

Description

The present invention relates to an apparatus for photosynthesis comprising a reaction bath means for causing a photosynthetic reaction therein and a plurality of narrow tubular photoradiators arranged upright in said reaction both parallel to each other, each of said filter radiators being constructed to radiate light which propagates therethrough. An apparatus of this type is known in the art and is depicted in figures 1, 2 and 3. Photosynthetic apparatuses heretofore proposed include an apparatus for culturing chlorella (unicellular microorganism containing chlorophyll). Difficulty experienced in culturing chlorella is that illumination with intensities higher than a certain level destroys the chlorophyll and produces a toxin (phaeophobite) while illumination with intensities lower than a certain level fails to cause photosynthesis altogether. It is therefore a primary requisite for effective photosynthesis that all the cells containing a photosynthetic substance be constantly supplied with light in even distribution. An ideal situation is, therefore, that a photosynthetic substance be passed through a very narrow clearance while a predetermined intensity of light is directed perpendicular to the clearance. Then, sufficient light will be evenly applied to all the cells containing the photosynthetic substance with a minimum of attenuation and without any change in its wavelength component. Meanwhile even supply of a sufficient amount of CO₂ all over the reaction bath is essential in attempting efficient photosynthesis.

The applicant has proposed an apparatus for photosynthetic reaction in various forms contemplated to implement the demands discussed above. The present invention constitutes a further improvement over the precedent implementations.

It is an object of the present invention to provide an apparatus for photosynthesis which effectively supplies light into a reaction bath for photosynthetic reactions and which is able to communicate CO₂ containing air to a reaction bath in a sure and stable manner and to provide an apparatus which is furnished with a simple and economical device for producing CO₂.

This task is solved with an apparatus of the type stated above, which is characterised in that said reaction bath means comprising an inner transparent wall and an outer transparent wall surrounding and spaced from said inner transparent wall to define an annular space between the inner and the outer transparent walls, the inner and outer transparent walls being generally vertically disposed, that a light source is positioned radially inwardly in the inner wall, and that photoradiators are arranged in the annular space between the inner and outer transparent wall and that a disc rotatable in a horizontal plane below the reac-

tion bath means is provided and is positioned perpendicular to the photoradiators to eject jets of carbon dioxide-containing air into the annular space.

In accordance with the present invention, an apparatus for photosynthesis includes a unique arrangement for supplying light and CO₂-containing air to a reaction chamber in a sure and stable manner. The reaction chamber is irradiated for photosynthesis from the inside and/or outside thereof in an intermittent mode. CO₂-containing air is routed from a CO₂ source to a rotatable disc which is positioned in a bottom portion of the apparatus. Part of the CO₂-containing air is ejected sideways from the disc to cause it to rotate while the rest of the air is ejected upwardly into the reaction chamber. The reaction chamber is partitioned into a plurality of compartments which are sequentially supplied with the CO₂-containing air in accordance with the rotation of the disc.

The above and other objects, features and advantages of the present invention will become apparent from the following detailed description taken with the accompanying drawings.

Brief description of the drawings

Figure 1 is a sectional side elevation of a prior art apparatus for photosynthesis;

Figure 2 is a section along line II—II of Figure 1;

Figure 3 is a section along line III—III of Figure 1;

Figure 4 is a fragmentary section of another prior art apparatus for photosynthesis;

Figure 5 is a section along line V—V of Figure 4;

Figure 6 is a schematic perspective view of an apparatus for photosynthesis embodying the present invention;

Figure 7 is a sectional side elevation of the apparatus shown in Figure 6;

Figure 8 is a section along line VIII—VIII of Figure 7;

Figure 9 is a fragmentary sectional plan view of a modification to the embodiment shown in Figures 6—8;

Figure 10 is a sectional plan view of another embodiment of the present invention;

Figure 11 is a fragmentary section of another embodiment of the present invention;

Figure 12 is a plan view as seen in a direction XII—XII;

Figure 13 is a fragmentary section of a modification to the construction shown in Figures 11 and 12;

Figure 14 is a fragmentary section of another embodiment of the present invention;

Figure 15 is an exploded view of the embodiment shown in Figure 14; and

Figure 16 is a schematic view of a device for producing CO₂-containing air associated with the apparatus of the present invention.

Description of the preferred embodiments

While the apparatus for photosynthesis of the present invention is susceptible of numerous physical embodiments, depending upon the environment and requirements of use, substantial numbers of the herein shown and described embodiments have been made, tested and used, and all have performed in an eminently satisfactory manner.

To facilitate understanding of the present invention, a reference will be made to a prior art apparatus for photosynthesis which the applicant has proposed.

Referring to Figures 1—3, the apparatus includes a reaction bath generally designated by the reference numeral 10. A number of photoradiators 12 in the form of narrow tubes are arranged upright and in parallel with each other within the reaction bath 10. Each of the photoradiators 12 is rigidly fitted in a short tube 14 at its lower end in a fluid tight manner. The photoradiator 12 comprises a transparent tube or sheath 16, an optical rod 18 and a mirror 20 located at a lower end portion of each photoradiator 12. A lid 22 removably covers the top of the reaction bath 10 and has threaded openings 22a in which threaded upper portions 16a of the respective tubes 16 are engaged. Thus, when the lid 22 is removed from the reaction bath 10, it is accompanied by the photoradiators 12 to facilitate cleaning of the reaction bath 10 or the photoradiators 12. Fiber optic cables 24 are in threaded engagement respectively with the upper end of the threaded portions 16a of the tubes 16 at their light output ends. In this position of each cable 24, its optical fiber 24a is aligned at its end with the end of the optical rod 18 in the associated photoradiator 12, so that the light propagating through the optical fiber 24a is effectively transferred to the optical rod 18.

Each optical rod 18 is made of quartz, plastics or the like. The rod 18 carries thereon a light diffusing material 18a at desired spaced locations along its length. The light diffusing material 18a has a refractive index which is larger than that of quartz or plastics, thereby causing the light to break through the material 18a out of the rod 18.

A conduit 26 is communicated with the reaction bath 10 to supply CO₂-containing air therein. As shown in Figure 3, the short tubes 14 in which the lower ends of the photoradiators 12 are fitted are bonded together at their outer surfaces while defining gaps 28 therebetween. The gaps 28 are stopped up in a central area of the reaction bath 10 (black gaps 28 in Figure 3). CO₂-containing air fed into the reaction bath 10 by the conduit 26 flows through the open gaps 28 adjacent to the periphery of the bath 10, advances upward through the spaces between the photoradiators 12 as indicated by arrow A in Figure 1, flows toward the center of the bath 10 at the upper end of the latter, flows down along the center as indicated by arrows B, and is then redirected by the closed gaps 28 in the central area toward the periphery of the reaction bath 10, thus recirculat-

ing within the reaction bath 10. With this arrangement, the recirculating air moves at a substantial velocity along the outer periphery of each photoradiator 12 while entraining the culture medium, thereby preventing the photosynthetic substance from becoming deposited on the photoradiators 12. This frees the output light of the photoradiators 12 from interception to thereby supply all the photosynthetic substance with optical energy and CO₂ each in an even distribution.

It will be seen in the above construction that, if the area is made smaller at the region where the air flows downward than at the region where the air flows upward, the velocity of water will be increased at the downward flow region to minimize contamination to the photoradiators 12 in this region. While the gaps 28 in the central area of the bath 10 are stopped up, those in the peripheral area may be stopped up instead.

An auxiliary bath 280 is mounted on an upper side portion of the reaction bath 10 and communicated with the latter through openings 30 and 32 which are located one above the other. A valve 34 is positioned in the vicinity of the lower end of the auxiliary bath 280 so as to discharge the product of photosynthesis from the apparatus. A second valve 36 is mounted on the top of the auxiliary bath 280. This valve 36 is operable to supplement the culture medium and pH control solution to make up for the shortage which results from the discharge of the product through the valve 34. A third valve 38 is mounted on an upper side portion of the auxiliary bath 280 in order to controllably let the air out of the reaction bath 10 to control the pressure inside the reaction bath 10. Where use is made of a pressure regulating valve as the valve 38 for automatically controlling the bath pressure to a reference level, the CO₂ concentration in the water can be increased to promote photosynthesis and, at the same time, the pressure in the reaction bath 10 is prevented from lowering to change CO₂ into M⁺HCO₃⁻. Disposed inside the auxiliary bath 280 are various instruments 40 for monitoring the photosynthetic reaction in the reaction bath 10, e.g. thermometer, pressure gauge, pH meter and densitometer. The conditions inside the reaction bath 10 are so controlled as to effect photosynthesis in an optimum manner in response to outputs of such instruments. For example, the temperature in the reaction bath 10 may be controlled by controlling a heat generating/absorbing device 42 which is positioned in the auxiliary bath 280. Also, the outputs of the instruments are processed to notify the timing to collect the product.

As long as the photosynthetic reaction is to be carried out without interruption, the product will be collected through the auxiliary bath 280. When interruption of the reaction is permissible, the end (not shown) of the conduit 26 may be communicated to a vacuum source (not shown) or the like instead of the CO₂-containing air supply, so that the product can be controlled through the conduit 26.

Another apparatus the applicant has proposed

is shown in Figures 4 and 5. In these drawings, the same structural elements as those shown in Figures 1—3 are designated by the same reference numerals. The conduit 26 (Figure 1) has an extension 26' which protrudes into the reaction bath 10 to a position below the photoradiators 12. The conduit extension 26' is shaped at its upper end portion to have an axial passageway 26'a and a plurality of radial passageways 26'b which extend obliquely and radially outwardly from the axial passageway 26'a. A rotor 56 is movably coupled over the top of the conduit extension 26'. The rotor 56 is formed with passageways 58 and a plurality of air ejection ports 60 which extend throughout the rotor 56 from each of the passageways 58, as illustrated.

In operation, air fed through the axial passageway 26'a of the conduit extension 26' is discharged from the radial passageways 26'b to impinge on side wall portions 58a of the respective passageways 58 and 58b, thereby giving the rotor 56 the tendency to rotate clockwise as indicated by arrows R in Figure 5. The air passed through the passageways 58 are ejected from the ejection ports 60 to drive the rotor 56 in the direction R. The rotor 56 is caused to float by the air coming out through the upper end of the axial passageway 26'a of the conduit extension 26', a clearance d_1 thus developing between the upper end of the conduit extension 26' and the rotor 56. This part of the air, therefore, flows radially outward through the clearance d_1 as indicated by arrows in Figure 4. Meanwhile, the air flowing through the gap d_1 and the air discharged from the radial passageways 26'b is partly routed through an annular clearance d_2 between the outer surface of the conduit extension 26' and the inner wall of the rotor 56 into a clearance d_3 between the bottom of the rotor 56 and the bottom of the reaction bath 10. As a result, the air streams in the clearance d_1 and d_3 serve as an air cushion for supporting the rotor 56 while the air stream in the clearance d_2 functions as an air bearing for rotatably supporting the rotor 56. The major torque acting on the rotor 56 is created by the air jets from the ejection ports 60. If desired, the rotor 56 may be formed with a through upward passageway 62 to pass the air into a clearance d_4 between the bottoms of the photoradiators 12 and the top of the rotor 56. The air stream in this clearance d_4 will more effectively air-cushion the rotor 56 in cooperation with the other air streams.

Referring to Figures 6—8, an apparatus for photosynthesis embodying the present invention is shown and includes a reaction bath 100. The reaction bath 100 is defined by an inner transparent wall 100a and an outer transparent wall 100b which surrounds the inner wall 100a. A number of photoradiators 102 are arranged side by side in the generally annular space defined between the inner and outer transparent walls 100a and 100b. Each photoradiator 102 is constructed essentially in the same manner as the photoradiators of the prior art apparatuses. A

light source or lamp 104 is disposed at the center of the reaction bath, i.e., inwardly of the inner wall 100a, parallel to the photoradiators 102. In this construction, light emanating from the lamp 104 will be transmitted through the inner transparent wall 100a into the reaction bath 100 to cause photosynthetic reactions of a desired substance to occur therein.

Concerning the lamp 104, it may comprise a fluorescent lamp or a xenon lamp by way of example. Where a xenon lamp is selected, it is a primary requisite to prevent ultraviolet and infrared rays issuing from the lamp from entering the reaction bath. An implementation available for intercepting such undesired rays is, as shown in Figure 9, disposing coaxial inner and outer tubes 106a and 106b around the lamp 104, and filling the annular space 108 between the tubes 106a and 106b with water or the like. The tubes 106a and 106b are commonly made of a transparent material which does not transmit ultraviolet rays. The water 108 serves to absorb infrared rays.

If necessary, the reaction bath 100 may be designed for outdoor use or the lamp 104 may be positioned outwardly of the outer wall 100b. In such a case, even the light from the external light source such as the sun will be transmitted through the outer wall 100b into the reaction bath 100 contributing to the photosynthetic reaction. The availability of light from both the inside and outside of the reaction bath for photosynthetic reactions is desirable from an efficiency standpoint.

The reaction bath 100 may be supplied with CO_2 -containing air by the same construction which has been discussed with reference to Figures 4 and 5. As shown, the CO_2 -containing air supply arrangement is disposed below the reaction bath 100 and includes the conduit 26 with the axial passageway 62 and the rotor 56 with the ejection ports 60. The rest of the construction is similar to that of the prior art ones and, therefore, the same structural elements thereof are designated by the same reference numerals.

As well known in the art, it is desirable for efficient photosynthesis that a photosynthetic reaction occur in an intermittent manner rather than continuous one. A modification to the reaction bath 100 is shown in Figure 10 which is designed to meet such a demand.

Referring to Figure 10, the modified reaction bath, generally 110, comprises an inner wall 110a and an outer wall 110b which cooperate to define a generally annular space therebetween. The space between the walls 110a and 110b is divided into a plurality of compartments A, B, C, D, E and F by partitions 112 which are individually reflective for light. Each partition 112 is made up of two transparent plates 114 and 116, and a reflective layer 118 held between the transparent plates 114 and 116 to furnish the partition 112 with reflectivity. A plurality of photoradiators 102 are arranged side by side in each of the compartments A—F.

With the construction shown in Figure 10, the apparatus is capable of promoting efficient use of

light reached the reaction bath for photosynthesis. An arrangement may be made such that the photosynthetic reaction occurs in some of the chambers A—F and not in the others (interruption of the supply of light and CO₂-containing air), the reacting and non-reacting chambers being sequentially switched. The adjacent compartments A—F may be intercommunicated at upper and lower portions thereof so that in any of the compartments which the rotor 56 has reached the culture medium and CO₂ are moved upwardly and then downwardly via the adjacent compartment. This will insure smooth circulation of the culture medium and CO₂.

Although the particular construction of the partition 112 shown and described is only illustrative, such is advantageous over others due to the greater ease of production, capability of preventing the reflective layer from being damaged by the culture medium or the like, and, therefore, significant durability.

Referring to Figures 11 and 12, another embodiment of the present invention is shown. The apparatus in Figures 11 and 12 includes a rotatable disc 120 formed with horizontal air ejection passageways 122 and 124 and vertical air ejection passageways 126 and 128. The disc 120 is born and cushioned by CO₂-containing air which is fed under pressure to a conduit 130, which is configured similarly to previously mentioned conduit 26'. The illustrated construction of the apparatus above the disc 120 is essentially the same as the construction of the prior art apparatus and, therefore, the same structural elements are designated by the same reference numerals. The disc 120 is rotated as indicated by an arrow R in Figure 12 by the jets of air ejected from the passageways 122 and 124 while, at the same time, the air ejected from the vertical passageways 126 and 128 is routed into the reaction bath through the gaps between the adjacent photoradiators 12.

The disc 120 is advantageous over the prior art rectangular rotor 56 because it maintains the whole arrangement in a well-balanced condition and promotes positive and stable supply of CO₂-containing air into the reaction bath. Also, the disc 120 serves to effectively dissipate the culture medium from therebelow toward the reaction bath. The upper part of the apparatus including the reaction bath and the lower part including the disc may be detachably assembled as illustrated, so that the apparatus may be readily produced and maintained.

A modification to the apparatus described with reference to Figures 11 and 12 is shown in Figure 13. A characteristic feature of the modified apparatus is that the rotary disc 120 is supported by the conduit 130 through an air-tight bearing 132. Such a bearing construction will add to the stability of rotation of the disc 120.

Referring to Figures 14 and 15, another embodiment of the present invention is shown which includes the disc support construction shown in Figure 13 and a unique conduitwork for the supply of CO₂-containing air from the disc 120 to

the reaction bath. In Figures 14 and 15, the same or similar structural elements as those of the previous embodiments are designated by the same reference numerals.

In Figures 14 and 15, the apparatus comprises a plate 140 formed with apertures 142 at predetermined positions which will be described, and tubes 144 adapted to respectively connect the apertures 142 in the plate 140 to the gaps 28 (Figure 3) between the adjacent photoradiators. The disc 120 is located below the apertured plate 140 and rotatably supported by the fluid-tight bearing 132.

As shown in detail in Figure 15, a plurality of radial arrays of apertures 142 are positioned in the plate 140 such that the apertures 142 in each radial array are registered with those in the other arrays on concentric circles. Each aperture 142 is communicated to a gap 28 between adjacent photoradiators by one of the tubes 144. Further, the apertures 142 in each radial array are located such that they will register with the vertical passageways 126 or 128 in the disc 120 when the latter arrive thereat.

In the construction shown in Figures 14 and 15, the disc 120 rotating in a predetermined direction brings its vertical passageways 126 and 128 into register with the aperture arrays sequentially, e.g., aperture arrays 142a, 142b, 142c ... CO₂-containing air is routed through the aligned holes into the tubes 144 and, therefrom to the gaps 28 corresponding to the specific aperture array. In accordance with the rotation of the disc 120, the position to which the CO₂-containing air is supplied is changed every moment.

It will be apparent to those skilled in this art that the partitioned reaction bath design described with reference to Figure 10 is also applicable to the embodiment shown in Figures 14 and 15 in order to achieve smaller pneumatic resistance and, thereby, smoother supply of CO₂-containing air.

Referring to Figure 16, a source of CO₂-containing air supply in accordance with the present invention is shown. The source of air supply, generally 150, comprises a housing 152 the interior of which is communicated to the conduit 130 (26). A burner 154 for burning any kind of hydrocarbon gas such as natural gas or propane is disposed in the housing 152 and communicated to a gas supply (not shown) by a valved piping 156. Located above the burner 154 is a heat exchanger 158. A filter 160 for filtering dust is positioned above the heat exchanger 158. When the hydrocarbon gas is burned by the burner 154, CO₂ and water are produced in the housing 152. A pump 162 compresses the CO₂ to feed it under pressure to the reaction bath via the conduit 130 (26).

As previously discussed, the intermittent photosynthesis mode is more desirable than the continuous photosynthesis mode. While photosynthesis is interrupted, it is necessary to supply oxygen to the desired substance in the reaction bath. Such oxygen supply is readily attainable

with the device shown in Figure 16, that is, merely by interrupting the combustion of the gas in the housing 152. As such, CO₂ and oxygen can be switched with ease from one to the other.

The heat exchanger 158 in the housing 152 serves to prevent hot air in the housing 152 from being communicated to the reaction bath. If desired, the heat exchanger 158 may bifunction to prevent cool air from being communicated to the reaction bath while the photosynthetic reaction is interrupted, so that air can be supplied constantly at an optimum temperature to the reaction bath to further enhance the efficiency of photosynthesis.

In summary, it will be seen that the present invention provides an apparatus for photosynthesis which effectively and stably supplies light and CO₂-containing air into a reaction bath to promote efficient photosynthetic reactions. The apparatus is furnished with an economical and simple device for the supply of CO₂-containing air. In an intermittent photosynthesis mode, carbon dioxide and oxygen can be alternately supplied with ease. Combustion of hydrocarbon gas in accordance with the present invention serves to kill germs in the air before the air is supplied to the housing 152.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof. For example, while the embodiments shown in Figures 11—15 have employed the reaction bath and photoradiator arrangement of the prior art apparatuses, use may naturally be made of the generally annular construction discussed with reference to Figures 6—10.

Claims

1. An apparatus for photosynthesis comprising:
a reaction bath means (100, 110) for causing a photosynthetic reaction therein,

a plurality of narrow tubular photoradiators (102) arranged upright in said reaction bath means (100, 110) parallel to each other, each of said photoradiators (102) being constructed to radiate light which propagates therethrough, characterised in that said reaction bath means (100, 110) comprises an inner transparent wall (100a, 110a) and an outer transparent wall (100b, 110b) surrounding and spaced from that inner transparent wall to define an annular space between the inner and the outer transparent walls, the inner and outer transparent walls being generally vertically disposed, that a light source (104) is positioned radially inwardly of the inner wall;

and that a plurality of photoradiators (102) are arranged in the annular space divided between the inner and outer transparent walls and that a rotatable disc (56, 120) is provided in a horizontal plane below the reaction bath means (100, 110), and is positioned perpendicular to the photoradiators (102) to eject jets of carbon dioxide-containing air into the annular space.

2. An apparatus as claimed in claim 1, in which the reaction bath means (100, 110) comprises reflector plates (112) for separating said annular space into a plurality of compartments (a, b, c, d, e and f).

3. An apparatus as claimed in claim 1, in which said reaction bath means (100, 110) further comprises coaxial inner and outer tubes (106a, 106b) around the light source (104).

4. An apparatus as claimed in claim 3, in which an annular space is defined between the inner and outer tubes (106a, 106b) and a material (108) is filled in said annular space which absorbs infra-red rays.

5. An apparatus as claimed in claim 4, in which said material comprises water.

6. An apparatus as claimed in claim 1, further comprising carbon dioxide gas supply means (26) for supplying carbon dioxide gas to the reaction bath means (100, 110) via the rotatable disc (56, 120) said carbon dioxide gas supply means comprising a burner for burning hydrocarbon gas to produce said carbon dioxide gas and water.

7. An apparatus as claimed in claim 6, in which the carbon dioxide gas supply means further comprises a heat exchanger through which the carbon dioxide gas is delivered to the reaction bath means (100, 110).

8. An apparatus as claimed in claim 6 in which said carbon dioxide gas supply means further comprises a filter through which the carbon dioxide gas is delivered to the reaction bath means.

9. An apparatus as claimed in claim 6, in which said carbon dioxide gas supply means is activated during a photosynthetic reaction in said reaction bath means (100, 110) to feed carbon dioxide containing air under pressure to the reaction bath means (100, 110) and deactivated during a suspension of a photosynthetic reaction to allow natural air to be fed under pressure to the reaction bath means (100, 110).

10. An apparatus for photosynthesis comprising a reaction bath (100, 110) for causing a photosynthetic reaction therein;

a plurality of narrow tubular photoradiators (102) arranged upright in said reaction bath (100, 110) to each other and with gaps (28) therebetween, each of said photoradiators (102) being constructed to radiate light which propagates therethrough, characterised by a disc (56, 120) rotatable in a horizontal plane below and perpendicular to the photoradiators (102) said disc being formed with horizontal passageways (56, 122, 124) for ejecting jets of carbon dioxide containing air and vertical passageways (126, 128) for ejecting jets of carbon dioxide containing air towards said gaps (28) between the adjacent photoradiators (102) said horizontal passageways being oriented to apply a moment of a force which tends to rotate the disc (56, 120) about its axis, whereby the disc is caused to rotate while supplying the carbon dioxide-containing air into the reaction bath (100, 110) via the vertical passageways.

with the device shown in Figure 16, that is, merely by interrupting the combustion of the gas in the housing 152. As such, CO₂ and oxygen can be switched with ease from one to the other.

The heat exchanger 158 in the housing 152 serves to prevent hot air in the housing 152 from being communicated to the reaction bath. If desired, the heat exchanger 158 may bifunction to prevent cool air from being communicated to the reaction bath while the photosynthetic reaction is interrupted, so that air can be supplied constantly at an optimum temperature to the reaction bath to further enhance the efficiency of photosynthesis.

In summary, it will be seen that the present invention provides an apparatus for photosynthesis which effectively and stably supplies light and CO₂-containing air into a reaction bath to promote efficient photosynthetic reactions. The apparatus is furnished with an economical and simple device for the supply of CO₂-containing air. In an intermittent photosynthesis mode, carbon dioxide and oxygen can be alternately supplied with ease. Combustion of hydrocarbon gas in accordance with the present invention serves to kill germs in the air before the air is supplied to the housing 152.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof. For example, while the embodiments shown in Figures 11-15 have employed the reaction bath and photoradiator arrangement of the prior art apparatuses, use may naturally be made of the generally annular construction discussed with reference to Figures 6-10.

Claims

1. An apparatus for photosynthesis comprising:
a reaction bath means (100, 110) for causing a photosynthetic reaction therein,

a plurality of narrow tubular photoradiators (102) arranged upright in said reaction bath means (100, 110) parallel to each other, each of said photoradiators (102) being constructed to radiate light which propagates therethrough, characterised in that said reaction bath means (100, 110) comprises an inner transparent wall (100a, 110a) and an outer transparent wall (100b, 110b) surrounding and spaced from that inner transparent wall to define an annular space between the inner and the outer transparent walls, the inner and outer transparent walls being generally vertically disposed, that a light source (104) is positioned radially inwardly of the inner wall;

and that a plurality of photoradiators (102) are arranged in the annular space divided between the inner and outer transparent walls and that a rotatable disc (56, 120) is provided in a horizontal plane below the reaction bath means (100, 110), and is positioned perpendicular to the photoradiators (102) to eject jets of carbon dioxide-containing air into the annular space.

2. An apparatus as claimed in claim 1, in which the reaction bath means (100, 110) comprises reflector plates (112) for separating said annular space into a plurality of compartments (a, b, c, d, e and f).

3. An apparatus as claimed in claim 1, in which said reaction bath means (100, 110) further comprises coaxial inner and outer tubes (106a, 106b) around the light source (104).

4. An apparatus as claimed in claim 3, in which an annular space is defined between the inner and outer tubes (106a, 106b) and a material (108) is filled in said annular space which absorbs infrared rays.

5. An apparatus as claimed in claim 4, in which said material comprises water.

6. An apparatus as claimed in claim 1, further comprising carbon dioxide gas supply means (26) for supplying carbon dioxide gas to the reaction bath means (100, 110) via the rotatable disc (56, 120) said carbon dioxide gas supply means comprising a burner for burning hydrocarbon gas to produce said carbon dioxide gas and water.

7. An apparatus as claimed in claim 6, in which the carbon dioxide gas supply means further comprises a heat exchanger through which the carbon dioxide gas is delivered to the reaction bath means (100, 110).

8. An apparatus as claimed in claim 6 in which said carbon dioxide gas supply means further comprises a filter through which the carbon dioxide gas is delivered to the reaction bath means.

9. An apparatus as claimed in claim 6, in which said carbon dioxide gas supply means is activated during a photosynthetic reaction in said reaction bath means (100, 110) to feed carbon dioxide containing air under pressure to the reaction bath means (100, 110) and deactivated during a suspension of a photosynthetic reaction to allow natural air to be fed under pressure to the reaction bath means (100, 110).

10. An apparatus for photosynthesis comprising a reaction bath (100, 110) for causing a photosynthetic reaction therein;

a plurality of narrow tubular photoradiators (102) arranged upright in said reaction bath (100, 110) to each other and with gaps (28) therebetween, each of said photoradiators (102) being constructed to radiate light which propagates therethrough, characterised by a disc (56, 120) rotatable in a horizontal plane below and perpendicular to the photoradiators (102) said disc being formed with horizontal passageways (56, 122, 124) for ejecting jets of carbon dioxide containing air and vertical passageways (126, 128) for ejecting jets of carbon dioxide containing air towards said gaps (28) between the adjacent photoradiators (102) said horizontal passageways being oriented to apply a moment of a force which tends to rotate the disc (56, 120) about its axis, whereby the disc is caused to rotate while supplying the carbon dioxide-containing air into the reaction bath (100, 110) via the vertical passageways.



11. An apparatus as claimed in claim 10, further comprising air bearing means which causes the disc (56, 120) to be supported by the carbon dioxide-containing air.

12. An apparatus as claimed in claim 10, further comprises an air-tight bearing (132) for supporting the disc (120).

13. An apparatus as claimed in claim 10, further comprising an apertured plate (140) formed with a plurality of apertures (142) and located in a horizontal plane between the photoradiators and the rotatable disc (120), and a plurality of tubes (144) each communicating any of the apertures in the apertured plate to any of the gaps between the adjacent photoradiators.

14. An apparatus as claimed in claim 13, in which the vertical passageways (126, 128) in the rotatable disc (120) are sequentially brought into register with the apertures (142) in the apertured plate (140) while the disc is rotated.

15. An apparatus as claimed in claim 14, in which the apertures (142) in the apertured plate (140) are positioned in a plurality of radially extending arrays (142a, b, c) and on a plurality of concentric circles, the vertical passageways (126, 128) in the disc (120) sequentially registering with at least one of the radial aperture arrays in the apertured plate at a time.

16. An apparatus as claimed in claim 15, in which the reaction bath (100, 110) comprises partitioning means (112) for partitioning the reaction bath (100, 110) into compartments (A, B, C, D, F) which correspond to the radial aperture arrays (142) in the apertured plate (140) respectively, the gaps (28) between the adjacent photoradiators (102) in each of the compartments corresponding to any of the radial aperture arrays (142a, 142b, 142c).

17. An apparatus as claimed in claim 10, further comprising carbon dioxide gas supply means for supplying carbon dioxide gas to the reaction bath (100, 110) via the rotatable disc (56, 120) said carbon dioxide gas supply means comprising a burner for burning hydrocarbon gas to produce the carbon dioxide gas and water.

18. An apparatus as claimed in claim 17, in which the carbon dioxide gas supply means further comprises a heat exchanger through which the carbon dioxide gas is delivered to the reaction bath (100, 110).

19. An apparatus as claimed in claim 17, in which the carbon dioxide gas supply means further comprises a filter through which the carbon dioxide gas is delivered to the reaction bath (100, 110).

20. An apparatus as claimed in claim 17, in which the carbon dioxide gas supply means is activated during a photosynthetic reaction in the reaction bath (100, 110) to feed the carbon dioxide-containing air under pressure to the reaction bath and deactivated during a suspension of the photosynthetic reaction to allow natural air to be fed under pressure to the reaction bath (100, 110).

Patentansprüche

1. Photosyntheseapparat mit einem Reaktionsbad (100, 110), in dem eine photosynthetische Reaktion erzeugt wird, mit einer Vielzahl von engbeieinanderliegenden röhrenförmigen Leuchtkörpern (102), die aufrecht in dem Reaktionsbad (100, 110) parallel zueinander angeordnet sind, wobei jeder Leuchtkörper (102) Licht abstrahlt, das dort hindurchtritt, dadurch gekennzeichnet, daß das Reaktionsbad (100, 110) eine innere durchsichtige Wand (100a, 110a) und eine äußere durchsichtige Wand (100b, 110b) aufweist, die beabstandet zur inneren Wand, diese umgibt, so daß ein ringförmiger Raum zwischen der inneren und der äußeren durchsichtigen Wand definiert wird, wobei die innere und die äußere durchsichtige Wand sich im wesentlichen sich vertikal erstrecken, und daß eine Lichtquelle (104) radial einwärts von der inneren Wand angeordnet ist und daß mehrere Leuchtkörper (102) in dem durch die innere und äußere durchsichtige Wand definierten Ringraum angeordnet sind und daß eine Drehscheibe (56, 120) in einer Horizontalebene unterhalb des Reaktionsbades (100, 110) angeordnet ist, die sich quer zu den Leuchtkörpern (102) erstreckt, um Kohlenstoffdioxid enthaltende Luft in den Ringraum einzustrahlen.

2. Vorrichtung nach Anspruch 1, wobei das Reaktionsbad (100, 110) Reflektorplatten (112) aufweist, die den Ringraum in mehrere Räume (a, b, c, d, e und f) unterteilt.

3. Vorrichtung nach Anspruch 1, wobei das Reaktionsbad (100, 110) koaxiale innere und äußere Röhren (106a, 106b) um die Lichtquelle (104) herum aufweist.

4. Vorrichtung nach Anspruch 3, wobei zwischen der inneren und der äußeren Röhre (106a, 106b) ein Ringraum definiert ist, in den ein Material (108) eingefüllt ist, das Infrarotstrahlung absorbiert.

5. Vorrichtung nach Anspruch 4, wobei dieses Material Wasser umfaßt.

6. Vorrichtung nach Anspruch 1, wobei weiterhin eine Versorgungseinrichtung (26) zur Einspeisung von Kohlendioxidgas in das Reaktionsbad (100, 110) über die Drehscheibe (56, 120) vorgesehen ist, und wobei diese Versorgungseinrichtung für Kohlendioxid einen Brenner umfaßt, mit dem Kohlenwasserstoffgas verbrannt wird, um so Kohlendioxidgas und Wasser zu erzeugen.

7. Vorrichtung nach Anspruch 6, wobei die Einrichtung zur Zuführung von Kohlendioxidgas weiterhin einen Wärmetauscher aufweist, über den das Kohlendioxidgas in das Reaktionsbad (100, 110) eingeleitet wird.

8. Vorrichtung nach Anspruch 6, wobei die Versorgungseinrichtung für das Kohlendioxidgas weiterhin einen Filter aufweist, durch den das Kohlendioxidgas in das Reaktionsbad eingespeist wird.

9. Vorrichtung nach Anspruch 6, wobei die Kohlendioxidgasversorgungseinrichtung während der photosynthetischen Reaktion in dem Reaktionsbad (100, 110) in Gang gesetzt wird, um



Kohlendioxid enthaltende Luft unter Druck in das Reaktionsbad (100, 110) einzuspeisen und wobei diese Einrichtung ausgeschaltet wird, während die photosynthetische Reaktion unterbrochen ist, so daß dann natürliche Luft unter Druck in das Reaktionsbad (100, 110) eingebracht wird.

10. Vorrichtung zur Photosynthese mit einem Reaktionsbad, in dem eine photosynthetische Reaktion hervorgerufen wird, mit mehreren engbeabstandeten röhrenförmigen Leuchtkörpern (102) die aufrechtstehend in dem Reaktionsbad (110, 110) zueinander angeordnet sind und mit Zwischenräumen (28) dazwischen, wobei jeder Leuchtkörper (102) so gestaltet ist, daß er Licht, das dort hindurchtritt, abstrahlt, gekennzeichnet durch eine Scheibe (56, 120), die in einer Horizontalebene unterhalb und quer zu den Leuchtkörpern (102) drehbar ist, wobei die Scheibe mit horizontal verlaufenden Leitungen (56, 122, 124) versehen ist, über die düsenstrahlförmige, Kohlendioxid enthaltende Luft austreten kann und mit vertikalen Leitungen (126, 128), die Kohlendioxid enthaltende Luft in Richtung auf die Zwischenräume (28) zwischen den benachbarten Leuchtkörpern (102) ausströmen lassen, wobei die horizontalen Leitungen so ausgerichtet sind, daß sie ein Drehmoment erzeugen, das die Scheibe (56, 120) um ihre Achse in Drehung versetzt, wodurch die Scheibe während der Zuführung von Kohlenstoffdioxid enthaltender Luft in das Reaktionsbad (100, 110) über die vertikalen Leitungen in Drehbewegung versetzt wird.

11. Vorrichtung nach Anspruch 10, die weiterhin eine Luftkissenlagerung für die Scheibe (56, 120) umfaßt, wobei das Luftkissen von Kohlendioxid enthaltender Luft gebildet wird.

12. Vorrichtung nach Anspruch 10, die weiterhin eine Luftdichte Lagerung (132) für die Scheibe (120) umfaßt.

13. Vorrichtung nach Anspruch 10, die weiterhin eine Lochplatte (140) aufweist, die eine Vielzahl von Öffnungen (142) umfaßt und die in einer Horizontalebene zwischen den Leuchtkörpern und der drehbaren Scheibe (120) angeordnet ist und mit mehreren Röhren (144), die jeweils eine der Öffnungen der Lochplatte mit einem Zwischenraum zwischen den benachbarten Leuchtkörpern verbindet.

14. Vorrichtung nach Anspruch 13, wobei die vertikalen Leitungen (126, 128) der drehbaren Scheibe (120) nacheinander in Ausrichtung mit den Öffnungen (142) der Lochplatte (140) gebracht werden, während sich die Scheibe dreht.

15. Vorrichtung nach Anspruch 14, wobei die Öffnungen (142) in der Lochplatte (140) in mehreren sich radial erstreckenden Reihen (142a, b, c) und auf mehreren konzentrischen Kreisen liegend angeordnet sind, und wobei die vertikalen Leitungen (126, 128) in der Scheibe (120) aufeinanderfolgend mit wenigstens einer radialen Öffnungsreihe in der Lochplatte zu einem Zeitpunkt in Ausrichtung kommt.

16. Vorrichtung nach Anspruch 15, wobei das Reaktionsbad (100, 110) eine Unterteilung (112)

zur Unterteilung des Reaktionsbades (100, 110) in einzelne Kammern (A, B, C, D, F) aufweist, die den radialen Öffnungsreihen (142) in der Lochplatte (140) entsprechen, und wobei die Zwischenräume (28) zwischen benachbarten Leuchtkörpern (102) in jeder Kammer jeder radialen Öffnungsreihe (142a, 142b, 142c) entsprechen.

17. Vorrichtung nach Anspruch 10, die weiterhin eine Kohlendioxidgasversorgungseinrichtung umfaßt, mit der Kohlendioxidgas in das Reaktionsbad (100, 110) über die drehbare Scheibe (56, 120) eingeleitet werden kann, und wobei die Kohlendioxidgasversorgungseinrichtung einen Brenner umfaßt, der Kohlenwasserstoff verbrennt und dabei Kohlendioxidgas und Wasser erzeugt.

18. Vorrichtung nach Anspruch 17, wobei die Kohlendioxidgasversorgungseinrichtung weiterhin einen Wärmetauscher aufweist, über den das Kohlendioxidgas in das Reaktionsbad (100, 110) eingeleitet wird.

19. Vorrichtung nach Anspruch 17, wobei die Kohlendioxidgasversorgungseinrichtung weiterhin einen Filter aufweist, durch den das Kohlendioxidgas in das Reaktionsbad (100, 110) eingeleitet wird.

20. Vorrichtung nach Anspruch 17, wobei die Kohlendioxidgasversorgungseinrichtung während der Photosynthesereaktion in dem Reaktionsbad (100, 110) in Gang gesetzt wird, wobei dadurch Kohlendioxid enthaltende Luft unter Druck in das Reaktionsbad eingespeist wird und wobei diese Vorrichtung ausgeschaltet wird, während die photosynthetische Reaktion unterbrochen ist, so daß dann natürliche Luft unter Druck in das Reaktionsbad (100, 110) eingeleitet werden kann.

Revendications

1. Appareil pour la photosynthèse, comprenant:

un dispositif à bain de réaction (100, 110) servant à produire une réaction photosynthétique dans ce bain,

des photoradiateurs tubulaires étroits (102) disposés verticalement et parallèlement entre eux dans ce dispositif à bain de réaction (100, 110), chacun des photoradiateurs (102) étant construit pour rayonner de la lumière qui est propagée à travers lui, caractérisé en ce que le dispositif à bain de réaction (100, 110) comprend une paroi transparente interne (100a, 110a) et une paroi transparente externe (100b, 110b) qui entoure la paroi transparente interne et est espacée de celle-ci, de manière qu'un espace annulaire soit formé entre les parois transparentes interne et externe, les parois transparentes interne et externe étant orientées sensiblement verticalement, qu'une source de lumière (104) est disposée radialement à l'intérieur de la paroi interne;

que plusieurs photoradiateurs (102) sont placés dans l'espace annulaire formé entre les parois transparentes interne et externe et qu'un disque rotatif (56, 120) est disposé dans un plan horizontal au-dessous du dispositif à bain de réaction



(100, 110) et est orienté perpendiculairement aux photoradiateurs (102), ce disque étant destiné à émettre des jets d'air contenant du gaz carbonique dans l'espace annulaire.

2. Appareil selon la revendication 1, dans lequel le dispositif à bain de réaction (100, 110) comporte des plaques réfléchissantes (112) pour diviser l'espace annulaire en plusieurs compartiments (A, B, C, D, E et F).

3. Appareil selon la revendication 1, dans lequel le dispositif à bain de réaction (100, 110) comporte en outre des tubes coaxiaux, intérieur et extérieur (106a, 106b) disposés autour de la source lumineuse (104).

4. Appareil selon la revendication 3, dans lequel un espace annulaire est défini entre les tubes intérieur et extérieur (106a, 106b) et une matière (108) absorbant le rayonnement infrarouge remplit cet espace annulaire.

5. Appareil selon la revendication 4, dans lequel ladite matière est de l'eau.

6. Appareil selon la revendication 1, comprenant en outre un dispositif (26) d'alimentation en gaz carbonique pour apporter du gaz carbonique au dispositif à bain de réaction (100, 110) au moyen du disque rotatif (56, 120), ce dispositif d'alimentation en gaz carbonique comprenant un brûleur pour brûler un hydrocarbure gazeux en vue de la production de gaz carbonique et d'eau.

7. Appareil selon la revendication 6, dans lequel le dispositif d'alimentation en gaz carbonique comprend en outre un échangeur de chaleur, à travers duquel le gaz carbonique est fourni au dispositif à bain de réaction (100, 110).

8. Appareil selon la revendication 6, dans lequel le dispositif d'alimentation en gaz carbonique comprend en outre un filtre à travers duquel le gaz carbonique est fourni au dispositif à bain de réaction.

9. Appareil selon la revendication 6, dans lequel le dispositif d'alimentation en gaz carbonique est actionné pendant une réaction photosynthétique dans le dispositif à bain de réaction (100, 110) en vue de l'amenée d'air sous pression, contenant du gaz carbonique au dispositif à bain de réaction (100, 110), et est rendu inactif pendant une interruption d'une réaction photosynthétique, afin de permettre l'amenée d'air naturel sous pression au dispositif à bain de réaction (100, 110).

10. Appareil pour la photosynthèse, comprenant un bain de réaction (100, 110), conçu pour provoquer une réaction photosynthétique dans ce bain, dans lequel sont disposés verticalement, les uns à côté des autres, des photoradiateurs tubulaires étroits (102), avec formation d'interstices (28) entre eux, chacun des photoradiateurs (102) étant construit pour rayonner de la lumière qui se propage à travers lui, caractérisé par un disque (56, 120) monté rotatif dans un plan horizontal, sous les photoradiateurs (102) et perpendiculairement par rapport à eux, ce disque étant pourvu de passages horizontaux (56, 122, 124) pour éjecter des jets d'air contenant du gaz carbonique, ainsi que de passages verticaux (126, 128) pour éjecter des jets d'air contenant du gaz carbonique en

direction des interstices (28) entre les photoradiateurs voisins (102), les passages horizontaux étant orientés pour produire un moment de force tendant à faire tourner le disque (56, 120) autour de son axe, de sorte que le disque est animé d'une rotation pendant qu'il introduit l'air contenant du gaz carbonique dans le bain de réaction (100, 110) à travers les passages verticaux.

11. Appareil selon la revendication 10, comprenant en outre un dispositif formant palier d'air pour supporter le disque (56, 120) au moyen de l'air contenant du gaz carbonique.

12. Appareil selon la revendication 10, comprenant en outre un roulement (132) étanche à l'air pour supporter le disque (120).

13. Appareil selon la revendication 10, comprenant en outre une plaque perforée (140), dans laquelle sont formés des trous (142) et qui est située dans un plan horizontal entre les photoradiateurs et le disque rotatif (120), ainsi que des tubes (144) qui font chacun communiquer l'un des trous de la plaque perforée avec l'un des interstices entre les photoradiateurs voisins.

14. Appareil selon la revendication 13, dans lequel les passages verticaux (126, 128) du disque rotatif (120) sont amenés, séquentiellement, en coïncidence avec les trous (142) de la plaque perforée (140) pendant que le disque est animé d'une rotation.

15. Appareil selon la revendication 14, dans lequel les trous (142) de la plaque perforée (140) sont disposés en rangées radiales (142a, b, c) et sur des cercles concentriques, les passages verticaux (126, 128) du disque (120) coïncidant chaque fois, séquentiellement, avec au moins l'une des rangées radiales de trous de la plaque perforée.

16. Appareil selon la revendication 15, dans lequel le bain de réaction (100, 110) comporte un dispositif de division (112) pour partager le bain de réaction (100, 110) en compartiments (A, B, C, D, F), qui correspondent aux rangées radiales de trous (142) de la plaque perforée (140), les interstices (28) entre les photoradiateurs (102) voisins dans chacun des compartiments correspondant à l'une des rangées radiales de trous (142a, 142b, 142c).

17. Appareil selon la revendication 10, comprenant en outre un dispositif d'alimentation en gaz carbonique, destiné à fournir du gaz carbonique au bain de réaction (100, 110) au moyen du disque rotatif (56, 120), ce dispositif d'alimentation comprenant un brûleur pour brûler un hydrocarbure gazeux en vue de la production de gaz carbonique et d'eau.

18. Appareil selon la revendication 17, dans lequel le dispositif d'alimentation en gaz carbonique comporte en outre un échangeur de chaleur à travers duquel le gaz carbonique est amené au bain de réaction (100, 110).

19. Appareil selon la revendication 17, dans lequel le dispositif d'alimentation en gaz carbonique comporte en outre un filtre à travers duquel le gaz carbonique est amené au bain de réaction (100, 110).

20. Appareil selon la revendication 17, dans



lequel le dispositif d'alimentation en gaz carbonique est actionné pendant une réaction photosynthétique dans le bain de réaction (100, 110), en vue de l'amenée au bain de réaction d'air sous pression contenant du gaz carbonique, et est

rendu inactif pendant une interruption de la réaction photosynthétique afin de permettre l'amenée sous pression d'air naturel au bain de réaction (100, 110).

5

10

15

20

25

30

35

40

45

50

55

60

65

10

