions, wherein in use the central portion forms the bottom of the reactor element and the side portions extend in a substantially upright position so as to form the side walls of the reactor element.



WO 2009/096773 A1

METHOD OF MANUFACTURING A REACTOR ELEMENT
OF A PHOTO BIOREACTOR, A PHOTO BIOREACTOR AND A REACTOR
ELEMENT THEREFOR

5 The present invention relates to a method of manufacturing a reactor element for receiving a mixture of liquid and phototropic organisms, including (but not limited to) (micro-) algae, the reactor element being part of a photo bioreactor. The invention also relates to a reactor element for a photo bioreactor and to photo bioreactor comprising a plurality of reactor elements.

10 Photo bioreactors are reactors in which phototropic micro-organisms, such as (micro)algae and bacteria, can be cultivated. The micro-organisms are mixed with a liquid, for example water, and introduced into the reactor. In the reactor, the growth of the organisms is stimulated by the addition of carbon dioxide (CO₂) and photosynthesis takes place on account of the light coming into the bioreactor. In this process, various
15 useful substances (biomass) are produced carbon dioxide in energy-rich compositions. It has been known for some years that it is potentially possible to produce biomass by means of photosynthesis techniques. The great significance of the capability of simple micro-organisms, such as algae, to use sunlight and carbon dioxide to produce complex organic substances while releasing oxygen, is also recognized.

20 In addition to carbon dioxide, further nutrients are necessary to stimulate the growth of algae, such as phosphorus (P), nitrogen (N) and certain metals. When growing algae in a bioreactor, it is important to add a suitable amount of nutrients, such as carbon dioxide, phosphorus and nitrogen, to the mixture of algae and water. The nutrients and/or the carbon dioxide are often already available in large amounts as these are, for
25 example, discharged by industrial installations. The required light is normally also freely available, as daylight can be used. However, in certain embodiments artificial light can be used instead thereof or in addition thereto. It is also possible to add the nutrients to the mixture in the bioreactor separately.

 Currently, there are two known basic types of photobioreactors, i.e. bioreactors of
30 the open and of the closed type. Closed photobioreactors are reactors which reduce the exchange of gases, water and contaminants between the culture and the environment,

whereas in the case of open photobioreactors (also referred to as “open pond” systems) the culture is directly exposed to the outside air. Although the bioreactors of the open type can be constructed in a relatively simple and inexpensive manner, there are a number of drawbacks associated with this type of bioreactor. One of the most important
5 drawbacks is the influence of the environment on the culture, such as the influence of temperature fluctuations, contamination of (and from) the air, etc. It has also been found that the physical or chemical parameters for controlling the process of forming the micro-organisms are difficult to adjust, partly due to the relatively large influence of the environmental factors. Compared to photobioreactors of the open type, those of the
10 closed type inter alia have the following advantages: improved control of the culture of micro-organisms due to reduced outside influence; a larger surface-feed ratio; improved control of gas transfer; improved control of the light intensity; reduced evaporation of the medium; even temperature; and better protection against outside influences or contaminations.

15 The above shows that the photobioreactors of the closed type are preferred for producing large amounts of biomass. A particularly effective design for such bioreactors uses a number of elongate tubes in which the organisms (usually algae cells), nutrients, liquid (usually water) and carbon dioxide are circulated, in which case the tubes are transparent in order to maximize the amount of light which reaches the algae. In addition
20 to the transparent tubes, a non-transparent feed tank is also provided which ensures that the algae are also subjected to a so-called dark phase in order to stimulate the more complex protein-forming function of the algae. A stream of nutrients and carbon dioxide is supplied during the dark phase of this process. From time to time, the biomass produced by the bioreactor is removed and processed further.

25 The biomass can be processed in many different ways, depending on the final application. One important application is the conversion of the biomass into biodiesel. To this end, biomass is first dried, for example by first centrifuging it and then allowing it to dry further. The dried biomass is then pressed, which inter alia results in algae oil. This algae oil can be used for producing biodiesel.

30 It is desirable to design reactor elements with a minimal size. It is known that light which enters a reactor element has a specific depth of penetration. The depth of

penetration may, for example, be 40 cm. It is then possible to reactor element that receive a mixture of liquid and phototrophic organisms that is 50 cm or 60 cm in depth. Causing the liquid with organisms in the reactor elements to flow allows them to mix and allows the algae present in the liquid to be exposed to light repeatedly.

5 Closed tubular systems for photobioreactors are costly. The costs for manufacturing the tubes and transporting the tubes to the site where the bioreactor is to be positioned are high. Furthermore, the tubular system needs a specially designed support order to obtain a stable position on the surface of the site.. Further still the time needed for deploying a closed tubular system for for example a one hundred ton
10 production facility is considerable, for instance six months or more.

It is an object of the invention to provide a method of manufacturing a reactor element of a photobioreactor and to provide such photobioreactor at lower costs.

It is a further object of the invention to provide a method of manufacturing a reactor element of a photobioreactor wherein the time for manufacturing such a
15 photobioreactor is reduced.

It is an object of the invention to provide a method of manufacturing a reactor element of a photobioreactor and to provide such photobioreactor wherein less material is used.

Another object is to reduce the complexity of manufacturing a reactor element.

20 According to a first aspect of the invention at least one of the objects is achieved in a method of manufacturing a reactor element for receiving a mixture of liquid and phototropic organisms, including (but not limited to) (micro-) algae, the method comprising:

- 25 - providing a sheet of base material for the reactor element, the sheet having edge portions and a central portion formed between the edge portions;
- placing the sheet of base material on the surface of the site where the bioreactor is to be provided so that the central portion forms the bottom of the reactor element;
- arranging the side portions of the sheet of base material in a substantially upright position, so that the side portions form the side walls of the reactor element.

30 Since the connection between the bottom and the upwardly extending walls is prefabricated, time can be saved when assembling the photobioreactor at the site. Not

only has it become possible to manufacture reactor elements on site, also the base material of the elements may be transported easily and efficiently, for instance after a several flat sheets of base material have been stacked on one another. In a preferred embodiment, however, the sheet of base material is provided as a roll, preferably having the sheets of base material wound around a reel.. Placing the base material then
5 comprises at least partly unrolling the roll of base material on the surface of the site. After unrolling the sheet, the walls are arranged in upright position to form a receptacle for the mixture. In this way the reactor element may be manufactured in a time and costs efficient manner. By providing rolls of material, the transport costs for transporting the
10 base material to the site may be reduced as well. Transport of large rolls of material, comprising for example five hundred meters of sheet of material, are relatively low. Further a roll of material is easily to handle.

According to an embodiment the reactor elements may be formed by positioning the roll at a desired location on the site for forming the reactor element and unwinding
15 the sheet from the roll by rolling the roll with material from a starting point to an end point wherein the reactor element is to be formed in between these two points. Unwinding the material from the roll is combined with placing the reactor element to be formed at a desired surface or location at the site.

According to a further embodiment a suitable length of sheet of material can be
20 taken, for example by cutting, from the roll of material allowing to obtain a reactor element of suitable length at the site. Use of a roll of material has the further advantage of providing a continuous sheet of material that can be cut to a suitable length. The sheet may be an integral piece of material. Costs for e.g. welding different parts together for forming the elongate reactor element are dispensed with or at least may be kept low.

25 The site may be of a type that has been prepared for positioning a photobioreactor, for example by levelling the surface thereof. On top of the levelled surface the roll may be positioned, and a sheet of material may be unwound from the roll in order to obtain a desired length for the reactor element to be formed. The method according the invention allows the positioning of a large piece of material suitable for forming a reactor element
30 at a site, and in particular forming the reactor element at the desired position at the site.

A suitable base material for the reactor element may be a plastic, such as polypropylene, preferable high density polypropylene. The polypropylene may have a thickness of 1 mm up to 5 mm, preferably 1.2 mm to 2.5 mm. Other suitable materials, for instance metals, such as aluminium, and other suitable thicknesses are also conceivable.

5 Although it is possible to form reactor elements having a length that differs from the length of sheet separated from the roll, the length of the reactor element formed using a length of sheets unwound from the roll are generally the same. This allows obtaining reactor elements of considerable length, for example 20 meters, preferably 50 meters of a 100 meters or more from a single sheet of material.

10 In a further embodiment the sheet of base material is formed by extruding the base material. Extrusion of the sheet allows the formation of the sheet at a suitable thickness for each site and preferably allows the extrusion of functional details. In other embodiments of the invention the sheet of material is at least 50 cm wide and preferably at least 50 m long. The surface of the base material have any suitable colour, but
15 preferably is white or black.

 It is preferred to form the reactor element by at least forming a bottom part and an upwardly extending part of the reactor element from the sheet. This allows obtaining a reactor element for a photobioreactor having an open system. The bottom part and side wall are formed from an integral piece of sheet. The sheet of material for the reactor
20 element can be positioned directly on surface, preferably the levelled surface of the site and at least apart of the sheet forms the upwardly extending part of the reactor. This can be a side wall of the reactor element. According to the invention the different parts of the reactor element are formed from an integral piece of material transported to the site in one piece on the roll.

25 It is preferred to form the reactor element by at least bending, for instance by folding, the sheet. Although it is possible to form the bottom part in an upwardly extending part already in a prefabricated way, the method according to further embodiments comprises bending (folding) the sheet after it has been positioned at the site from the roll. Bending at the site according to the invention allows the use of an
30 integral piece of material, the sheet of base material, for forming at least two parts, preferably three parts of the reactor element having different functions, such as the

bottom part for supporting the mixture of liquid and phototrophic organisms, and side walls for forming a receptacle for holding the mixture.

According to another embodiment at least one of the edge portions is formed by a strip extending longitudinally along the central portion of the sheet of base material, so that the strip when arranged in an upright position, forms a longitudinal side wall of the reactor element. In further embodiments two longitudinal side walls are formed by strips extending longitudinally along the central portion, the longitudinal walls being connected by at least one, but in many cases two opposite end walls formed by strips extending transversely along the central portion of the sheet of base material and being arranged in the upright position. In this way an inner space may be defined in which the mixture may be caused to flow.

Arranging the edge elements in an upright position may be performed by properly bending the sheet of base material. In some embodiments bending of the sheet involves folding the sheet along at least one folding line provided in the sheet. In an embodiment the sheet of material is formed having a fold in the sheet in the direction of extrusion (i.e. in the longitudinal direction of the sheet, or in the winding direction of the sheet when it is provided on a roll). The fold will allow the folding of at least a longitudinal part of the sheet. On the one side of the fold a bottom part may be formed of the reactor element, and on the other side of the fold a side wall may be formed that can extend upwardly from the bottom part for forming the receptacle for holding a mixture of liquid and phototrophic organisms. This allows the use of relatively stiff materials for the sheet, for example the plastic material mentioned earlier.

The steps of forming the sheet and providing the fold(s) therein may be performed at the manufacturing plant for production of the sheets and these steps may be carried out before winding the sheet onto the reel and or transporting the sheet to the site. These steps are a part of the prefabrication phase of the sheet. By adjusting steps in the prefabrication of the sheets, considerable costs can be saved when manufacturing the reactor element at the site.

According to yet a further embodiment a part of the sheet can be folded along the length of the sheet, and the sheet can be wound, in the folded condition, upon the reel to form the roll that is transported to the site for forming the reactor element. The folded

part is folded over 180 degrees on top of the part of the sheet that is not folded. This allows the transport of a folded sheet to the site. According to yet a further embodiment a double folded winding the sheet onto the reel. The roll with preformed folded parts can be transported to the site and can be unwound for forming the reactor element.

- 5 Especially the upwardly extending portion of the reactor element may be pre-folded. Only when the folded material has arrived at the site the folded portion(s) of the sheet are folded back partly, preferably to an upwardly extending position from the bottom part, to form the side (end) walls of the reactor element. However, in other embodiments the sheet is kept in a substantially flat condition and in this condition is wound upon the
10 reel.

In a further embodiment the method comprises:

- arranging at least one longitudinal edge portion in upright position to form at least one longitudinal side wall;
- arranging at least one edge portion of an end of the sheet in upright position to
15 form at least one end wall;
- connecting the at least one longitudinal side wall to the end wall.

Connecting the walls may be performed by folding the corner part of the edge portion and end portion of the sheet of base material and by attaching the corner part to either of the portions, for instance by riveting, gluing, clamping, etc. Connecting the
20 walls in this way is fast and efficient and moreover provides for a watertight (mixture tight) coupling between the walls. A further benefit is that by connecting one or more side walls to an end wall, the walls may be maintained in a generally upright position, in some embodiments even without any additional stabilizing support elements. In other
25 embodiments one or more support elements are provided to keep the walls of the reactor element in the generally upright position, not only when the bioreactor is empty, but also when it is filled with the mixture of liquid and phototropic organisms.

In situations wherein providing a further support element is contemplated, use may be made of an elongated support element connecting two opposing side walls of the reactor element. The support element has a length generally corresponding to the width
30 of the bottom part and is attached to the upper edges of both side walls. By making use of the elongated support elements connecting side walls, a tubular form in cross section

is obtained strengthening the construction in both the transverse and longitudinal direction.

The strengthening or connecting element can also be a functional element such as a roof construction. The roof may be attached to the side walls (possibly also to the end wall(s)) and as such provides for a support and stabilization of the walls. Another benefit is that the roof construction enables the bioreactor to be a closed system allowing an improved control of bioreactor parameters such as temperature, inflow of CO₂ or nitrogen, light, pH, etc.

According to yet another embodiment at least two reactor elements are formed from the sheets, and these reactor elements are positioned abreast. In particular when a roll with prefolded side walls is used, the material can be unwound directly abreast an already reactor element, and this will allow obtaining a closely packed system of reactor elements. Preferably the side walls are positioned in abutment with each other. There is no or little space in between the abutting reactor elements. The site is now used to maximum extent.

The method according to another embodiment comprises connecting the two abreast reactor elements by removing (including bending or folding down) part of the abutting side walls. This will create an opening between the two reactor elements allowing a flow of the mixture containing the phototrophic organisms between the at least two reactor elements.

When two adjacent reactor elements are connected to each other preferably a flow guiding element, for instance a flow guiding wall is provided for guiding the circulation of the fluid. The flowing guide elements preferably positioned close to the end part. Such a flow guiding element may reduce friction caused by the change of direction of the flow at the connecting end. According to another embodiment a guide element may take a curved shape to provide for a smooth flow of the mixture.

According to another aspect of the invention a reactor element for receiving a mixture of liquid and phototropic organisms, especially (micro-) algae, is provided, the reactor element being made of a sheet of base material, the sheet comprising edge portions and a central portion formed between the edge portions, wherein in use the

central portion forms the bottom of the reactor element and the side portions extend in a substantially upright position so as to form the side walls of the reactor element.

The reactor element may use a single sheet of material for forming both the bottom part and one or more reactor element walls. At the construction site of the reactor
5 elements, this construction will result in costs and time savings, since the two parts do not have to be connected, e.g. welded together, anymore.

Preferably the reactor element comprises two upwardly extending sidewalls each connected by a fold to the bottom part. The fold allows on the one hand the forming of an integral sheet comprising both the bottom part and the sidewalls, and allows on the
10 other hand forming the sidewalls obliquely or perpendicular with respect to the bottom part. The fold may be prefabricated, reducing the amount of work at the site of manufacturing.

Preferably the reactor element comprises one reinforcing element for reinforcing the upwardly extending sidewalls in the upward position. This can be an anchoring
15 element or an L-shaped hook that can be positioned at intervals over the length of the reactor element on the external or internal sides of the upwardly extending sidewalls.

In another embodiment the upwardly extending sidewalls are connected with a device located at a distance from the bottom part. This allows the reactor element to locally attain a cross section with a substantially tubular shape, which improves the
20 structural strengthening properties of the reactor element.

Preferably the reinforcing element (or support element) is a part of a roof construction of the reactor element. This allows not only formation of a closed system for cultivation of phototrophic organisms, but the arrangement is also strengthening.

According to yet a further embodiment the support element is a flow device for
25 generating a flow of liquid in the reactor element, wherein the flow device can be positioned over the upwardly extending sidewalls. Preferably the flow device is modular flow device. The flow device acts as a clamp surrounding the upwardly extending sidewalls, and can also provide circulation in the mixture of phototrophic organisms received in the reactor element.

30 It is preferred to connect at least two reactor elements to each other and having the two reactor elements positioned in an arrangement of abutting sidewalls of the reactor

elements. A mixture received in between the sidewalls in a reactor element will exert an outwardly directed force on the sidewall, but according to this embodiment, these outward forces are kept to a minimum because of counter force from the abutting other side wall. The outward or external sidewalls of the arrangement of reactor elements can still be provided with an extra strengthening device.

In an embodiment according to the invention at least two reactor elements are connected to each other by a passage formed by removing a part of the respective sidewalls. The passage allows the flow or circulation of the mixture of phototrophic organisms from the one reactor element to the other reactor element. A part of the sidewall can be removed for forming the passage by pivoting the sidewall 90 degrees towards the bottom part, locking the removed part of the sidewall to the bottom part and providing a watertight sealing between the connecting parts of the reactor elements.

According to an embodiment the reactor element comprises a flow guiding element for guiding the mixture flow. The flow guiding element is preferably arranged in a corner of the reactor element so as to provide for a smooth circulation of the mixture (and the phototrophic organisms), for instance from one reactor element to another reactor element through the passage defined between the elements.

Preferably the reactor element comprises at least two flow devices for creating a flow of liquid in the photobioreactor comprising multiple reactor elements, wherein the flow devices are connected to each other by linked axle. This allows use of a single motor or generator for actuation of the flow device, for example a simple paddlewheel.

This application provides a disclosure of several novel elements unknown from prior art. These new elements are described and the advantages of these novel elements will be clear to the skilled person, even if the advantage is not disclosed explicitly. The application could be directed at any of these explicit or implicit novel features according to this disclosure.

Further advantages, characteristics and details of the present invention may also become apparent from the following description of several embodiments thereof. In the description reference is made to the annexed drawings, that show

- Figure 1 a partly taken-away view on perspective of an embodiment of a photobioreactor for growing algae;

- Figure 2 a view in perspective of roll containing a sheet of base material for manufacturing a photobioreactor according to the invention;
- Figure 3A a schematic view in cross-section of a sheet of base material according to an embodiment of the invention;
- 5 - Figure 3A a schematic view in cross-section of a sheet of base material according to an embodiment of the invention, in initial condition;
- Figure 3B a schematic view in cross-section of a sheet of base material according the embodiment of figure 3A, in a condition with the longitudinal edges arranged in a first upright position;
- 10 - Figure 3C a schematic view in cross-section of a sheet of base material according the embodiment of figure 3A, in a condition with the longitudinal edges arranged in a second upright position;
- Figure 3D a schematic view in cross-section of a sheet of base material according to another embodiment of the invention, in initial condition;
- 15 - Figure 3E a schematic view in cross-section of a sheet of base material according the embodiment of figure 3D, in a condition with the longitudinal edges arranged in a first upright position;
- Figure 3F a schematic view in cross-section of a sheet of base material according the embodiment of figure 3D, in a condition with the longitudinal edges arranged in a
- 20 second upright position;
- Figures 4A-4E schematic bottom views in perspective of an embodiment of a reactor element, showing respective manufacturing stages;
- Figure 5 a cross sectional view of a reactor element according to a further embodiment;
- 25 - Figure 6 a cross sectional view of a further embodiment of a reactor element, and
- Figure 7 shows a cross sectional view of a further embodiment of a reactor element.

Figure 1 shows a photobioreactor 1 for the producing of microalgae such as blue-green algae and green algae. Microalgae are microscopic, single-cell plants which grow in a liquid environment. In order to grow, algae use light and specific nutritive

30 substances, chiefly carbon dioxide, soluble nitrogen compounds and phosphate. For the

required light, in practice daylight is generally used, although artificial light can replace or supplement daylight. A small quantity of the microorganisms are mixed with the liquid, for example water, in particular fresh water or seawater. The organisms thrive in this aqueous environment. If use is made of microalgae which utilize the available light and the nutritive substances extremely efficiently, these algae can grow two to more than
5 five times more rapidly than traditional agricultural crops.

Figure 1 shows an embodiment of a photobioreactor 1 in accordance with the invention. The photobioreactor comprises a plurality of reactor elements 2-2^{VI} arranged next to each other and forming a receptacle for a mixture of liquid (for instance water) and phototropic organisms. For clarity reasons the mixture has not been depicted in the
10 figures. In use the mixture will be present (at a liquid level (height) of typically 20-30 cm above the bottom of the reactor element). Also for clarity reasons only a part of the bioreactor is shown. It will be apparent to the skilled person that the end portions of the reactor elements shown in figure 1 are in fact connected to further reactor elements
15 (shown partly in dotted lines) so that a flow space for the mixture is present forming a closed loop. The mixture therefore is able to circulate along the reactor elements of the bioreactor.

Reactor element 2^{IV} is connected to a line 10 which in turn is connected to a feed barrel 11. In the embodiment shown use is made of one single line for output and input
20 of mixture from and to the feed barrel 11. In other embodiments use is made of separate input and output lines. The feed barrel 11 is non-transparent, so the algae located therein are not exposed to daylight. In the feed barrel 11, the mixture of algae and liquid undergoes the aforementioned "dark phase". The feed barrel 11 comprises a number of sensors (not shown) and sensors for measuring the temperature, the electrical
25 conductivity, the pH and the level of the mixture in the barrel. These sensors are connected to an electronic control unit which determines, based on the specific sensor values, whether the algae in the feed barrel 11 require additional nutritive substances and/or carbon dioxide to improve the growth of the algae. If additional nutritive substances and/or carbon dioxide are necessary, the control unit operates one or more
30 pumps provided in a housing 12. The pumps may regulate respectively the pH of the

mixture in the feed barrel 11 and the level of the nutritive substances. The harvesting pump regulates the flow to a filter system (not shown).

A bioreactor element 2 may be manufactured in the following way. Using standard transport means, for instance a truck, one or more rolls 14 (cf. figure 2) of sheet base material is supplied and positioned on the surface (S) of the area or site where the
5 bioreactor is to be provided. The sheet is positioned by unwinding the roll 14 until the desired length of the reactor element is reached. The unwound sheet is then cut from the roll and the roll is transported to another position to place a further piece of sheet material on the surface (S) to manufacture the next reactor element, for instance the
10 element 2¹ parallel to the first reactor element 2.

The sheet of base material comprises a central portion 4 and two edge portions 5 and 6 along the longitudinal edges of the sheet. The central portion 4 is integrally formed with edge portions 4,5. Between the central portion 4 and the edge portions 5,6 a folding line 12,12 is present, as can be derived from figures 2 and 3A.

15 Once the sheet of base material has been properly placed on the surface (S), the edge parts 5,6 are folded upwardly along the folding lines 12,13 to the position shown in figure 3B (angle α between 20 and 160 degrees, preferably between 70 and 110 degrees, most preferably about 90 degrees, as shown in figure 3C). The folded edge parts 5,6 may form the side walls of the reactor element 2.

20 In another embodiment the sheet base material has been wound upon a reel in a folded situation, i.e. a situation wherein the longitudinal edge portions 5,6 have been folded. Figure 3D then shows the sheet base material just after it has been unloaded from the means of transport and has been placed at the proper position on the surface (S) of the site. One of the advantages of transporting the sheet on a roll in a folded position is
25 that the width of the roll can be reduced. Similarly as described in connection with figures 3A-3C the edge portions 5,6 may be folded back to an upright position, as for instance is shown in figures 3E and 3F.

Referring to figure 4A, a further edge portion 7, extending transversely to the longitudinal edge portions 5,6, may be formed at the begin portion and end portion of
30 the sheet. Between the edge portion 7 and the central portion 4 a folding line 9 is formed. Edge portion 7 may be folded upwardly or downwardly (in the orientation

shown in figures 4B-4E). In practical situations the edge portion will be folded upwardly since the central portion has been placed on the surface of the site. However, for easy of description the orientation is different in figures 4B-4E. The corner portion 8 between the edge portion 7 and a edge portion 5 or 6 is provided with further folding lines 30, 31 and 32, so that at the corners the side portions may be connected easily and firmly to one another, as is shown in figures 4C-4E. The described connection between the longitudinal edge portions 5,6 and the transversal portion 7 can be made watertight.

Figure 5 shows a cross section of a further reactor element 42. The reactor element 42 according extends in a longitudinal direction and is formed from a elongated sheet. The sheet is formed into a receptacle having a bottom part 43 positioned on a levelled surface 44 at a site for a bioreactor. Upwardly extending walls 45,46 are formed from the sheet by bending the side panels of the sheet upright under an angle of approximately 90 degrees as shown in the cross section.

The plastic sheet can be any suitable plastic, such as polypropylene or polyethylene, or metal, for instance aluminium.

The so formed receptacle is able to receive a mixture of liquid containing phototrophic organisms. Figure 5 shows the level 47 of the surface of the mixture contained in the reactor element 42. The level 47 can be 15 cm – 60 cm, preferably approximately 25-40 cm, from the bottom part 42. The side panels 45,46 can have a length of approximately 10 cm higher than the surface 47.

The cross section of the reactor element 42 is such that it allows for a proper circulation of the mixture.

Figure 5 shows another embodiment of the invention of the so called closed system type. A roof construction 49 is arranged over the open side of the reactor element 42 formed from a sheet. The roof construction 49 comprises according to this embodiment a polycarbonate sheet having at least three bending points 35-37. A sheet of transparent material is transported to the site and is formed according to the cross section as shown in Figure 5. At least three longitudinal folds are formed in order to obtain the cross section according to figure 5. This allows the formation of a roof having a top ridge 36 and two lateral extending roof parts 50,51 towards side folds 35,37. This closed

system gives protection to the mixture contained in the reactor element 42 from precipitation and other external influences.

From folds 35,37 a side panel extends toward the surface 44 having two anchoring parts 53,54 formed at the ends. A suitable anchor can be used to obtain a rigid ground connection to the surface 44. This secures the roof construction 49 to the ground. A further connection 38 can be formed in order to connect the roof construction 49 to the sheet, in particular to the side panels 45,46. A suitable connection such a penetrating connection including a bolt or other suitable connector can be used to form a secure connection. The weight of the reactor element 42 can be used to secure the roof construction against storms.

Figure 6 shows a cross section of a further embodiment. Reactor element 60 comprises a single sheet for integrally forming a closed system for a photo bioreactor. Two side panels 62,63 of the sheet adjacent to the central bottom part 61 are bended towards each other over an angle of more than 90 degree and are connected to each other using a suitable connector 64 connecting the end part 65 of the sheet. If a more flexible material is used for the sheet the triangular form according to the cross section could be lost, without losing the benefits of the invention. A sheet of transparent material is used for forming the reactor element. Although this embodiment is less efficient in use of the surface at the site, a higher surface level of the liquid can be used, since more surface is exposed to incoming sun light.

Figure 7 shows a further embodiment of a reactor element 67. Now the side wall 70 of the receptacle 69 for receiving the phototrophic mixture are formed from parts of a sheet more internal to the middle of the sheet forming the bottom part 68. Further side walls 70 can be secured to the ground using the outside flap 71.

Referring to figure 1, the corners in the flow space of the reactor elements is provided with a plurality of curved guiding walls 15. The curvature of the guiding walls 15 is set so as to ensure a smooth flow of the mixture from one reactor element to the other.

Also referring to figure 1, the reactor elements 2 and 2^{II} have been provided with a number of rotating blades 22 of pumps 20 arranged in a housing 21 and driven by an electric motor. The rotating blades cause the mixture to flow in a desired direction.

The housing 21 is arranged between the side walls of the abutting reactor elements and function as support elements for keeping the side walls in the upright position. The pump provided in the first reactor element 2 is driven directly by an electric motor (not shown) in the housing, while the pump in the further reactor element 2^{II} is driven by a common axle 23 connected between both pumps 20. Also the axle 23 will maintain a fixed distance between the housings and as a consequence will support the support function of the housing.

The passages between neighbouring reactor elements may formed by folding down parts of the side walls (cf. the side walls between reactor elements 2 and 2^I) or by completely removing parts of the side walls (cf. the side walls between reactor element 2^I and 2^{II}).

Although the invention has been described with reference to specific embodiments thereof, it will be appreciated that invention is not limited to these embodiments and that changes and modifications to the system and method described herein may be made without departing from the invention. The rights applied for are defined by the appended claims.

NEW CLAIMS

1. Method of manufacturing a reactor element for receiving a mixture of liquid and phototropic organisms, especially (micro-) algae, the reactor element being part of a photo bioreactor, the method comprising:

- providing a sheet of base material for the reactor element, the sheet having edge portions and a central portion formed between the edge portions;

- placing the sheet of base material on the surface of the site where the bioreactor is to be provided so that the central portion forms the bottom of the reactor element;

- arranging the side portions of the sheet of base material in a substantially upright position, so that the side portions form the side walls of the reactor element.

2. Method according to claim 1, wherein the sheet of base material is provided as a roll of base material and wherein placing the base material comprises at least partly unrolling the roll of base material on the surface of the site.

3. Method according to claim 1, wherein at least one of the edge portions is formed by a strip extending longitudinally along the central portion of the sheet of base material.

4. Method according to claim 3, wherein two edge portions are formed by strips extending longitudinally along the central portion and at least one further edge portions is formed by a strip extending transversely along the central portion of the sheet of base material.

5. Method according to claim 1, wherein arranging an edge element in an upright position comprises bending the sheet of base material.

6. Method according to claim 5, wherein bending the sheet comprises folding the sheet along at least one folding line provided in the sheet.

7. Method according to any of the preceding claims, wherein forming the reactor element comprises forming the reactor element as a receptacle for holding the mixture.

8. Method according to any of the preceding claims, wherein forming the part of the reactor element comprises unwinding a length of base material from a roll of base material and forming a reactor element generally having said length.

5 9. Method according to any of the preceding claims, wherein the sheet is formed by extruding the base material.

10 10. Method according to any of the preceding claims, wherein forming the sheet of base material for the roll comprises forming at least one fold in the sheet.

11. Method according to claim 10, wherein the at least one fold is formed by combined local heating and compression of the base material along a line.

15 12. Method according to any of the preceding claims, wherein providing a sheet of base material comprises folding the sheet along the length of the sheet and winding the folded sheet to form the roll.

13. Method according to any of the preceding claims, comprising:

- 20 - arranging at least one longitudinal edge portion in upright position to form at least one longitudinal side wall;
- arranging at least one edge portion of an end of the sheet in upright position to form at least one end wall;
- connecting the at least one longitudinal side wall to the end wall.

25 14. Method according to claim 13, wherein connecting walls comprises folding the corner part of the edge portion and end portion and attaching the corner part to either of the portions.

30 15. Method according to any of the preceding claims, wherein the method comprises forming at least two reactor elements from sheets and positioning the reactor elements abreast at the site.

16. Method according to claim 15, wherein the reactor elements are formed with upward extending side walls and wherein positioning the reactor elements abreast comprise positioning the side walls in abutment.

5 17. Method according to claim 16, wherein the method further comprises connecting the two abreast reactor elements by partly removing abutting side walls.

10 18. Method according to claim 17, wherein removing a part of the side walls comprises arranging said part in a substantially lying position on top of or beneath the bottom part.

19. Method according to any of the claims 15-18, the method further comprising forming a string of connected reactor elements for enabling a fluid circulation therein.

15 20. Method according to any of the preceding claims, wherein the method further comprises forming an end part at at least one end of the sheet by bending a transverse part of the sheet so that it extends vertically.

20 21. Method according to any of the preceding claims, wherein two end parts are connected to each other and wherein a flow guiding wall is provided in the end parts for guiding the circulation of fluid.

25 22. Reactor element for receiving a mixture of liquid and phototropic organisms, especially (micro-) algae, the reactor element being part of a photo bioreactor, the reactor element being made of a sheet of base material, the sheet comprising edge portions and a central portion formed between the edge portions, wherein in use the central portion forms the bottom of the reactor element and the side portions extend in a substantially upright position so as to form the side walls of the reactor element.

30 23. Reactor element according to claim 22, wherein at least one of the edge portions is formed by a strip extending longitudinally along the central portion of the sheet of base material.

24. Reactor element according to claim 23, wherein two edge portions are formed by strips extending longitudinally along the central portion and at least one further edge portions is formed by a strip extending transversely along the central portion of the sheet of base material.

5

25. Reactor element according to claim 22, wherein the sheet of base material comprises a bend between an edge element and the central portion so as to arrange the edge element in an upright position.

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26. Reactor element according claim 22, wherein the sheet of base material comprises one or more folding lines along which the one or more edge elements are foldable.

27. Reactor element according to claim 22, wherein the reactor element comprises two upwardly extending side walls each connected by a fold to the bottom part.

15

28. Reactor element according to claim 22, wherein the reactor element comprises at least one reinforcing element for reinforcing the upwardly extending side wall in an upward position.

20

29. Reactor element according to claim 20, wherein the reinforcing element connects the upwardly extending side walls at a distance from the bottom part.

30. Reactor element according to claim 29, wherein the reinforcing element is part of a roof construction for the reactor element.

25

31. Reactor element according to claim 29 or 30, wherein the reinforcing element is formed by a modular flow device for generating a flow of liquid in the reactor element, wherein the modular device is positionable over the upwardly extending side walls.

30

32. Reactor element according to any of the claims 22-31, wherein at least two reactor elements are connected to each other and wherein the side walls of the reactor elements are arranged in abutment.

33. Reactor element according to any of the claims 22-32, wherein the flow spaces of at least two reactor elements are connected to each other by a passage formed by removing parts of the side walls.

5 34. Reactor element according to claim 33, wherein the removed parts of the side walls are parts of the side walls that have been arranged in a lying position on top of or beneath the bottom portion.

10 35. Reactor element according to any of claims 22-34, wherein the reactor element comprises a flow guiding element for guiding the mixture flow.

15 36. Reactor element according to any of the claims 22-35, wherein the reactor elements comprises at least two flow devices for creating a mixture flow in the reactor element, wherein the flow devices are connected to each other by a linked axle.

37. Reactor element as claimed in any of claims 22-36, comprising two opposing side walls and two opposing end walls, the end walls being connected to both side walls so as to provide a substantially mixture tight receptacle for the mixture.

20 38. Photobioreactor comprising a number of connected reactor elements according to any of the claims 22-37.

25 39. Method according to any of claims 1-21, wherein at least one reactor element according to any of claims 22-38 is used.

40. Method of manufacturing a reactor element for receiving a mixture of liquid and phototropic organisms, especially (micro-) algae, the reactor element being part of a photobioreactor, the method comprising:

- 30
- providing a sheet of base material for the reactor element, the sheet having edge portions and a central portion formed between the edge portions;
 - placing the sheet of base material on the surface of the site where the bioreactor is to be provided and forming the reactor element;

wherein the sheet of base material is provided as a roll of base material and wherein placing the base material comprises at least partly unrolling the roll of base material on the surface of the site.

- 5 41. Method according to claim 40 and any of claims 1-22.

Fig 2

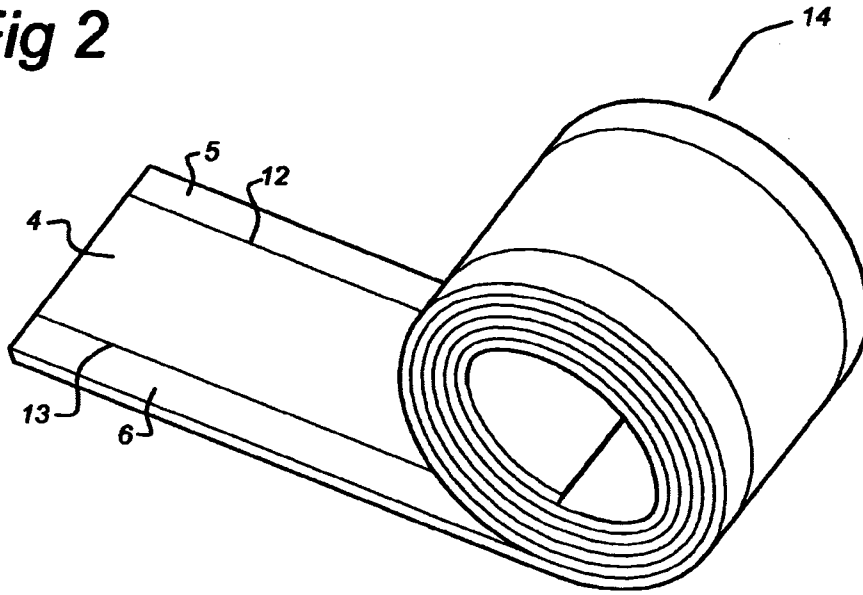


Fig 3a

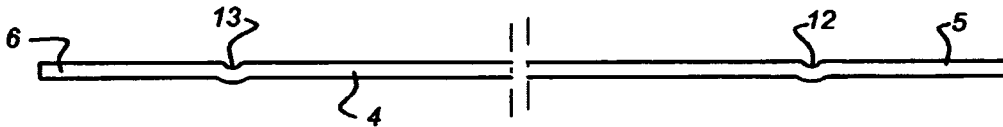


Fig 3b

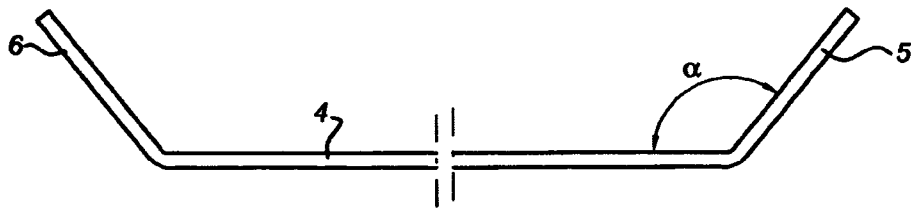


Fig 3c

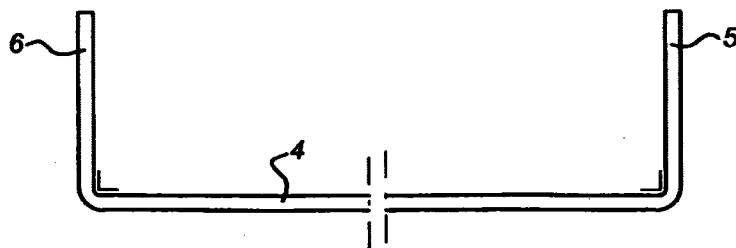


Fig 3d

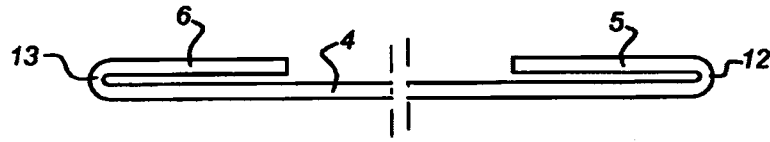


Fig 3e

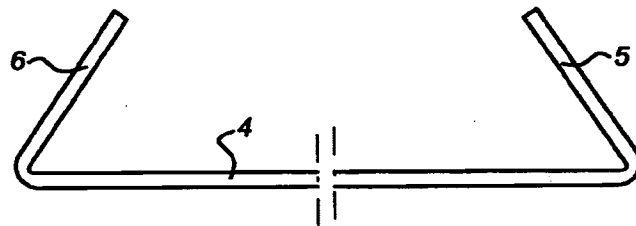


Fig 3f

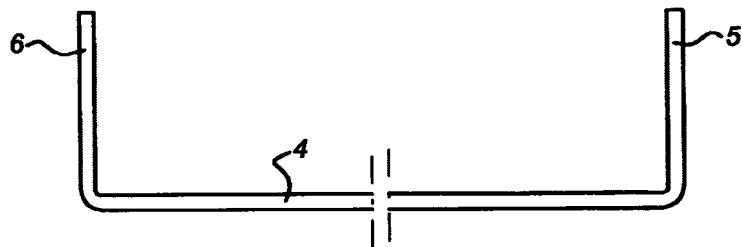


Fig 4a

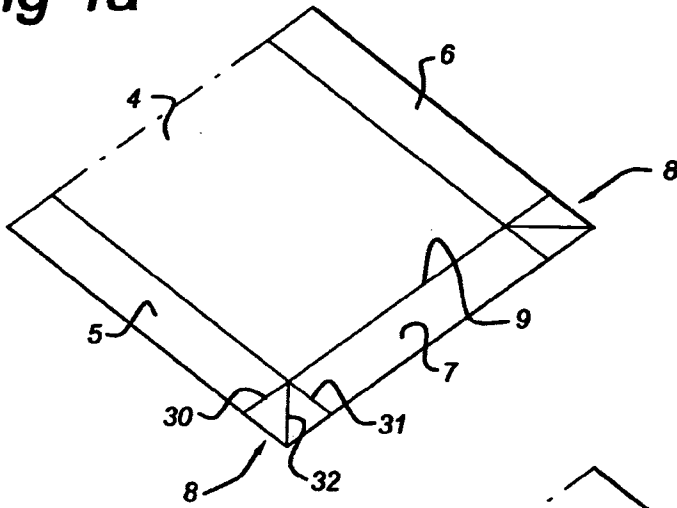


Fig 4b

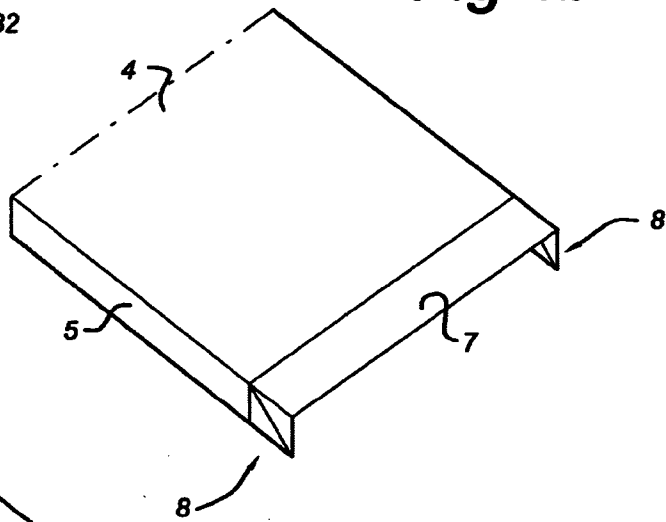
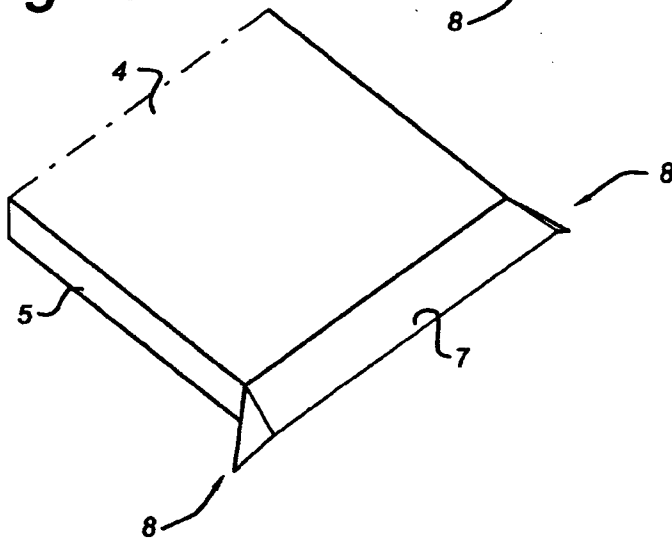


Fig 4c



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Fig 4d

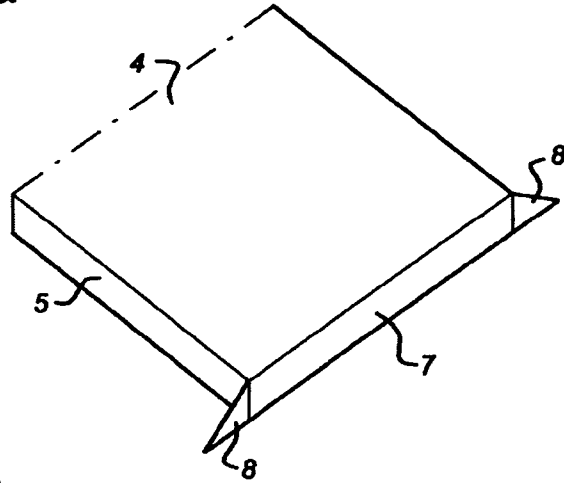


Fig 4e

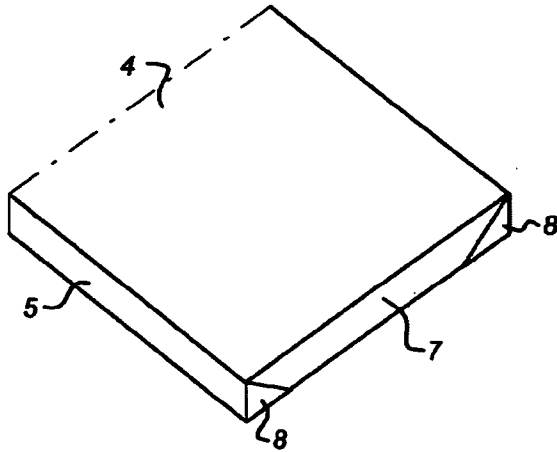
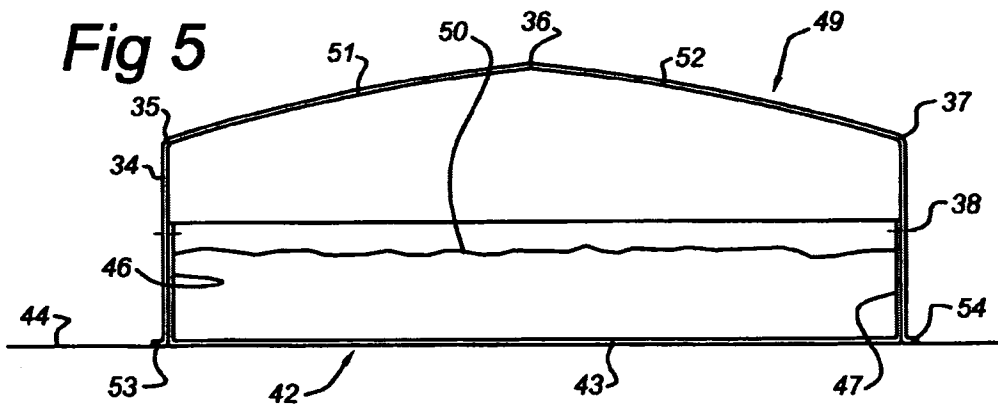
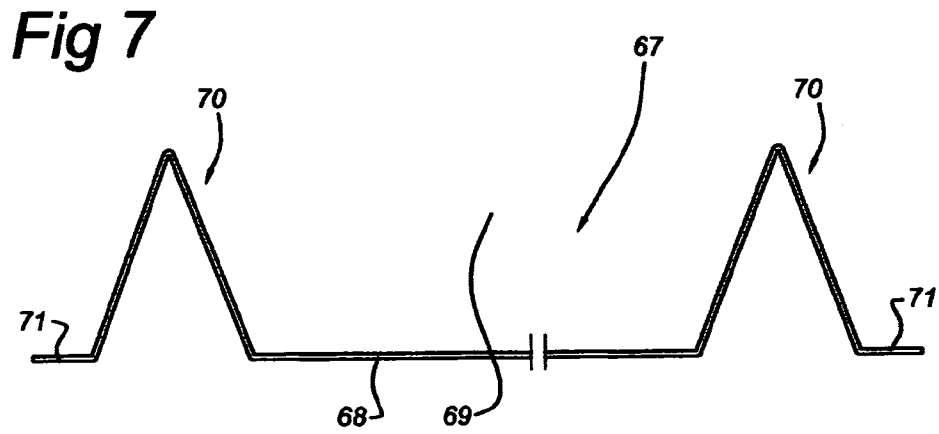
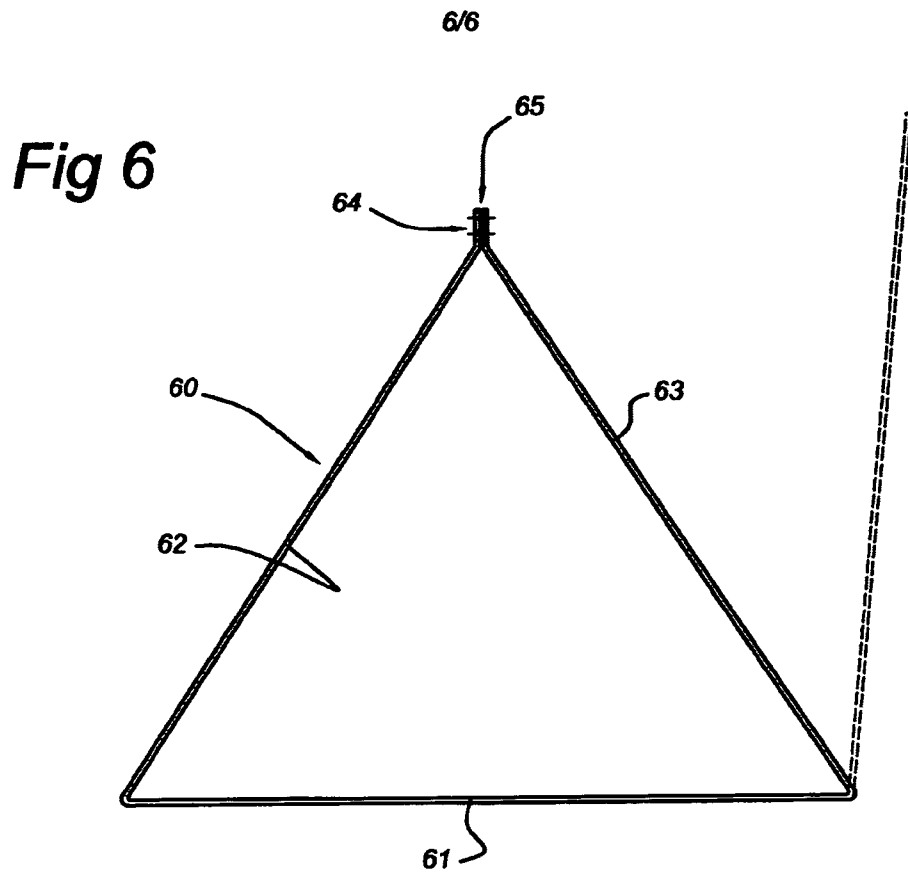


Fig 5





INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2008/050061

A. CLASSIFICATION OF SUBJECT MATTER
INV. C12M1/00

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)
C12M C12N A01G A01H

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/26452 A (CONNOLLY MICHAEL [IE]) 19 April 2001 (2001-04-19) page 2, line 26 - line 29 page 11, line 14 - line 23 page 12, line 1 - line 13 page 13, line 1 - line 10 page 13, line 30 - page 14, line 15 figures 1-4 -----	1-41
X	US 2 732 663 A (DEWEY II) 31 January 1956 (1956-01-31) column 1, line 15 - line 23 column 2, line 65 - column 4, line 20 figures 1-6 -----	1-41
A	US 5 988 422 A (VALLOT BERNARD [FR]) 23 November 1999 (1999-11-23) column 3, line 47 - column 7, line 5 figures 3-5 -----	1-41

Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search

30 October 2008

Date of mailing of the international search report

07/11/2008

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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