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(54) Title: METHOD FOR ANAEROBIC DIGESTION AND DEVICE FOR IMPLEMENTING SAID METHOD

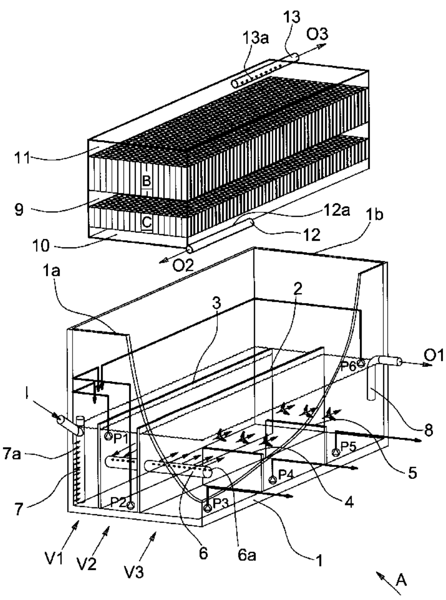

Fig. 1

(57) Abstract: This invention relates to a method and to a device for the implementation of said method, to decompose and to selectively extract methane, carbon dioxide, NPK salts (nitrogen, phosphorus and potassium salts) of various titre and clarified water, from an organic matrix; said components will be the raw material for further industrial processes. The method is characterized in that it includes the following phases: • implementation of a hydrolytic phase, constituted by the fission action by means of the water, by hydration; • implementation of a acidogenesis phase generated by means of specific bacteria; • implementation of a acetogenesis phase generated by means of specific bacteria; • implementation of a methanogenesis phase by means of specific bacteria, with a simultaneous gravimetric separation of a mainly oleic phase, lighter and of a predominantly protein phase, heavier; • gravimetric separation of solutions of said NPK salts of different titres • taking of clarified water. The device is characterized in that it comprises a basin (1) divided into various zones (V1), (V2), (V3), in each of which biological reactions occur, in accordance with the claimed method, said zones being all communicating and identified by suitable separation baffles, in particular: • a first baffle (2) extended from a first end (1a) of the basin to a second end (1b) of said basin (1), dividing it into two parts; • a second baffle (3), of height equal to said first baffle that divides one of said parts in a first zone (V1) and in a second zone (V2) extending from said first end (1a) of the basin (1) until it reaches the vicinity of said second end of the basin (1), so that said two zones (V1) and (V2) are communicating through an opening, of substantially vertical development, between the end of said second baffle (3) and the second end (1b) of the basin (1); • a plurality of baffles (4) and (5) transversely arranged to said first baffle (2) and inside a third zone (V3), delimited by said first baffle (2), said third zone (V3) being placed in communication with said second zone (V2) through a transfer pipe (6), positioned at about half height of said first baffle (2); • two blocks (B) and (C), placed in the upper part of said basin (1) and provided by taking means (12, 12a, 13, 13a), each of said blocks (B) and (C) including a plurality of vertical pipes and being fitted to carry out a gravimetric separation of the gases that are generated during the treatment of said mixture; said baffles (2) and (3) and said transfer pipe (6), by identifying a path crossed by the liquid mixture to be treated, that runs into the beginning of said first zone (1) where it is placed an inlet pipe (7) of the liquid mixture to be treated and comes out from various points of said third zone (V3).

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METHOD FOR ANAEROBIC DIGESTION AND DEVICE FOR IMPLEMENTING SAID METHOD

DESCRIPTION

This invention relates to a method and to a device for the implementation of said method, to decompose and to selectively extract methane, carbon dioxide, NPK salts (nitrogen, phosphorus and potassium salts) of various titre and clarified water, from an organic matrix; said components will be the raw material for further industrial processes.

It is strongly felt the need to have systems for the reclamation of limited quantities of organic matrices, indicatively lower than 10 quintals per day (for example agro-food sub-products of manufacturing companies as well as small agro-zootechnical companies, large organized distribution (GDO), hotel, restaurant and catering (Ho.Re.Ca.) and residential settlements, suitable to supply continuous users (for example 20 kW for 24h, or even up to sizes of 1 kW, with for example only 50 kg per day). At the same time there is a general need for the supply of energy, better if by the simultaneous reclamation of organic materials, wastewaters, wet and grass cuttings arising from urban life. The costs and the inconveniences are relevant in the management of these reclamations, because of the specific treatments which must be subjected (along all the related passages), with poor containment of environmental and especially odour impacts. The environmental impact is usually not correctly assessed, as both CO_2 and CH_4 are odourless (natural evolutions of the organic material, already at ambient temperatures), but of great contribution to the greenhouse anthropic effect (especially the CH_4, produced in double size than CO_2 and 25 times more incisive than CO_2). The current state of the art includes anaerobic digesters normally directed to higher productions, with very high costs and generally ineffective for small size to which you think as potential applications of this invention. The digesters currently present on the market, moreover, does not offer effective solutions for the management of digestate and of other sub-products.

Other solutions such as the differentiated collection and the partial local treatments, are costly and ineffective on many fronts. They are not even detected solutions pointing at strategies of "distributed and pervasive solutions", to resolve the problems as close as possible to the source and in the respect of the general principle according to which “the polluter pays”. These issues afflict many companies in the food and the agro-zootechnical sectors, that are in proximity to urban life.

This invention aims at giving the best solution to all these issues. In particular it is not possible, by a single device, to produce multiple components directly usable, in particular with small volumes of organic matrices, because of the critical mass and of the actual technologies costs.

The purpose of this invention is to propose a method and a device for the implementation of said method, respectively conform to claims 1 and 5, to decompose an organic matrix and selectively extracting methane, carbon dioxide, NPK salts (nitrogen, phosphorus and potassium salt) of various titre and clarified water.

The method is characterized in that it includes the following steps:

• implementation of a hydrolytic phase, constituted by the fission action by means of the water, by hydration;

• implementation of a acidogenesis phase generated by means of specific bacteria;

• implementation of a acetogenesis phase generated by means of specific bacteria;

• implementation of a methanogenesis phase by means of specific bacteria, with a simultaneous gravimetric fission of mainly oleic phase, lighter and a predominantly protein phase, heavier;

• gravimetric separation of solutions of said NPK salts of different titres

• taking of clarified water.

The device is characterized in that it comprises a basin divided into various zones, in each of which biological reactions occur, in accordance with the described method, said zones being all communicating and identified by suitable separation baffles, in particular:

- a first baffle that extends from a first end of the basin to a second end of said basin, dividing it into two parts;
- a second baffle, of height equal to said first baffle that divides one of said parts in a first zone and a second zone extending from said first end of the basin until it reaches the vicinity of said second end of the basin, so that said two zones are communicating through an opening, of substantially vertical development, between the end of said second baffle and the second end of the basin;
- a plurality of baffles transversely arranged to said first baffle and inside a third zone, delimited by said first baffle, said third zone being placed in communication with said second zone through a transfer pipe, placed at about half height of said first baffle;
- two blocks, placed in the upper part of said basin and provided by taking means, each of said blocks comprising a plurality of vertical pipes and being fitted to carry out a gravimetric separation of the gases that are generated during the treatment of said mixture;

said baffles and said transfer pipe, by identifying a path crossed by the liquid mixture to be treated, that runs into the beginning of said first zone where it is placed an inlet duct of the liquid mixture to be treated and comes out from various points of said third zone.

Other characteristics, such as for example the possibility to improve the subtraction of hydrogen sulphides, by submersed homogeneous diffusers, by resorting to photosynthesis in absence of oxygen, will be the subject of the dependent claims.

The use of a device according to this invention allows, for example, to receive matrices of different concentrations and to optimize them by internal water, directly or by providing it to preliminary treatment, limiting the overall consumption of the primary water resource.

The invention finds application in the purification of water bodies and in the production of organic substances (protein fraction and oleic fraction) and

NPK salts, said materials find use in the production of:

- biofuels;
- fertilizing mixtures for various industrial sectors (agro-zootechnical, chemical, etc.);
- hydrogen, as present in solution in the liquid phase;
- raw materials for vegetable crops (terrestrial or maritime);
- carbon dioxide for agronomic industries, metallurgical industries, fire services, agro-food and conservation.

The invention will now be described for illustrative and not limitative purpose, according to a preferred embodiment and with reference to the enclosed drawings, in which:

- the figure 1 is a perspective view of a device according to the invention;
- figure 2 shows, in two orthogonal views, the device according to the invention.

With reference to figures 1 and 2, with (A) it is indicated a device according to the invention, fitted to decompose and to separate the components of an organic matrix. Said device (A) includes a basin (1) divided into zones (V1), (V2) and (V3), in each of which biological reactions occur, said zones being all communicating and identified by suitable separation baffles. In particular:

- a first baffle (2) that extends from a first end (1a) of the basin (1) to a second end (1b) of said basin (1), subdividing it into two parts;
- a second baffle (3), having a height equal to said first baffle (2), that divides one of said parts in a first zone (V1) and in a second zone (V2), extending from said first end (1a) of the basin (1) until it reaches the vicinity of said second end (1b) of the basin (1), so that said two zones (V1) and (V2) are communicating through an opening, with a substantially vertical development, between the end of said second baffle (3) and the second end (1b) of the basin (1);
- a plurality of baffles (4), (5), having a height preferably equal to half of

said first and second baffle (2), (3), transversely arranged to said first baffle (2) and inside a third zone (V3), delimited by said first baffle (2), said third zone (V3) being placed in communication with said second zone (V2) by means of a transfer pipe (6), positioned at about half the height of the first baffle (2), in which said transfer pipe (6) includes a tube closed at the ends and on which they have been made a plurality of holes (6a) aligned along a generatrix and facing towards the inside of the basin (1).

According to a preferred embodiment, said first baffle (2) divides the basin (1) into two substantially equal parts, while said second baffle (3) divides said first part, in said zones (V1) and (V2) in which the volume of the second zone (V2) is substantially double of the volume of the first zone (V1).

Said baffles (2) and (3) and said transfer pipe (6) identify a path crossed by the liquid mixture to be treated, that runs into the beginning of the first zone (V1), in which it is placed an inlet pipe (7) of the liquid mixture to be treated and comes out at various points of the third zone (V3).

At the bottom of the third zone (V3) it is positioned an outlet pipe (8), including a tube for the taking of clarified water to half the height of said first baffle (2).

Said first inlet pipe (7) includes a tube closed at the ends, with a Y shaped diversion, provided with a plurality of holes (7a), aligned along a generatrix and directed towards the corner of the basin (1), in order to favour the mixing and to avoid dead zones (or not operating). In addition, along said path, they are positioned some submerged pumps (P1,P2,P3,P4,P5,P6), whose function will be specified later on.

The basin (1), in the zone (V1) and (V2) is heated to a temperature suitable to favour the biological processes (typically comprised between 30 and 60°C). In order to sustain a slight excitation through convective motions, the basin (1) is thermally insulated on the outside and heated by heating means (not shown) positioned in the lower part of the basin itself.

In the upper part of the basin (1) they are placed two blocks (B) and

(C), each of which includes a plurality of vertical pipes. The upper block (B), of greater development in height, is preferably made of plastic material (PE, PVC or similar) and the lower block (C), made of metal, are separated by a gap (9). The lower block (C) is cooled by means of a coil (not shown) crossed by a heat transfer fluid suitable to slightly lower the temperature of said lower block (C).

Said blocks (B) and (C) are inserted so as to obtain also a bottom gap (10) and an upper gap (11). At the ends of said gaps (10) and (11) they are positioned two pipes (12) and (13) respectively, at the antipodes and along the larger dimension of the basin (1), on which they are made a plurality of holes (12a) and (13a) respectively, aligned along a generatrix of said pipes.

To operate the described device (A) makes use of a hydraulic dynamic state of communicating vessels, so as to reduce the waste of mechanical energy for the necessary advancement movements of the fluid mixture.

The flow of the liquid mixture to be treated, indicated by the arrow (I), runs into the first zone (V1) of the basin (1), said mixture homogeneously spreading through the holes (7a) made on the first inlet tube (7). The mixture crosses through the various areas in which it is divided the basin (1), in which various reactions chemical-biological occur; in particular:

• in the first zone (V1) it is implemented the hydrolytic phase, constituted by the fission action of the water, by hydration, possibly also in high thermal conditions;

• in the final stretch of the first zone (V1) it is implemented the acidogenesis phase by specific bacteria;

• in the zone comprised between the first zone (V1) and the second zone (V2), it carries out a acetogenesis phase by specific bacteria;

• in the second area (V2) it is implemented a methanogenesis phase by specific bacteria (in this zone, because of the larger section, the flow speed will be lower in order to have a greater permanence time that favours the massive production of CH_4 and the gravimetric separation of one mainly oleic phase, lighter and a protein predominantly phase, heavier);

• In the end portion of the second zone (V2) it is taken a given quantity of liquid mixture through said submerged pumps (P1) and (P2) and it is recycled to the beginning of the zone (V1), in particular the pump (P1), placed in the upper part, recycles said mainly oleic mixture, lighter, while the pump (P2), placed in the lower part, recycles said protein predominantly mixture, heavier;

• in the transit from the second zone (V2) to the third zone (V3), through the pipe (6), placed at mid-height of the liquid phase, a laminar horizontal flow is obtained;

• in the third zone (V3), following the generation of said laminar horizontal flow, a widespread and different gravimetric action on the various components present in the mixture occurs, obtaining their deposition in the different sectors provided by means of the transversal baffles (4) and (5), from which they will be taken by said submerged pumps (P3), (P4) and (P5), said taking being constituted by NPK salts of different titres;

• in the terminal portion of the third zone (V3), after the deposition of the NPK salts, the liquid mass is composed almost exclusively of water, that is taken from said outlet pipe (8), said taking being carried out at about half the height of the liquid mass, in which the level of purity is higher;

• in the terminal portion of the third region (V3), at the top and in the proximity of the static surface of the liquid phase, it is taken the liquid still containing oleic traces, that is recycled at the beginning of the first zone (V1), said taking being obtained by said submerged pump (P6) and in suitable amount to the processes of dilution to be implemented at the beginning of the zone V1, to correctly condition the organic matrix.

The gases developed during the treatment (CH_4 and CO_2) collects in the gap (10) above the liquid mass and, from here, they are gravimetrically separate: the CO_2, heavier, tends to remain in the lower part, from which it will be extracted through the holes (12a) of the pipe (12), while the methane, lighter, will rise up to the upper gap (11), from which it will be extracted through the holes (13a) of the pipe (13).

Inside the gases developed by the reaction it is also present the steam which, passing through the vertical channels of the lower block (C), condensate and returns in liquid form in the fluid mass below, said condensation being obtained by the lowering of the temperature of said vertical channels of the lower block (C) obtained by said coil, as the lowering of the temperature allows to reach the saturation condition (dew point).

According to a preferred embodiment, in the final stretch of the first zone (V1) and in the zone between the first zone (V1) and the second zone (V2), in which the following steps are carried out the acidogenesis and the acetogenesis phases, a system of homogeneous and diffused lighting can find place, in order to prevent the formation of H_2S by a photosynthesis in absebce of oxygen.

This invention has been described for illustrative and not limitative purposes, according to some preferred embodiments. The person skilled in the art could devise numerous other embodiments, all included within the scope of protection of the enclosed claims.

CLAIMS

1. Method to decompose an organic matrix and selectively extracting methane, carbon dioxide, NPK salts (nitrogen, phosphorus and potassium salt) of various titre and clarified water, characterized in that it includes the following steps:

- implementation of a hydrolytic phase, constituted by the fission action by means of the water, by hydration;
- implementation of a acidogenesis phase generated by means of specific bacteria;
- implementation of a acetogenesis phase generated by means of specific bacteria;
- implementation of a methanogenesis phase by means of specific bacteria, with a simultaneous gravimetric separation of a mainly oleic phase, lighter and a predominantly protein phase, heavier;
- gravimetric separation of solutions of said NPK salts of different titres
- taking of clarified water.

2. Method to decompose an organic matrix, according to claim 1, characterized by the fact of providing for the taking of a mainly oleic mixture and of a mainly protein mixture at the end of said methanegenesis phase and to recycle said mixtures taken in the initial phase of the treatment of said organic matrix.

3. Method to decompose an organic matrix according to claim 1, characterized by the fact of providing for a horizontal laminar advancing fitted to facilitate said gravimetric separation of said NPK salts.

4. Method to decompose an organic matrix according to claim 1, characterized by the fact of providing for a taking of liquid still containing oleic traces, in the terminal phase of said treatment, said taken liquid being recycled at the beginning of said treatment.

5. Device (A) fitted to decompose an organic matrix and to selectively extract methane, carbon dioxide, NPK salts (salts of nitrogen, phosphorus and potassium) of various titre and clarified water, characterized in that it

includes a basin (1) divided into zones (V1), (V2) and (V3), in each of which biological reactions occur, said zones being all communicating and located by suitable separation baffles. In particular:

- a first baffle (2) that extends from a first end (1a) of the basin (1) to a second end (1b) of said basin (1), subdividing it into two parts;
- a second baffle (3), having a height equal to said first baffle (2), that divides one of said parts in a first zone (V1) and in a second zone (V2), extending from said first end (1a) of the basin (1) until it reaches the vicinity of said second end (1b) of the basin (1), so that said two zones (V1) and (V2) are communicating through an opening, of a substantially vertical development, between the end of said second baffle (3) and the second end (1b) of the basin (1);
- a plurality of baffles (4), (5), transversely arranged to said first baffle (2) and inside a third zone (V3), delimited by said first baffle (2), said third zone (V3) being placed in communication with said second zone (V2) by means of a transfer pipe (6), positioned at about half the height of the first baffle (2), in which said transfer pipe (6) positioned at about half-height of aid first baffle (2);
- two blocks (B) and (C), positioned in the upper part of said basin (1) and provided with picking means (12, 12a, 13, 13a), each of said blocks (B) and (C) including a plurality of vertical pipes and being adapted to carry out a gravimetric separation of the gases that are generated during the treatment of said mixture;

said baffles (2) and (3) and said transfer pipes (6) defining a path crossed by the liquid mixture to be treated, which enters at the beginning of said first zone (V1), where it is placed an inlet duct (7) of the liquid mixture to be treated and comes out from various points of said third zone (V3).

6. Device (A) to decompose an organic matrix according to claim 5, characterized in that said first baffle (2) divides the basin (1) into two substantially equal parts.

7. Device (A) to decompose an organic matrix according to claim 5,

characterized in that said second baffle (3) divides said first part, in said areas (V1) and (V2) in which the volume of the second zone (V2) is substantially double of the volume of the first zone (V1).

8. Device (A) to decompose an organic matrix according to claim 5, characterized in that said transfer pipe (6) includes a tube closed at the ends and on which they have been made a plurality of holes (6a) aligned along a generatrix and directed towards the inside of said basin (1).

9. Device (A) to decompose an organic matrix, according to claim 5, characterized in that said baffles (4), (5), arranged transversely to said first baffle (2) and inside said third zone (V3), are of a height substantially equal to half of said first and second baffle (2), (3).

10. Device (A) to decompose an organic matrix, according to claim 5, characterized in that said first inlet pipe (7) includes a tube closed at the ends, with a Y shaped diversion, provided with a plurality of holes (7a) aligned along a generatrix and directed towards the corner of the basin (1), in order to support the mixing and to avoid dead or not operating zones.

11. Device (A) to decompose an organic matrix, according to at least one of the claims from 5 to 10, characterized in that it provides heating means positioned in the lower part of said basin (1), in correspondence with the said zones (V1) and (V2), said basin (1) being thermally insulated and heated to a temperature suitable to sustain the biological processes (typically comprised between 30 and 60°C), with the purpose of supporting a slight excitation through convective motions.

12. Device (A) to decompose an organic matrix, according to at least one of the claims from 5 to 11, characterized in that said lower block (C) is made of metallic material, being provided means suitable to cool said lower block (C), so as to cause the condensation of the water vapour that passes through the vertical channels of said lower block (C), said water vapour developing from the fluid mass contained in said basin (1).

13. Device (A) to decompose an organic matrix, according to at least one of the claims from 5 to 12, characterized in that said taking means (12, 12a, 13,

13a) include pipes (12) and (13), on each of which a plurality of holes are made, (12a) and (13a) respectively, aligned along a generatrix of said pipes (12) and (13), said blocks (B) and (C) being positioned in such a way as to obtain an intermediate gap (9), a lower gap (10) and an upper gap (11) and said ducts (12) and (13) being positioned in said lower (10) and upper (11) gaps.

14. Device (A) to decompose an organic matrix, according to at least one of claims 5 to 13, characterized by the fact that:

- In said first zone (V1) of the basin (1) it is implemented a hydrolytic phase, constituted by the fission action by means of the water, by hydration, possibly also in high thermal conditions;
- in the final stretch of said first zone (V1) it is implemented the acidogenesis phase by means of specific bacteria;
- in a zone comprised between said first zone (V1) and said second zone (V2), it is carried out a acetogenesis phase, generated by means of specific bacteria;
- in said second zone (V2) it is implemented a methanogenesis phase by means of specific bacteria, with contemporaneous gravimetric separation of a mainly oleic phase, lighter and a protein predominantly phase, heavier;
- in a terminal stretch of the second zone (V2) it is taken a given quantity of liquid mixture through the submerged pumps (P1) and (P2) and it is recycled to the beginning of the zone (V1), in particular the pump (P1), placed in the upper part, recycles said mainly oleic mixture, lighter, while the pump (P2), placed in the lower part, recycles said protein predominantly mixture, heavier;
- in the transit from the second zone (V2) to the third zone (V3), through the pipe (6), placed at mid-height of the liquid phase, a laminar horizontal advancing is obtained;
- in said third zone (V3), following the generation of said laminar horizontal flow, a widespread and diffused gravimetric action, on the

various components present in the mixture, occurs, obtaining their deposition in the different sectors provided by means of the transversal baffles (4) and (5), from which they will be taken by means of said submerged pumps (P3), (P4) and (P5), said taking being constituted by NPK salts of different titres;

• in a terminal stretch of the third zone (V3), after the deposition of the NPK salts, the liquid mass is composed almost exclusively of water, that is taken from said outlet pipe (8), said taking being carried out at about half the height of the liquid mass, in which the level of purity is higher;

• in said terminal stretch of said third region (V3), at the top and in the proximity of the static surface of the liquid phase, it is taken the liquid still containing oleic traces, that is recycled at the beginning of the first zone (V1), said taking being obtained by means of a submerged pump (P6) and in suitable amount to the processes of dilution to be implemented at the beginning of the first zone (V1), to correctly condition the organic matrix.

15. Device (A) to decompose an organic matrix, according to at least one of the claims from 5 to 14, characterized by the fact that in the final stretch of said first zone (V1) and in the zone included between said first zone (V1) and said second zone (V2), in which they are implemented said acidogenesis and acetogenesis phases it is placed a system of homogeneous and diffused lighting, in order to fight the formation of H_2S by photosynthesis in absence of oxygen.

16. Device (A) to decompose an organic matrix, according to at least one of the claims from 5 to 15, characterized in that the gases which are developed during the treatment (CH_4 and CO_2) are collected in said gap (10) above said liquid mass and, from here, they are gravimetrically separated: CO_2, heavier, tends to remain in the lower part, from where it will be extracted through the holes (12a) of said pipe (12), while the methane, lighter, will rise to the upper gap (11), from where it will be extracted through the holes (13a)

of the pipe (13).

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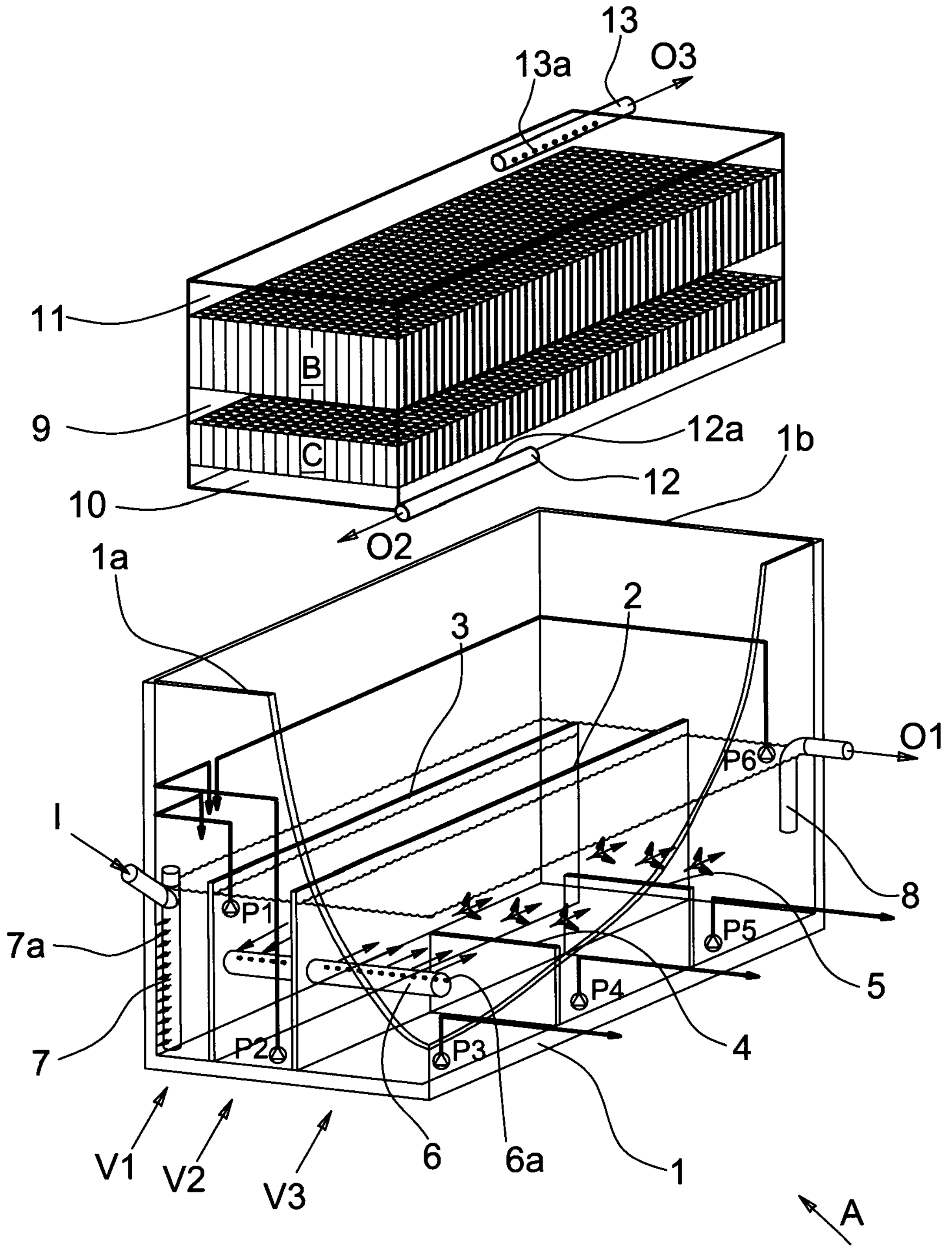
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Fig. 1

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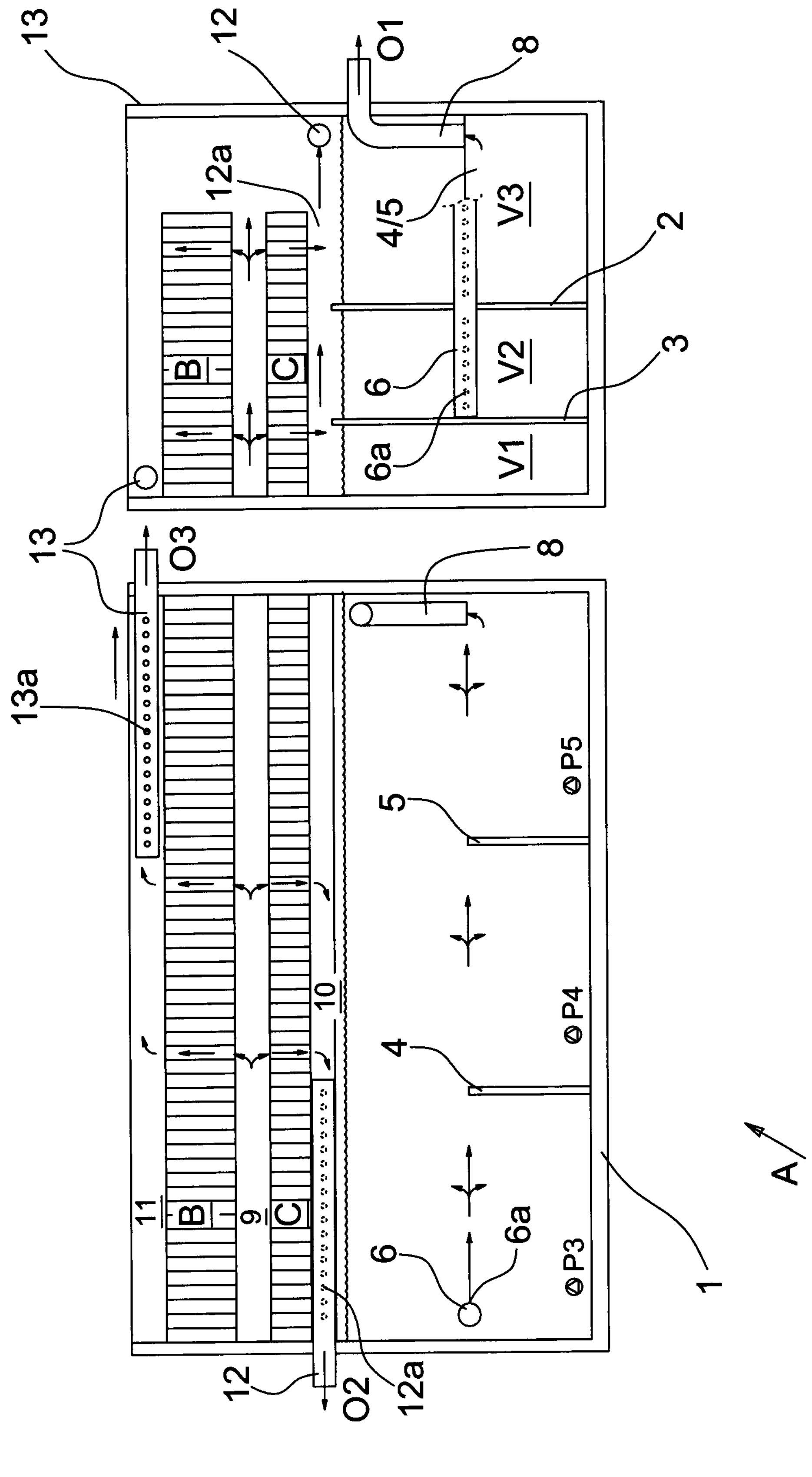
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5
10
P4
4
A
11
B
9
C
6
6a
P3
1
12
O2
12a

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2015/000306

A. CLASSIFICATION OF SUBJECT MATTER
INV. C12M1/107 C12M1/00 C12M1/02
ADD.

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

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 practicable, 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.
A	WO 2014/075192 A1 (GEA FARM TECHNOLOGIES CANADA INC) 22 May 2014 (2014-05-22) page 1, line 3 - line 5 page 14, line 7 - page 17, line 2; figures 1,2 -----	1-16
A	US 2010/206791 A1 (SANG BUM LEE ET AL.) 19 August 2010 (2010-08-19) figures 1-3 paragraphs [0003], [0009], [0040], [0041] -----	1-16
A	US 4 429 043 A (PATON) 31 January 1984 (1984-01-31) figure 1 -----	1-16
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 April 2016	03/05/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Alvarez Alvarez, C

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2015/000306

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/102746 A1 (OAG OBJEKT UND ANLAGEPLANUNG GMBH) 16 September 2010 (2010-09-16) claims 1-9; figures 1, 2	1-16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IT2015/000306

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014075192 A1	22-05-2014	CA 2891676 A1	22-05-2014
		WO 2014075192 A1	22-05-2014
US 2010206791 A1	19-08-2010	CN 101805689 A	18-08-2010
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		US 2010206791 A1	19-08-2010
US 4429043 A	31-01-1984	NONE	
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		EP 2406368 A1	18-01-2012
		US 2013122579 A1	16-05-2013
		WO 2010102746 A1	16-09-2010

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(54) **Title**: SYSTEM AND METHOD FOR PRODUCING BIOGAS

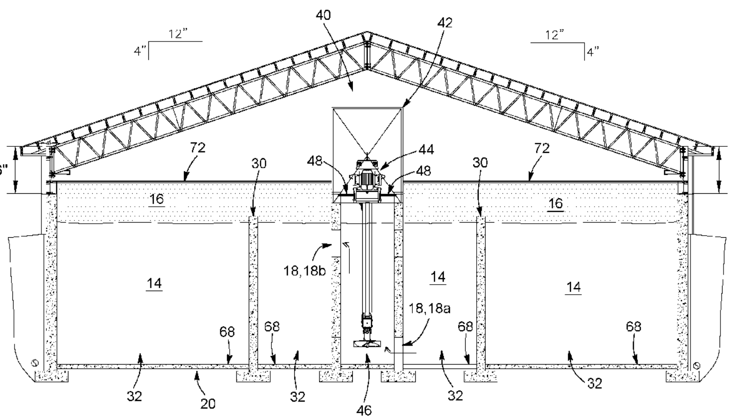

FIG. 2

(57) **Abstract**: A system (10) and method for producing biogas (16) from biomass (14). The system (10) includes a digestion reservoir (20) having a path defined by passageways (32) along which biomass (14) is conveyed and digested, the digestion reservoir (20) being configured for containing biogas (16) generated from a digestion of biomass (14) along the path. The system (10) also includes at least one mixing assembly (40) located along the path, each mixing assembly (40) being operatively connected between different passageway segments of the path so as to be able to selectively mix given biomass (14) from one segment to another, in order to increase overall production of biogas (16) along the path.

WO 2014/075192 A1

SYSTEM AND METHOD FOR PRODUCING BIOGAS

Field of the invention:

The present invention relates to biogas production. More particularly, the present invention relates to a system and method for producing biogas from decaying organic matter.

Background of the invention:

It is known to generate a biogas, typically made up of methane, from the decomposition of biomass. This process can be referred to as "biomass digestion".

As the biomass decomposes, the biogas is emitted and recuperated. Often, the recuperated biogas is combusted in a gas turbine so as to generate electrical energy. Although such a system of generating electrical energy has been demonstrated, it has been shown to have some of the following disadvantages: a) it requires a significant initial investment in the required equipment and is thus often dependent on governmental support; b) the technical skills needed to control, adjust and repair such a system is not in the normal field of competence of a lay person, such as a farmer (for example), who may supply the biomass, which results in increased maintenance and labour cost; c) there can be significant losses of energy during the generation of electricity from the biogas; d) etc.

Indeed, the energy losses mentioned in point c) above can occur during the transformation of the biomass from chemical to electrical energy, and ultimately reduce the amount of final usable energy. Firstly, to generate electrical energy, biogas must be combusted in the combustion chamber of the gas turbine. As the burning efficiency is often less than 100%, a first energy loss occurs. Secondly, the combusted biogas expands and pushes against a turbine/piston. At least some of the energy released by the combusted biogas is used up to move these components and to overcome mechanical friction, thereby resulting in a second energy loss. Thirdly, some of the components of the turbine are heated by the combustion of the biogas, and this heat is thus not usable energy, resulting in a third energy loss. Fourthly, the generator and control devices of the turbine provide electrical and mechanical resistance which must be overcome, thus resulting in a fourth energy loss. Finally, the electrical energy generated often must be consumed immediately, often cannot be stored, and/or can only be stored temporarily at great inefficiency, resulting in a fifth energy loss.

Some of the known systems used for generating biogas are described in the following American patents or patent applications known to the Applicant: 4,302,329; 4,350,588; 4,396,402; 4,927,530; 5,091,315; 5,096,579; 5,560,819; 6,342,378 B1; 6,395,173 B1; 6,451,589 B1; 6,521,129 B1; 6,613,562 B2; 6,783,677 B1; 6,811,701 B2; 6,841,072 B2; 6,982,035 B1; 7,078,229 B2; 7,179,642 B2; 7,608,439 B2; 7,641,796 B2; 7,727,396 B1; 7,820,429 B2; 7,951,296 B2; 7,993,521 B2; 8,202,721 B2; 8,298,424 B2; 8,318,997 B2; 8,394,271 B2; 2003/0111410 A1; 2004/0108267 A1; 2004/0154982 A1; 2006/0065593 A1; 2006/0289356 A1; 2007/0029243 A1; 2008/0138885 A1; 2008/0277336 A1; 2009/0123965 A1; 2009/0162914 A1; 2009/0218279 A1; 2009/0227003 A1; 2009/0280557 A1; 2009/0305376 A1; 2009/0305379 A1; 2010/0105128 A1; 2010/0151552 A1; 2010/0233778 A1; 2011/0042305 A1; 2011/0180633 A1; 2011/0226440 A1; 2011/0228633 A1; 2011/0256603 A1; 2011/0275141 A1; 2011/0281254 A1; 2012/0009668 A1; 2012/0329139 A1; 2013/0029410 A1; 2013/0095546 A1; 2013/0095561 A1; 2013/0133386 A1; 2013/0146533 A1; and 2013/0183752 A1.

Also known to the Applicant are the following documents: CA 1,198,605; DE 10 2007 024 947 A1; DE 20 2010 015 332 U1; WO 2013/039407 A1; and WO 2013/144703 A1.

In general, a first type of system for generating biogas, which can be referred to as an "infinitely mixed" system, typically consists of a large tank made of concrete which contains the digesting biomass (manure, for example). The tank is covered by a leaktight dome which prevents the generated biogas from escaping, and provides a volume in which the biogas accumulates over the digesting biomass. The biomass often must be lightly agitated to facilitate the bacterial reaction and so as to avoid creation of a top solid layer of dried biomass that would stop biogas emission. Such a system often requires 30 days to complete biomass digestion, and digested biomass must be evacuated at the end of the cycle and replaced by new biomass. Although such a system allows for the bacteria digesting the biomass at the end of the cycle to contact the new biomass to be digested and thus to activate the reaction on that new biomass, it can include some of the following disadvantages:

a) the new entering biomass is often mixed without control with old exiting biomass which is at the end of the digesting process, which can result in new biomass being expelled from the system and old biomass that has already been digested being kept in the system, and thus reducing biogas generation for a given volume of digesting biomass;

b) whenever maintenance or replacement needs to be performed, such as on the agitators of the biomass, for example, the system is stopped, accumulated biogas is evacuated to atmosphere, and digested manure is returned to the pit from whence it came. At this time, electrical energy production is stopped for many weeks, and system reboot requires roughly 60 days, which can correspond to the time needed to fill the tank again and reactivate the digestion reaction with bacteria, thereby reducing the amount of usable energy generated by the system, and also profitability; and

c) digesting biomass often must be maintained around 100°F to obtain the optimal reaction speed and quantity of biogas. Some energy must thus be injected into the biomass to maintain this temperature. This energy can represent around 25% of the total energy generated by the biogas system. Many systems of the prior art use the heat from the turbine along with a heat exchanger to pre-heat arriving new biomass before its addition in the tank. Such components often require maintenance and cleaning, and require the pumping and circulation of heated fluid, all of which increase complexity and reduce the final usable electric energy.

Another such system used for generating biogas, commonly referred to as a "plugged flow" system, often consists of a long tunnel. New biomass enters the tunnel, and pushes against the older biomass at the end of digesting process, which is expelled from the tunnel at the same rate as the arrival of the new biomass. The size and length of the tunnel can be calibrated with the daily manure production volume of the farm, or the input quantity for other processes, so as to obtain a processing time of about 30 days. A light tumbling effect is applied to avoid creation of a solid crust on the top of the biomass that would block biogas emission. Although such a system can allow for control of the digesting time of biomass in the tunnel because new biomass pushes against older biomass and thus forces the older biomass out the end of the tunnel, it can include some of the following disadvantages: a) the digestion reaction starts slowly because there is no mixing between the old biomass replete with bacteria and the new biomass which has much less, thus forcing the bacteria to migrate from old biomass to new; and b) the system does not address the maintenance and energy consumption disadvantages discussed above with respect to the "infinitely mixed" system.

Hence, in light of the above, there is a need for an improved system or method which, by virtue of their design, components and/or operating steps, would be able to overcome or at least minimize some of the aforementioned prior art disadvantages.

Summary of the invention:

An object of the present invention is to provide a system which satisfies some of the above-mentioned needs and which is thus an improvement over other related systems and/or methods known in the art.

According to the present invention, there is provided a system for producing biogas from biomass, the system comprising:

a digestion reservoir having a path defined by passageways along which biomass is conveyed and digested, the digestion reservoir having an inlet fluidly connected to the path for receiving biomass to be digested, and an outlet fluidly connected to the path for releasing digested biomass, the digestion reservoir being further configured for containing biogas generated from a digestion of biomass along the path; and

at least one mixing assembly located along the path, each mixing assembly being operatively connected between different passageway segments of the path so as to be able to selectively mix given biomass from one segment to another, in order to increase overall production of biogas along the path.

Other possible aspects, embodiments, variants and/or resulting advantages of the present invention, these being preferred and/or optional, are briefly described hereinbelow.

For example, according to a given possible embodiment, the path can be an internal path to the digestion reservoir, and the biomass can be agricultural manure provided by at least one neighboring farm, the manure displaying "fluid-like" behavior so as to be pumped into the system for processing (ex. digesting, biogas production, etc.), although various other types of biomass are contemplated by the present system, as will be explained hereinbelow.

According to another aspect of the present invention, there is also provided a system for producing biogas from biomass, the system comprising:

a digestion reservoir having a path along which biomass is conveyed and digested, the digestion reservoir having an inlet fluidly connected to the path for receiving biomass to be digested, and an outlet fluidly connected to the path for releasing digested biomass, the digestion reservoir being further configured for containing biogas generated from a digestion of biomass along the path; and at least one mixing assembly located along the path, each mixing assembly being operatively connected between upstream and downstream passageways of the path so as to be able to selectively transfer given biomass from one passageway to another, in order to increase overall production of biogas along the path.

According to yet another aspect of the present invention, there is also provided a system for producing biogas from decaying organic matter, the system comprising:

a reservoir for collecting the biogas, the reservoir comprising an inlet for receiving organic matter to be processed and an outlet for conveying decayed organic matter, organic matter being conveyed from the inlet to outlet; and

at least one vertical divider affixed to a base of the reservoir and configured for dividing the reservoir into a first passageway and a second passageway extending at least partially alongside the first passageway, organic matter decaying and producing biogas while being conveyed from the inlet along the first and second passageways and towards the outlet.

In some optional configurations, the reservoir is sealed, and/or heated such as with circulating heated water, thereby maintaining the organic matter at a certain temperature range. Optionally, the organic matter is agricultural manure, such as liquid manure.

The at least one vertical divider can be many vertical dividers, each vertical divider defining another passageway. For example, there can be one single vertical divider dividing the reservoir into two passageways. Alternatively, there can be two vertical dividers dividing the reservoir into three passageways. Alternatively also, there can be three vertical dividers dividing the reservoir into four passageways, etc. The vertical dividers can include an agitation unit for agitating the organic matter as it is conveyed. The agitation unit can also transfer decayed and/or partially decayed organic matter from one passageway to non-decayed organic matter in a preceding passageway.

The system can also include an energy storage unit. The energy storage unit can be a volume of liquid, such as water, contained within a suitable container, which stores the heat produced from burning the biogas. Optionally, the energy stored in the energy storage unit can be used wherever a reliable source of heat is required, such as in a greenhouse, for example.

According to another aspect of the present invention, there is provided a method for producing biogas from biomass (ex. organic matter), the method comprising the steps of:

a) conveying and digesting biomass in a digestion reservoir along a path defined by a plurality of passageways; and
b) transferring or mixing given biomass from one passageway to another in order to increase overall production of biogas along the path of the digestion reservoir.

The method may comprise the step of agitating biomass at discrete locations along the path.

The method may also comprise the step of introducing beneficial bacteria into the digestion reservoir.

The method may also comprise the step of regulating the temperature of the digestion reservoir, and/or of other basins used therewith.

The method may also comprise the step of maintaining the biomass at a temperature of about 100°F.

The above-mentioned step b) may comprise the step of digesting biomass during a period of about 30 days.

According to another aspect of the present invention, there is provided a method for producing biogas from decaying organic matter, the method comprising the steps of:

a) introducing the organic matter to a reservoir; and

b) displacing the decaying organic matter within the reservoir in adjacent passageways, the decaying organic matter producing biogas while being displaced.

In some optional configurations, the method also includes the steps of introducing beneficial bacteria into non-decayed organic matter. Such an introduction of bacteria can be accomplished by agitating and/or transferring the organic matter, as described above.

According to another aspect of the present invention, there is provided a fluid circuit provided with the above-mentioned system(s) and/or components thereof.

According to another aspect of the present invention, there is provided an facility (ex. farm, plant, etc.) provided with the above-mentioned system(s), fluid circuit and/or components thereof.

According to another aspect of the present invention, there is provided a method of installing (i.e. assembling) and/or operating the above-mentioned system(s), fluid circuit and/or facility.

According to another aspect of the present invention, there is provided a kit with corresponding components for assembling the above-mentioned system(s) and/or fluid circuit.

According to yet another aspect of the present invention, there is also provided a method of assembling components of the above-mentioned kit.

According to yet another aspect of the present invention, there is also provided a fluid (i.e. biogas) having been produced with the above-mentioned kit, system(s), fluid circuit, facility and/or method(s).

The objects, advantages and other features of the present invention will become more apparent upon reading of the following non-restrictive description of optional embodiments thereof, given for the purpose of exemplification only, with reference to the accompanying drawings.

Brief description of the drawings:

Figure 1 is top plan view of a system for producing biogas, according to an optional configuration of the present invention.

Figure 2 is an exposed side elevational view of a reservoir being shown with organic matter and biogas, according to an optional configuration of the present invention.

Figure 3 is top plan view of the system of Figure 1 being shown provided with greenhouses for receiving heat byproducts.

Figure 4a, 4b and 4c provide side elevational views of the system of Figure 1.

Figure 5a, 5b and 5c provide close-up views of certain components shown in Figure 4.

Figure 6 is an enlarged view of a portion of what is shown in Figure 1.

Figure 7 is an enlarged view of another portion of what is shown in Figure 1.

Figure 8 is a perspective view of a wall arrangement of a reservoir according to an optional configuration of the present invention.

Figure 9 is another perspective view of what is shown in Figure 8.

Figure 10 is a facility provided with a system for producing biogas, according to an optional configuration of the present invention, including the wall arrangement of Figure 8 being now shown covered by outer portions of the facility.

Detailed description of optional embodiments of the invention:

In the following description, the same numerical references refer to similar elements. The embodiments, geometrical configurations, materials mentioned and/or dimensions shown in the figures or described in the present description are optional embodiments only, given for exemplification purposes only.

Moreover, although the present invention was primarily designed for generating biogas from organic matter, it may be used with other types of matter and objects, and in other fields and for other purposes. For this reason, expressions such as "biogas", "biomass", "organic matter" , etc., used herein should not be taken as to limit the scope of the present invention and includes all other kinds of objects or fields with which the present invention could be used and may be useful.

Moreover, in the context of the present invention, the expressions "system", "kit", "plant", "reservoir", "device", "digester", "assembly", "station" and "unit", as well as any other equivalent expressions and/or compound words thereof will be used interchangeably. This applies also for any other mutually equivalent expressions, such as, for example: a) "fluid", "gas", "liquid", "slurry", "supply", "manure", etc.; b) "biomass", "organic matter", etc.; c) "decaying", "decomposing", "producing", "generating", "promoting, "increasing", etc.; d) "agitating", "perturbing", "mixing", "transferring", "displacing", "pumping", etc.; e) "new", "non-digested", "upstream", "less-digested", etc.;

f) "old", "downstream", "digested", "more-digested", etc.; g) "upper", "top", etc.; h) "lower", "bottom", etc.; and as well as for any other mutually equivalent expressions, pertaining to the aforementioned expressions and/or to any other structural and/or functional aspects of the present invention.

Furthermore, in the context of the present description, it will be considered that expressions such as "connected" and "connectable", or "mounted" and "mountable", may be interchangeable, in that the present invention also relates to a kit with corresponding components for assembling a resulting fully assembled system.

In addition, although the optional embodiments of the present invention as illustrated in the accompanying drawings may comprise various components, and although the optional embodiments of the system as shown consist of certain geometrical configurations as explained and illustrated herein, not all of these components and geometries are essential to the invention and thus should not be taken in their restrictive sense, i.e. should not be taken as to limit the scope of the present invention. It is to be understood that other suitable components and cooperation thereinbetween, as well as other suitable geometrical configurations may be used for the system and corresponding parts according to the present invention, as will be briefly explained hereinafter and as can be easily inferred herefrom, without departing from the scope of the invention.

<u>List of numerical references for some of the corresponding optional components illustrated in the accompanying drawings</u>:

10. system
12. evacuation pit
14. biomass (ex. "organic matter")
16. biogas
18. opening
18a. lower opening

18b. upper opening
20. digestion reservoir
22. inlet (of digestion reservoir)
24. outlet (of digestion reservoir)
26. hydrolysis pit
28. inflow pipe (to hydrolysis pit)
30. upright or vertical divider (or simply "divider")
32. passageway (along digestion path)
32a. first passageway
32b. second passageway
32c. third passageway
32d. fourth passageway
40. mixing assembly (or "transferring" assembly – ex. an "agitation unit")
42. vertical structure (or vertical "chimney")
44. agitation unit (or simply "agitator")
46. mixing device (ex. propeller, etc.)
48. cover
50. energy storage unit
52. hot water pit
54. burner
56. heat exchanging circuit
60. greenhouse
62. pipeline
64. feeding pipe
66. pump
68. base (of digestion reservoir)
70. temperature-regulating system
72. dome (of reservoir)

Broadly described, the present invention relates to a system 10 and a method for producing biogas 16 from decaying biomass 14, hereinafter referred to also as "organic matter" 14. The words "produce" and "producing" as used herein refer to the creation, generation, promotion, emission, etc. of biogas 16 from the decaying organic matter 14. Said differently, the decay of organic matter 14 results in the release of biogas 16, and it can therefore be said that the biogas 16 is "produced" from the decaying organic matter 14. The term "biogas" 16 can refer to any gaseous or semi-gaseous fluid produced by the breakdown of the organic matter 14, in aerobic, anaerobic, and/or any combination of these conditions. In some optional configurations, the biogas 16 is largely composed of methane. The term "decay" as used herein can refer to the rot, decomposition, break down, deterioration, dilapidation, disintegration, etc. of the organic matter 14 through natural or assisted processes. The expression "biomass" or "organic matter" 14 as used herein refers to any material that has come from a living and/or once-living organism and/or organisms, and which is capable of decay. As such, the organic matter 14 can be plant and/or animal-based biomass 14, manure, sewage, municipal waste, green waste, plant material, crops, etc. The organic matter 14 can be solid, gaseous, liquid, and/or any of these states of matter combined. In some optional configurations of the present invention, the organic matter 14 being used is agricultural animal manure, and some of these configurations may be described with reference to such manure. It is understood that such a description does not limit the use of the system or method to manure in particular.

Referring to Figures 1, 4, and 5, the system 10 has a reservoir 20, which may be sealed. The term "sealed" as used to describe the reservoir 20 means that the reservoir 20 is substantially impermeable to fluids contained therein. Some examples of such fluids include liquid portions of the organic matter 14, such as agricultural manure in liquid form (i.e. slurry). These liquid portions are contained within the reservoir 20, and the reservoir 20 is thus impermeable because it does not allow said liquid to escape. Another example of such fluids is the biogas 16. The reservoir 20 is intended to prevent the biogas 16 from escaping, thereby allowing it to accumulate above the organic matter and be collected. Therefore, the reservoir 20 can take the form of, or be equipped with, a leak-proof dome 72 in which the biogas accumulates. The reservoir 20 can also be impermeable to solid organic matter 14. The reservoir 20 is any volume within which fluid and/or solids can collect. As such, the reservoir 20 can be a basin, container, repository, holder, pond, pool, receptacle, reserve, etc. which stores the organic matter 14 and allows it to be digested so as to produce biogas.

The reservoir 20 includes an inlet 22. The organic matter to be processed is brought into the reservoir 20 through the inlet 22. As such, the inlet 22 can be any conduit, pipe, opening, aperture, etc. The inlet 22 can also include a pump 66 and/or other pressurized unit which allows the reservoir 20 to receive the organic matter under pressure, or from a fluid circuit. Consider now the example where the organic matter is agricultural liquid manure. In such an optional configuration, one farm or many farms transfer their liquid manure to a tempering reservoir, such as a hydrolysis pit 26, for example, via a series of inflow pipes 28. There, the manure is allowed to settle, and the manure temperature can be raised to 100°F and the a cidity level (PH) can be verified, adjusted, etc. Once ready, the liquid manure is then transferred to the main reservoir 20, which is known as the digestion reservoir 20 or "digester pit". From the hydrolysis pit 26, the manure enters the digestion reservoir 20 via the inlet 22.

The reservoir 20 also includes an outlet 24. The outlet 24 conveys the decayed organic matter from the reservoir 20. As with the inlet 22 described above, the outlet 24 can include a pump and/or pressurized unit to convey the decayed organic matter from the reservoir 20. As explained below, the passage of the decaying organic matter through the reservoir 20 results in the production of biogas. "New" organic matter (i.e. organic matter just introduced through the inlet 22 and/or organic matter that has not significantly decayed) thus moves through the reservoir 20. As the new organic matter decays, it becomes "older" (i.e. is not likely to decay further or as much), and is thus less likely to produce biogas. Advantageously, the outlet 24 of the reservoir 20 allows for this older organic matter to be evacuated, expelled, removed, etc. from the reservoir

20, thereby creating space within the reservoir 20 for more productive new organic matter to be introduced into the system 10.

The organic matter is in motion within the reservoir 20, such that it is conveyed from the inlet 22 to the outlet 24. Such motion and/or conveyance can be achieved through many different techniques. Indeed, one example of such a technique involves having a digestion reservoir 20 with a downwardly-sloping base 68, that is, angling a base 68 of the reservoir 20 towards the outlet 24 such that the organic matter flows under gravity from the inlet 22 to the outlet 24, which advantageously reduces the complexity of the system 10. Alternatively, if a faster motion and/or conveyance is desired, a mechanical conveyance, such a pump, pressurized unit, a conveyor, etc. can be used. In yet another possible alternative, the mere addition of organic matter at the inlet 22 can propel organic matter already in the reservoir 20 toward the outlet 24. Of course, many other such techniques can be used to convey the organic matter, and these techniques are within the scope of the present invention. In some optional configurations, a hot-water circulation circuit and/or other temperature-regulating system 70 (i.e. a temperature-"maintaining" system 70 or temperature-"adjusting" system 70) is provided around and/or under the hydrolysis pit 26 and/or digester reservoir 20, such as in the wall(s) and/or floor(s) of these structures. Temperature-regulating can be done "actively" by means of heating/cooling systems, or can be simply done "passively" by means of insulating panels, for example. This advantageously allows for the maintenance of the temperature of the digesting organic matter at an optimal level of around 100℉, for example. The energy required for this temperature maintenance can advantageously be provided by burning the produced biogas, for example.

The system 10 also includes at least one vertical divider 30, which can be affixed to the base of the reservoir 20. The divider 30 can be any wall, partition, barrier, impediment, etc. which extends in a substantially upright manner (such as vertically from the base, for example), and which divides the reservoir 20 into passageways 32. Each passageway 32 can be any aisle, alley, couloir, path, etc. along which the organic matter can be conveyed, and which alone or in conjunction with other such passageways 32, takes the organic matter from the inlet 22 to the outlet 24. As such, the passageways can be of any dimension, shape, and/or configuration which allow such functionality.

One optional configuration of the pathways 32 is shown in Figure 1. The passageways 32 being exemplified are "rectangular" (although various other possible geometrical configurations and/or dispositions are within the scope of the present invention) and extend alongside each other such that the end of one passageway 32 exits into the entrance of the subsequent, adjacent passageway 32. It is apparent that the passageways 32 are not limited to such a configuration, and can take any other configuration, shape, form, etc. depending on the following non-restrictive list of factors: available area and/volume of reservoir 20, the expected processing rate of organic matter, the nature of the organic matter being processed, etc. Indeed, another possible configuration of the passageways 32 can be a series of concentric circles, where new organic matter enters the inlet 22 of an outermost circular passageway 32 and is conveyed while it decays through the series of inner concentric circular passageways 32 before exiting through the outlet 24 near the shared center point of the concentric circles. Thus, it is understood that the expression "extends alongside" as used to describe the orientation of the passageways 32 refers to any configuration of the passageways 32 that allows them to remain, at least in part, adjacent and/or in proximity to one another.

In the optional configuration shown in Figure 1, each divider 30 after the first divider 30 adds another rectangular passageway 32. Therefore, the three dividers 30 shown in Figure 1 provide four passageways 32 within the enclosed reservoir 20. Furthermore, each divider 30 can divide the reservoir 20 into first and second passageways 32. It is understood that the expressions "first" and "second" as used herein do not limit the number of passageways 32 to only two, nor do they require that each divider 30 create two passageways 32.

The dividers 30 and/or the system 10 may include "mixing" or "transferring" assemblies 40, herein referred to also as agitation units 40. The agitation units 40 can be used to maintain mixing of the organic matter, thereby preventing a hardening and/or drying out of its upper surface which may prevent the emission of biogas. The agitation units 40 can also be used to add older organic matter to the new organic matter, thereby advantageously transferring the beneficial bacteria from the older organic matter to the new and thus accelerating activation of the new organic matter. As exemplified in Figure 1, each agitation unit 40 can be installed at an end of each divider 30 such that it performs the above-mentioned functions on the organic matter before it enters a different passageway 32.

In one optional configuration, and as exemplified in Figure 2, each agitation unit 40 may include a vertical chimney 42 installed at strategic locations in the reservoir 20, such as at the ends of the dividers 30. Each vertical chimney 42 can be equipped with an agitator 44 and/or any other similar agitating device that also acts as a transferring/mixing device. The agitator 44 can include a mixing device 46, such as a rotating propeller, which agitates the organic matter 14 so as to prevent it from solidifying and thus forming a barrier to the release of the biogas 16. The mixing device 46 can also create a force, pressure, impetus, etc. that is intended to transfer the organic matter 14 from a lower portion of one passageway 32 to the upper portion of an adjacent passageway 32, as exemplified by the arrows in Figure 2 showing the direction of movement of the organic matter 14. This transfer can occur through openings 18 in the dividers 30. In one example of such a transfer, the organic matter 14 is brought, pulled, forced, etc. through a lower opening 18a by the mixing device 46, up through the vertical chimney 42, and then into an upper portion of the organic matter 14 through an upper opening 18b. As exemplified in the accompanying drawing, the system may comprise pair of vertical chimneys 42 at different locations along the path of the digestion reservoir.

Each vertical chimney 42 can consist of two parts. A first part transfers older/digested organic matter 14 from the base of the reservoir 20 in one passageway 32 on one side of its divider 30 to the top of the new organic matter 14 in the preceding adjacent passageway 32 on the other side of its divider 30, as previously explained. Of course, the operation of the vertical chimney 42 is not limited to a bottom-to-top transfer. Indeed, a second part of the vertical chimney 42 can transfer not-yet-fully digested organic matter 14 from the top of the reservoir 20 in one passageway 32 on one side of its divider 30 to the bottom of the new organic matter 14 in a preceding adjacent passageway 32 on the other side of its divider 30. The advantage of having passageways 32 that extend alongside one another can thus be clearly understood. This agitation and transferring of organic matter 14 advantageously allows for a mixture of beneficial bacteria, thus allowing the new organic matter 14 to acquire the beneficial bacteria sooner in the process when compared to conventional systems, and thus further assisting production of the biogas. Of course, the configuration and operation of the vertical chimneys 42 is not limited to the description given herein, and the vertical chimneys 42 can operate differently than as described provided that they can agitate the organic matter 14 and effect a transfer of beneficial bacteria from one passageway 32 to another passageway 32 (whether an adjacent passageway 32, or a more remote passageway 32). Indeed, mixing assemblies 40 according to the present system are not necessarily limited to extending between immediately adjacent passageways 32, in that, for example, the system 10 contemplates the idea of transferring organic matter from one of the more "downstream" passageways 32, where "older" biomass rich in digestion bacteria can be found, to one of the more "upstream" passageways 32 where new biomass is found and which could benefit from such advantageous digestion bacteria so as to increase overall production of biogas for a same given time period or cycle (ex. 30 days), and for a given volume of biomass 14 inside the digestion reservoir 20, something that is not possible with conventional systems.

In some optional configurations of the present system 10, the vertical chimney 42 can have a cover 48 that can be opened on top of each individual part of each vertical chimney 42, thereby giving direct access to the interior of the vertical chimney 42. The cover 48 can be of any suitable size and configuration, and can limit the size of the opening in the vertical chimney 42 to only a small area such that the biogas 16 is prevented from escaping to atmosphere because the level of the organic matter 14 is higher than the level of the upper opening 18a, as exemplified in Figure 2, as but one possible configuration of the vertical chimney 42. The cover 48 also facilitates access so as to inspect, remove, maintain and/or reinstall the agitation unit 40, and/or other aspects of the system 10, without interrupting or impacting the digestion process. Advantageously, such access can increase the total production of biogas 16, and thus increase profitability and avoid significant downtime periods in energy production.

The technique for agitating/transferring the digesting organic matter 14 is not limited to the technique described above. Similarly, the agitation unit 40 is not limited to the vertical chimney 42 described, and can be any other mechanical device providing the same and/or similar functionality. Indeed, the techniques described above for opening the vertical chimneys 42 and/or for transferring digesting organic matter 14 from one passageway 32 to another is not limited to what is described above, and vertical chimneys 42 with intake and outlet opening(s) 18 that are on same side so as to only agitate in the same passageway 32 is also part of the present system 10.

Indeed, in most conventional digesters, such as "plug flow" digesters for example, sediments tend to accumulate and solidify at the bottom of the reservoir over time, and these ever-increasing deposited layers tend to reduce the effective flow rate of biomass along the reservoir, in some cases, causing the digester to become very inefficient or even inoperable. The provision of a mixing assembly 40 according to the present system 10, at one or several discrete locations along the path of the digestion reservoir 20, with corresponding optional components (agitation units 44, openings 18, etc.) enables to prevent or at the very least minimize the occurrence of sediments depositing at the bottom of the reservoir 20 along the path, via localized agitations of and/or mixing between passageways 32, thereby enabling an effective flow rate of biomass 14 along the entire digestion reservoir 20 and corresponding system 10.

It is of course understood that the size, configuration, and/or capacity of the system 10 and/or its features and components can be adapted to specific on-site requirements and is not limited to a particular size, configuration, and/or capacity. Furthermore, the system 10 and/or its features and components can be applied separately to upgrade an existing system for generating biogas 16 or for burning combustibles. Also, the use of dividers 30 and/or of mixing assemblies 40 according to the present system is not limited to the digestion reservoir 20, and may be employed in other parts of the system 10 (ex. hydrolysis pit 26, etc.), as exemplified in Figures 8 and 9.

Having described some of components of the system 10, the production of biogas by conveyance through said system 10 will now be described.

Returning to Figure 1, in one optional configuration, the reservoir 20 is configured to digest the organic matter in about 30 days. The series of passageways 32 force the digesting organic matter forward when new organic matter is added to the reservoir 20 at the inlet 22. Older digested organic matter is thus expelled from the system 10 at the outlet 24, and can be returned by gravity or under pressure to an evacuation pit 12 for its transfer to to another application. It is thus apparent how digestion time is controlled in the reservoir 20 by the addition of new organic matter and the expulsion of older organic matter, which has been allowed to remain in the reservoir 20 (and thus produce biogas) for a relatively long period. The digestion time can be varied as required by simply varying the rate of addition of new organic matter, for example.

Biogas is generated as the organic matter decays while being conveyed through the passageways 32. To "kick-start" digestion, bacteria can be added to the organic matter. The bacteria can be any microorganism which releases biogas as it consumes the organic matter. The addition of bacteria can be performed manually, at the inlet 22, for example. Alternatively, and advantageously, the digestion reaction of the organic matter can be started by adding the bacteria which is already found in relatively large numbers in the organic matter in adjacent and/or passageways 32 in front (i.e. "downstream") of the organic matter. Thus, a part of older digesting organic matter already containing bacteria can be conveniently and advantageously transferred from the end of one passageway 32 to the beginning of another passageway 32. In the optional configuration shown in Figure 1, the transfer of older organic matter can occur from passageway 32 "B" to the beginning of passageway 32 "A", thereby activating digestion of the new organic matter. This transfer can be affected with the agitation units 40 described above. At the same time, the local movement of the agitation units 40 can provide a mixing effect to maintain a smoothly-moving organic matter, thereby stimulating biogas production and avoiding creation of a solid dry layer on top of the organic matter that would prevent biogas from escaping the digesting organic matter.

It can thus be appreciated that the system 10 can allow for a controlled mixing and digesting of older and new organic matter. At the end of passageway 32 "B", the digesting organic matter can be about 15 days old, for example. Thus, the transfer of organic matter between passageways 32 can be done from one passageway 32 to its immediately preceding and/or adjacent passageway 32, thereby avoiding transferring organic matter from the outlet 24 to the inlet 22 which may be too decayed to be kept in the reservoir 20. In some optional configurations, the transferring/mixing/agitation action can be controlled in frequency and time to facilitate mixing and agitation.

In some optional configurations, the system 10 can have an energy storage unit 50. The biogas produced in the reservoir 20 has relatively high energy potential due to its chemical energy. In order to take advantage of such energy, it is often desirable to store it such that it can be used at a later time. This can be achieved in many ways. For example, the energy of the biogas can be converted to electrical energy, such as by combusting the biogas in an electrical turbine. Alternatively, the energy of the biogas can be stored as thermal energy. This accumulated thermal energy can then later be used for any application needing a reliable supply of heat energy.

The energy storage unit 50 can include a hot water pit 52, which can contain a large volume of a liquid for storing the heat energy, such as water. The energy storage unit 50 can also include a burner 54, which burns the accumulated biogas and transfers the heat generated thereby to the water of the hot water pit 52. This transfer of heat from the burner 54 to the hot water pit 52 can be performed by using a heat exchanging circuit 56, which can be a series of pipes forming a hot gas circuit originating at the burner 54 and ending at an outside evacuation. These pipes can transfer the hot gas from the exhaust of the burner 54 through the water of the hot water pit 52, thereby heating the water while the pipes are simultaneously cooled by the water. Thus, calorific energy is accumulated in the water as water temperature rises. In order to advantageously preserve as much calorific energy as feasible, the walls of the hot water pit 52 can be insulated (with insulating panels, for example), thereby helping to maintain a high efficiency level. Consider the example of a hot water pit 52 which has the following dimensions 12 ft. x 24 ft. x 24 ft., which provides a volume of 6,912 cubic ft. In such a hot water pit 52, the accumulated thermal energy can be about 1,400,000 BTU / ℉.

In yet another example, consider the biogas generated from a system 10 calibrated for a farm having about 400 cows. Such a system 10 may produce enough heat energy to maintain a hot water pit 52 of 7,000 cubic ft. at a temperature of 130℉ for a significant period of time. This hot water may maintain a difference of about 60℉ (for example) over a reference such as 70℉, for ex ample. The accumulated available calorific energy accumulated in this hot water can thus be a minimum of about 84,000,000 BTU.

Once the system 10 has generated a reliable and usable energy source (i.e. thermal energy), such energy can be used as desired. Such heat can be used to supply an application that requires heat input, and which could thus avoid energy losses associated with the transformation of energy. Referring to Figure 3, one such application could be a greenhouse 60, for example.

At least one greenhouse 60 can be built near the system 10 and/or near the hot water pit 52. The greenhouse 60 could be floor-heated by using the thermic energy accumulated in the water of the hot water pit 52. Thus, the use of this thermic energy without transforming it into another form of energy can increase considerably the efficiency and the total available energy. In one example of how such a greenhouse 60 could be installed, a hot water pipeline 62 can be installed in the floor of the greenhouse 60. The pipeline 62 can be connected to the hot water pit 52 so as to transfer the heat of the hot water to the floor of the greenhouse 60. Thus, and as mentioned, relatively little energy is lost because no transformation of energy occurs. Thermal energy that was in the water is now in the greenhouse 60. It is understood that the transfer of thermal energy from the hot water pit 52 is not limited to being performed by pipes or the pipeline 62, and that any other suitable technique to transfer the heat energy, with or without transforming it, is within the scope of the invention.

Consider the example of a greenhouse 60 installed in a northern climate such as that found in the province of Québec, Canada, for example. The daily heat input required for a 1-acre greenhouse 60 during the coldest period of the year (January) is about 23,000,000 BTU. The system 10 calibrated for the manure of about 400 cows can maintain a hot water pit of about 7,000 cubic ft. at about 130℉ and thus can have enough accumulated energy to maintain the required temperature of a 1-acre greenhouse 60 for 2 days of this coldest period. Since the system 10 can allow maintenance without interruption, operators of the greenhouse 60 thus have a reliable source of heat.

It is of course understood that the thermal energy stored by the energy storage unit 50 is not limited to being used in a greenhouse 60, and that the thermal energy can be used for any application where a reliable source of heat is required. Also, one example of such an application relates to food production and food preservation before delivery. The use of thermal energy may not be necessary in warmer months of the year, or may be limited to simply prevent food from freezing. In summer months, the biogas can be used to create a cold environment using technology such as a propane refrigerator adapted to biogas. During transition periods (i.e. spring and fall), the use of the biogas can be split between these two applications. The versatility of the produced biogas thus advantageously allows for efficient use of the biogas yearlong, which can increase profitability of the system 10, and that of farm(s) or other facilities associated to the system 10.

Returning to Figure 1, and according to one aspect of the present invention, there is provided a method for producing biogas from decaying organic matter. The method includes the steps of introducing the organic matter to the reservoir 20. The method also includes the step of displacing the decaying organic matter within the reservoir 20 in adjacent passageways 32, and the decaying organic matter produces biogas while being displaced. In some optional configurations, the method also includes the steps of introducing beneficial bacteria into non-decayed organic matter so as to activate the reaction of the organic matter. Such an introduction of bacteria can be accomplished by agitating and/or transferring the organic matter, as described above.

The system 10 and corresponding parts may be made of substantially rigid materials, such as metallic materials, hardened polymers, composite materials, cementitious mixture, and/or the like, as well as possible combinations thereof, depending on the particular applications for which the system 10 is intended for, and the desired end results.

As can be easily understood when referring to the accompanying drawings, the following optional components and features of the system 10 and method offer several advantages with respect to the prior art, as will be explained in greater detail hereinbelow.

Indeed, the system 10 and method described herein is an improvement over the prior art in that, by virtue of its design and components, they provide a profitable biogas system 10 that can reduce the environmental foot print of known systems, and which uses technology within the normal field of competence of a lay person, such as a farmer. It can now be understood that the system 10 is designed in a way to obtain the advantages of the prior art "infinitely mixed" and "plugged flow" systems, while eliminating or improving disadvantages of these concepts discussed above.

Furthermore, the system 10 and method allow for the production of a significant level of usable energy by eliminating many steps of energy transformation and the attendant energy losses associated therewith. Indeed, the system 10 and method allow for the direct transfer of calorific energy generated by biogas to a storage medium, such as water, for example. In can thus be appreciated that the accumulation of calorific energy allows for the storage of excess energy, which can later be made available during a period of high need. Therefore, the final total usable energy is increased significantly.

One optional aspect of the system 10, such as the vertical chimneys 42 for example, advantageously allow maintenance of the agitation units 40 without stopping biogas production, and without emitting biogas into atmosphere.

Further advantageously, in northern areas, during a significant duration of the year, fruits and vegetables come from southern areas. This equates to dependence on long transportation routes that generate pollution and increase the environmental foot print of every citizen. The use of greenhouses 60 with the present system 10 allows for the production of food locally, which procures significant environmental advantages and provides a diversified source of income for a dairy farmer, as but one example.

Although preferred embodiments of the present invention have been briefly described herein and illustrated in the accompanying drawings, it is to be understood that the invention is not limited to these embodiments and that various changes and modifications could be made without departing form the scope and spirit of the present invention, as defined in the appended claims.

CLAIMS:

1. A system (10) for producing biogas (16) from biomass (14), the system (10) comprising:

a digestion reservoir (20) having a path defined by passageways (32) along which biomass (14) is conveyed and digested, the digestion reservoir (20) having an inlet (22) fluidly connected to the path for receiving biomass (14) to be digested, and an outlet (24) fluidly connected to the path for releasing digested biomass (14), the digestion reservoir (20) being further configured for containing biogas (16) generated from a digestion of biomass (14) along the path; and

at least one mixing assembly (40) located along the path, each mixing assembly (40) being operatively connected between different passageway segments of the path so as to be able to selectively mix given biomass (14) from one segment to another, in order to increase overall production of biogas (16) along the path.

2. A system (10) for producing biogas (16) according to claim 1, wherein the path comprises a plurality of passageways (32).

3. A system (10) for producing biogas (16) according to claim 1 or 2, wherein the passageways (32) are adjacent to one another.

4. A system (10) for producing biogas (16) according to any one of claims 1-3, wherein the passageways (32) are rectangular.

5. A system (10) for producing biogas (16) according to any one of claims 1-4, wherein the passageways (32) are defined by least one upright divider (30).

6. A system (10) for producing biogas (16) according to any one of claims 1-5, wherein each divider (30) projects upwardly from a base of the digestion reservoir (20).

7. A system (10) for producing biogas (16) according to any one of claims 1-3, wherein the passageways (32) are cylindrical.

8. A system (10) for producing biogas (16) according to claim 7, wherein the passageways (32) are concentric to one another.

9. A system (10) for producing biogas (16) according to any one of claims 1-8, wherein the digestion reservoir (20) is substantially impermeable to fluids.

10. A system (10) for producing biogas (16) according to any one of claims 1-9, wherein the digestion reservoir (20) comprises a dome for retraining biogas (16) produced from the system (10).

11. A system (10) for producing biogas (16) according to any one of claims 1-10, wherein each mixing assembly (40) comprises a vertical structure, the vertical structure (42) having a first opening fluidly connected to a first given passageway (32) of the path of the digestion reservoir (20), and the vertical structure (42) having a second opening fluidly connected to a second given passageway (32) of the path of the digestion reservoir (20).

12. A system (10) for producing biogas (16) according to claim 11, wherein the first opening is a bottom opening (18a) and wherein the second opening is a top opening.

13. A system (10) for producing biogas (16) according to claim 11, wherein the first opening is a top opening (18b) and wherein the second opening is a bottom opening.

14. A system (10) for producing biogas (16) according to any one of claims 1-13, wherein each mixing assembly (40) comprises a pair of first and second vertical structures (42), the first and second openings (18) of the first vertical structure (42) being respectively bottom and top openings (18a,18b), and the first and second openings (18) of the second vertical structure (42) being respectively top and bottom openings (18b,18a).

15. A system (10) for producing biogas (16) according to claim 14, wherein the first and second vertical structures (42) are adjacent to one another.

16. A system (10) for producing biogas (16) according to any one of claims 11-15, wherein each given vertical structure (42) comprises a cover (48) for selectively allowing access to an inside portion of said given vertical structure.

17. A system (10) for producing biogas (16) according to any one of claims 1-16, wherein each mixing assembly (40) is located at a distal end of a given divider (30), and wherein openings (18) of the mixing assembly (40) are fluidly connectable to adjacent passageways (32) through said given divider (30).

18. A system (10) for producing biogas (16) according to any one of claims 1-17, wherein each mixing assembly (40) comprises at least one agitation unit (44) for locally mixing biomass (14) being conveyed along the path and travelling about said at least one agitation unit (44).

19. A system (10) for producing biogas (16) according to claim 18, wherein each agitation unit (44) is provided with a mixing device (46).

20. A system (10) for producing biogas (16) according to claim 19, wherein the mixing device (46) is positioned adjacent to a given opening of a given mixing assembly (40).

21. A system (10) for producing biogas (16) according to any one of claims 1-20, wherein a level of biomass (14) contained in a given passageway (32) of the digestion reservoir (20) is maintained above a corresponding opening of the least one mixing assembly (40) associated to said given passageway (32) so as to prevent biogas (16) from escaping the system (10) via said at least one mixing assembly (40).

22. A system (10) for producing biogas (16) according to any one of claims 1-21, wherein a level of biomass (14) contained in the digestion reservoir (20) is maintained above an uppermost opening of the least one mixing assembly (40) of the system (10) so as to prevent biogas (16) from escaping the system (10) via said at least one mixing assembly (40).

23. A system (10) for producing biogas (16) according to any one of claims 1-22, wherein the system (10) comprises a hydrolysis pit (26) for providing the digestion reservoir (20) with biomass (14).

24. A system (10) for producing biogas (16) according to any one of claims 1-23, wherein the system (10) comprises at least one pump (66) for pumping biomass (14) from the hydrolysis pit (26) to the digestion reservoir (20).

25. A system (10) for producing biogas (16) according to any one of claims 1-24, wherein the biomass (14) is agricultural liquid manure provided by at least one

neighboring farm operatively connected to the hydrolysis pit (26) of the system (10) via at least on inflow pipe (28).

26. A system (10) for producing biogas (16) according to any one of claims 1-25, wherein the system (10) comprises an evacuation pit (12) for receiving digested biomass (14) from the outlet (24) of the digestion reservoir (20).

27. A system (10) for producing biogas (16) according to any one of claims 1-26, wherein the system (10) comprises at least one pump (66) for pumping digested biomass (14) out from the system (10).

28. A system (10) for producing biogas (16) according to any one of claims 1-27, wherein the digestion reservoir (20) comprises a downwardly-sloping base (68), and wherein biomass (14) is conveyed along the path of the digestion reservoir (20) by gravity via said downwardly-sloping base (68).

29. A system (10) for producing biogas (16) according to any one of claims 1-28, wherein biomass (14) is conveyed along the path of the digestion reservoir (20) via an inflow of new biomass (14) at the inlet (22) of the digestion reservoir (20) and via an outflow of old biomass (14) at the outlet (24) of the digestion reservoir (20).

30. A system (10) for producing biogas (16) according to any one of claims 1-29, wherein biomass (14) is conveyed along the path of the digestion reservoir (20) via a mechanical conveyance.

31. A system (10) for producing biogas (16) according to any one of claims 1-30, wherein the system (10) comprises a temperature-regulating system (70) provided about the digestion reservoir (20).

32. A system (10) for producing biogas (16) according to claim 23, wherein the system (10) comprises a temperature-regulating system (70) provided about the hydrolysis pit (26).

33. A system (10) for producing biogas (16) according to any one of claims 1-32, wherein biomass (14) is digested along the path of the digestion reservoir (20) by a natural process.

34. A system (10) for producing biogas (16) according to any one of claims 1-32, wherein biomass (14) is digested along the path of the digestion reservoir (20) by an assisted process.

35. A system (10) for producing biogas (16) according to any one of claims 1-34, wherein digestion bacteria are introduced into the digestion reservoir (20).

36. A system (10) for producing biogas (16) according to any one of claims 1-35, wherein biomass (14) is digested along the path of the digestion reservoir (20) during a period of about 30 days.

37. A system (10) for producing biogas (16) according to any one of claims 1-36, wherein the system (10) is used to produce methane.

38. A system (10) for producing biogas (16) according to any one of claims 1-37, wherein biogas (16) produced from the system (10) is recuperated and converted into electrical energy.

39. A system (10) for producing biogas (16) according to any one of claims 1-37, wherein biogas (16) produced from the system (10) is recuperated and stored into thermal energy.

40. A system (10) for producing biogas (16) according to any one of claims 1-39, wherein the system (10) comprises an energy storage unit (50) for storing thermal energy

41. A system (10) for producing biogas (16) according to claim 40, wherein the energy storage unit (50) comprises a burner (54) for burning biogas (16) produced by the system (10).

42. A system (10) for producing biogas (16) according to any one of claims 1-41, wherein the system (10) comprises a hot water pit (52) for receiving heat from burnt biogas (16) via a heat exchanging unit (56) conducting said burnt biogas (16).

43. A system (10) for producing biogas (16) according to claim 42, wherein the hot water pit (52) is operatively connected to at least one neighboring greenhouse (60).

44. A system (10) for producing biogas (16) according to claim 43, wherein the least one neighboring greenhouse (60) has a floor circuit heated by means of hot water provided by the hot water pit (52) .

45. A system (10) for producing biogas (16) according to any one of claims 42-44, wherein the system (10) comprises a temperature-regulating system (70) provided about the hot water pit (52).

46. A kit with components for assembling a system (10) according to any one of claims 1-35.

47. A method for producing biogas (16) from biomass (14), the method comprising the steps of:

c) providing a system (10) according to any one of claims 1-46;
d) conveying and digesting biomass (14) along the path of the digestion reservoir (20); and
e) transferring given biomass (14) from one passageway (32) to another in order to increase overall production of biogas (16) along the path.

48. A method for producing biogas (16) according to claim 47, wherein the method comprises the step of agitating biomass (14) at discrete locations along the path.

49. A method for producing biogas (16) according to claim 47 or 48, wherein the method comprises the step of introducing beneficial bacteria into the digestion reservoir (20).

50. A method for producing biogas (16) according to any one of claims 47-49, wherein the method comprises the step of regulating the temperature of the digestion reservoir (20).

51. A method for producing biogas (16) according to any one of claims 47-50, wherein the method comprises the step of maintaining the biomass (14) at a temperature of about 100°F.

52. A method for producing biogas (16) according to any one of claims 47-51, wherein step b) comprises the step of digesting biomass (14) during a period of about 30 days.

53. A method for producing biogas (16) according to any one of claims 47-52, wherein the method comprises the step of recuperating biogas (16) produced by the system (10) and converting it into usable energy.

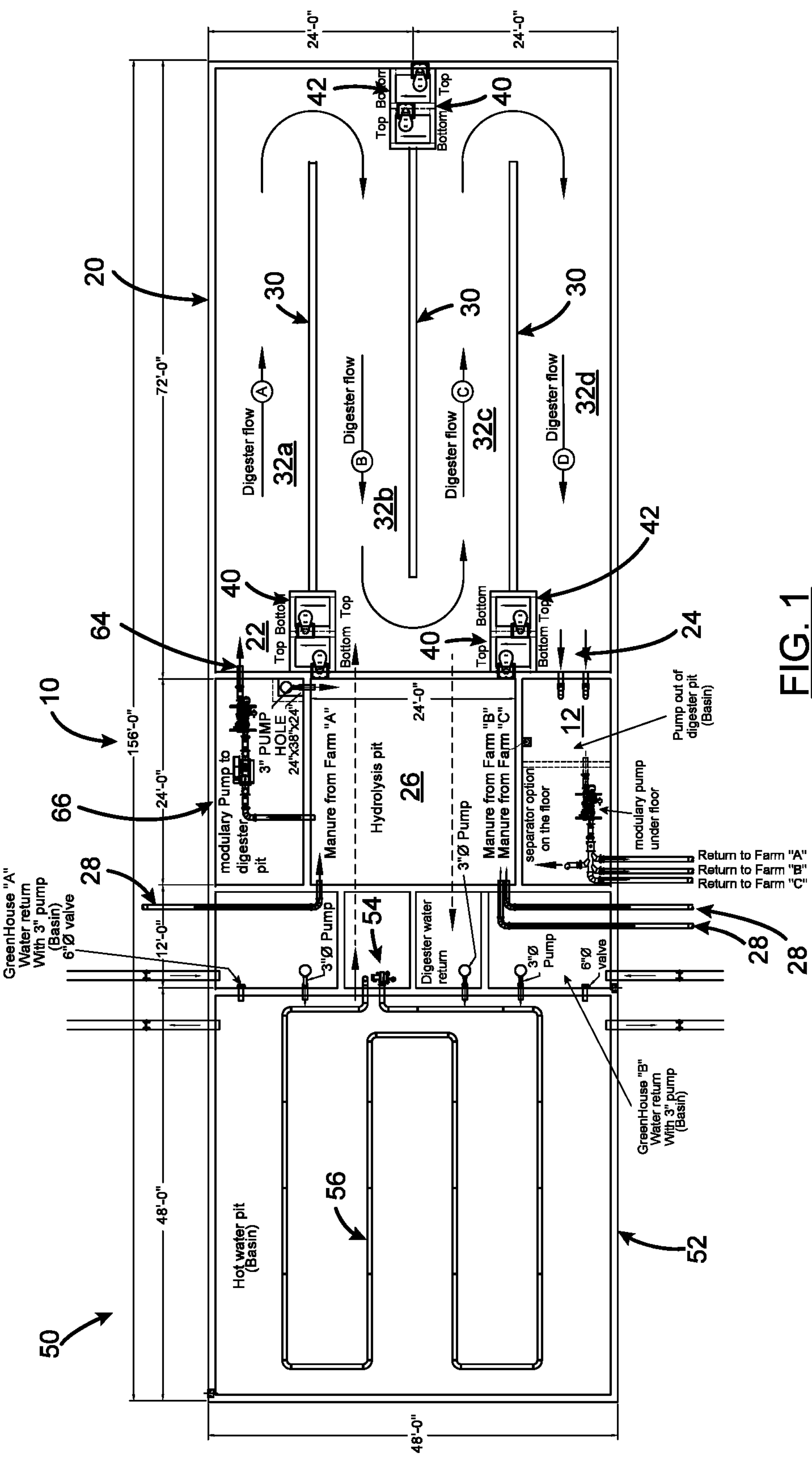
Digester flow
32a
32b
32c
32d
Hydrolysis pit
26
Manure from Farm "A"
Manure from Farm "B"
Manure from Farm "C"
3" PUMP HOLE 24"X38"x24"
modulary Pump to digester pit
modulary pump under floor
separator option on the floor
Pump out of digester pit (Basin)
Return to Farm "A"
Return to Farm "B"
Return to Farm "C"
3"Ø Pump
Digester water return
GreenHouse "A" Water return With 3" pump (Basin)
GreenHouse "B" Water return With 3" pump (Basin)
6"Ø valve
Hot water pit (Basin)
Top
Bottom
156'-0"
72'-0"
48'-0"
24'-0"
12'-0"
10
12
20
22
24
28
30
40
42
50
52
54
56
64
66

FIG. 1

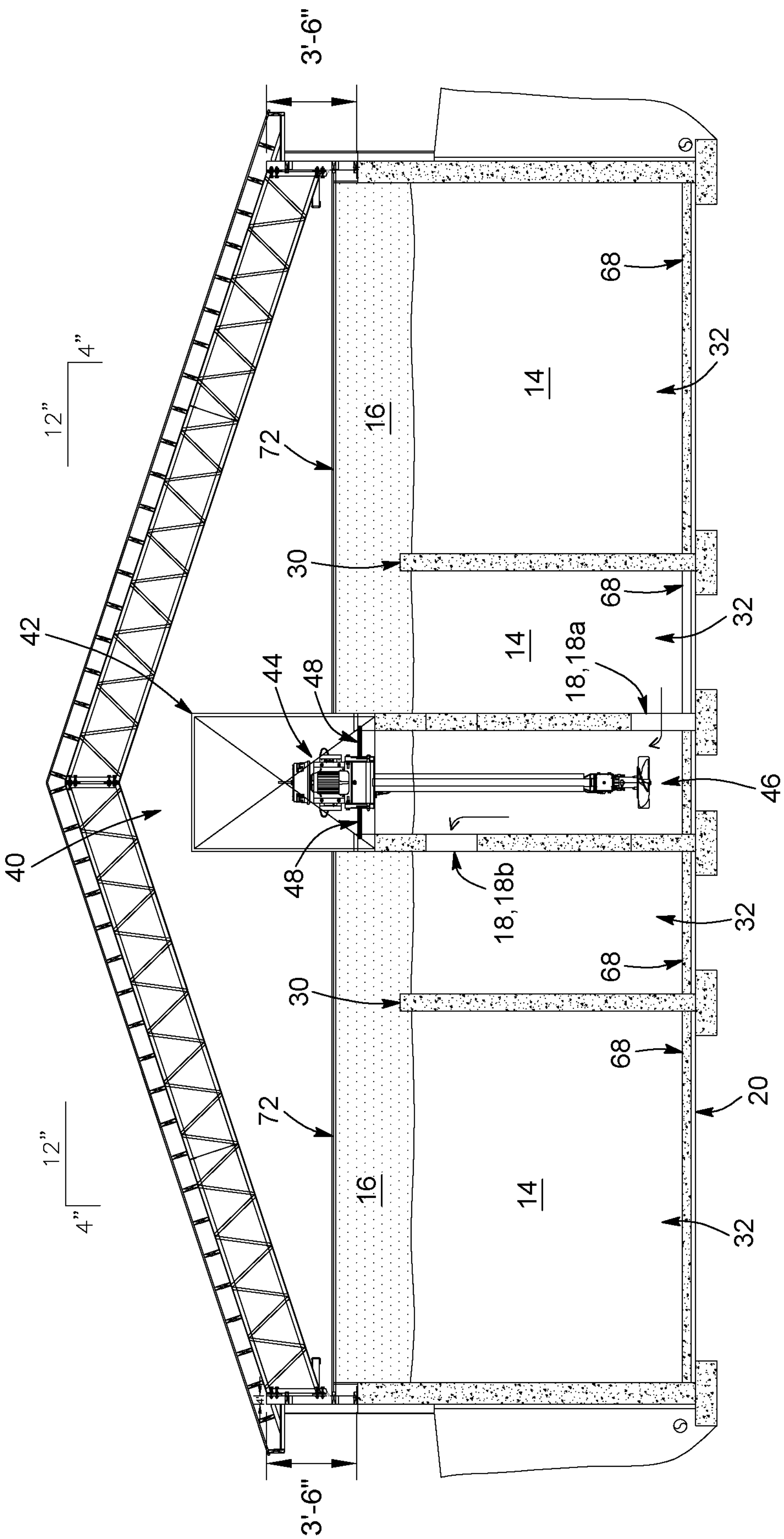
3'-6"
3'-6"
12"
4"
12"
4"
14
14
14
16
16
18,18a
18,18b
20
30
30
32
32
32
32
40
42
44
46
48
48
68
68
68
68
72
72

FIG. 2

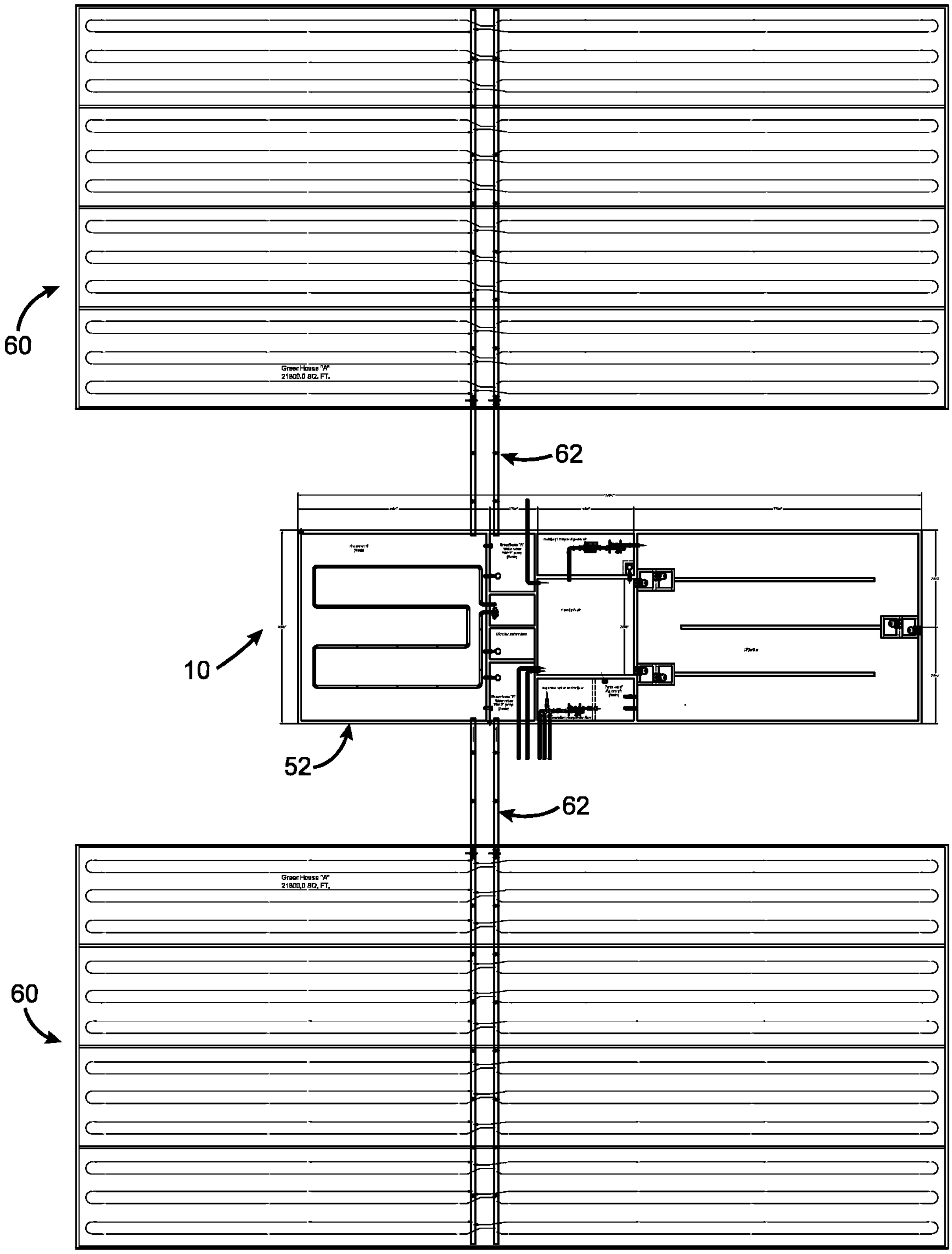
60
62
10
52
62
60
GreenHouse "A"
21800.0 SQ. FT.
GreenHouse "A"
21800.0 SQ. FT.

FIG. 3

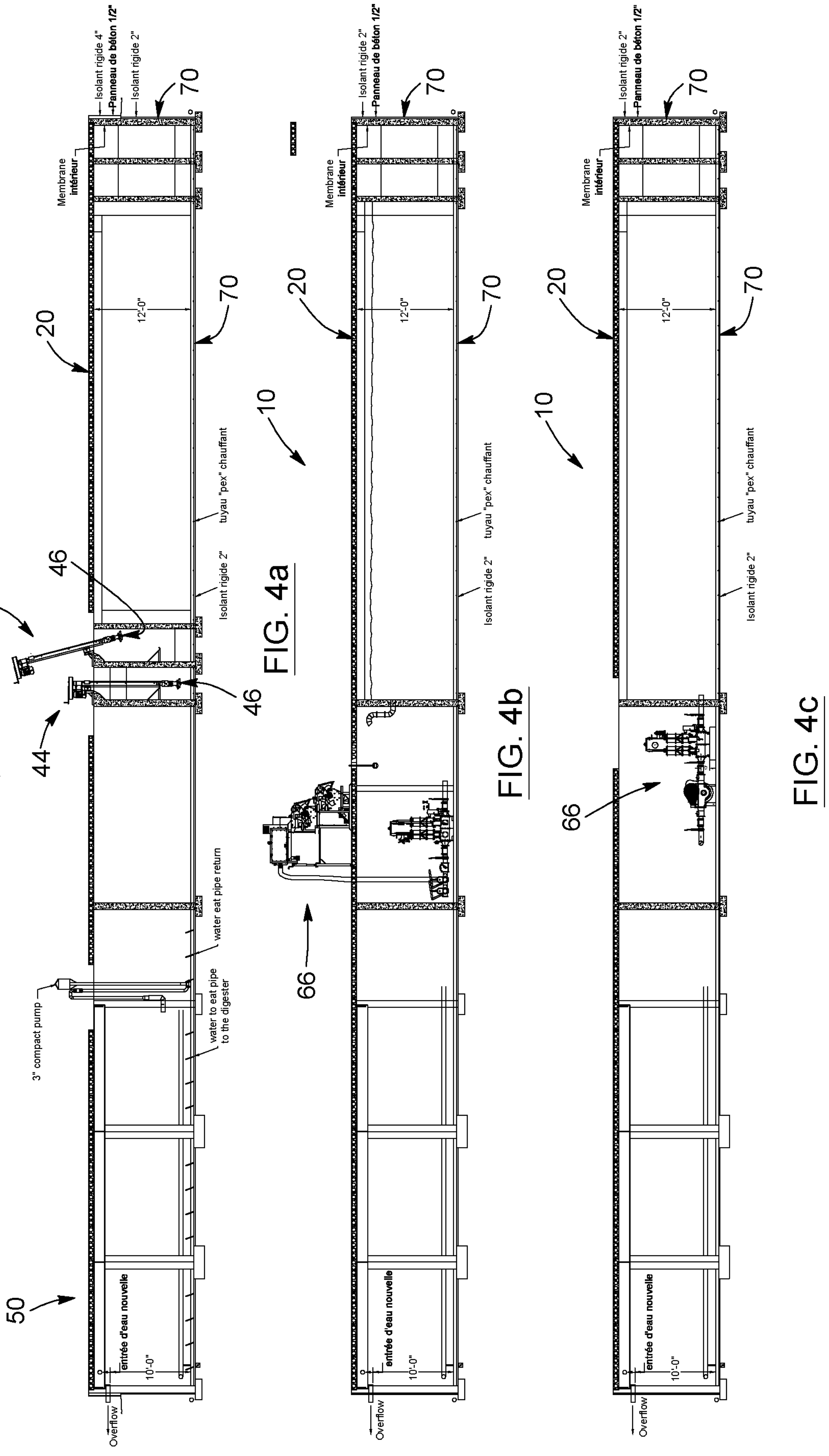

FIG. 4a

FIG. 4b

FIG. 4c

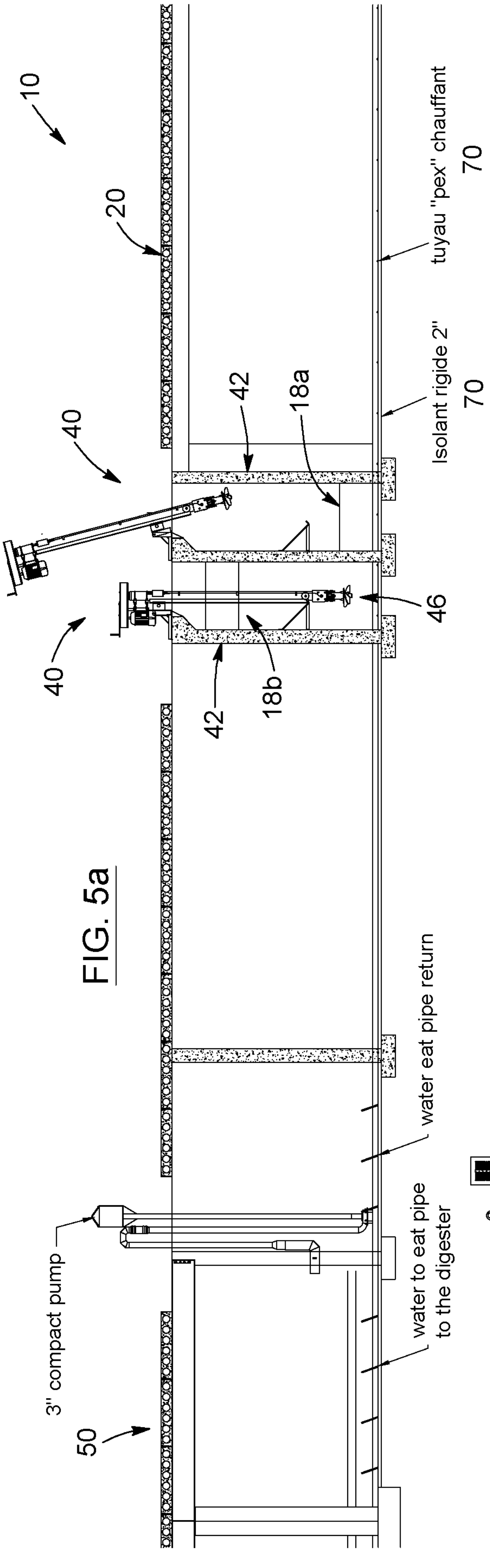

FIG. 5a

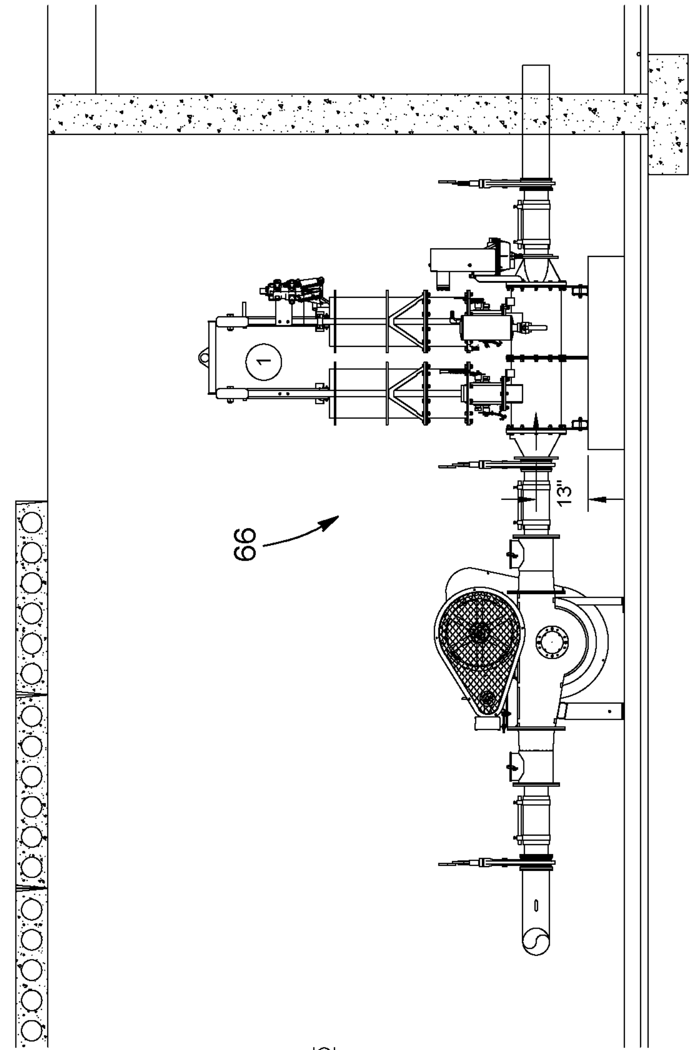

FIG. 5c

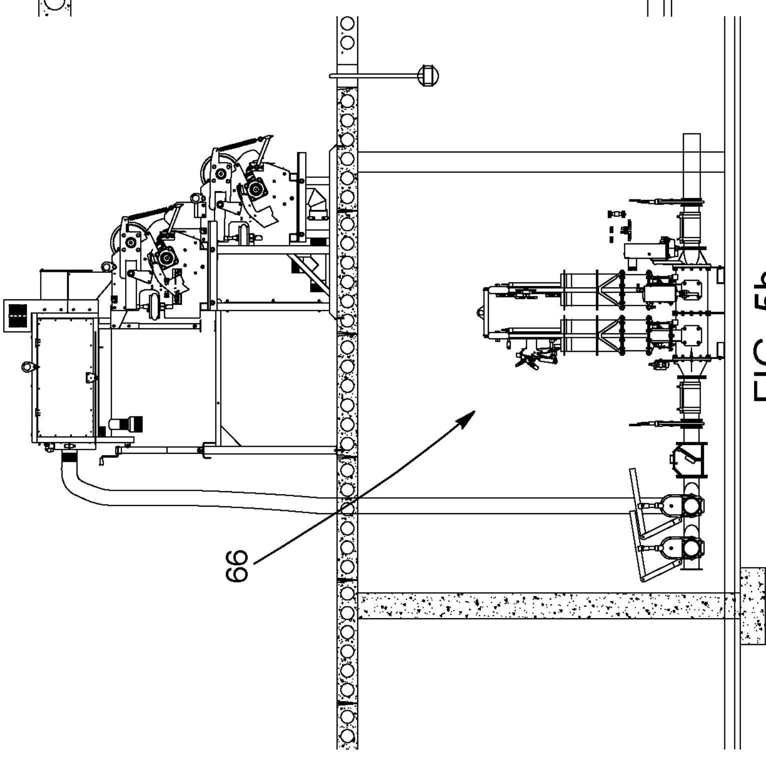

FIG. 5b

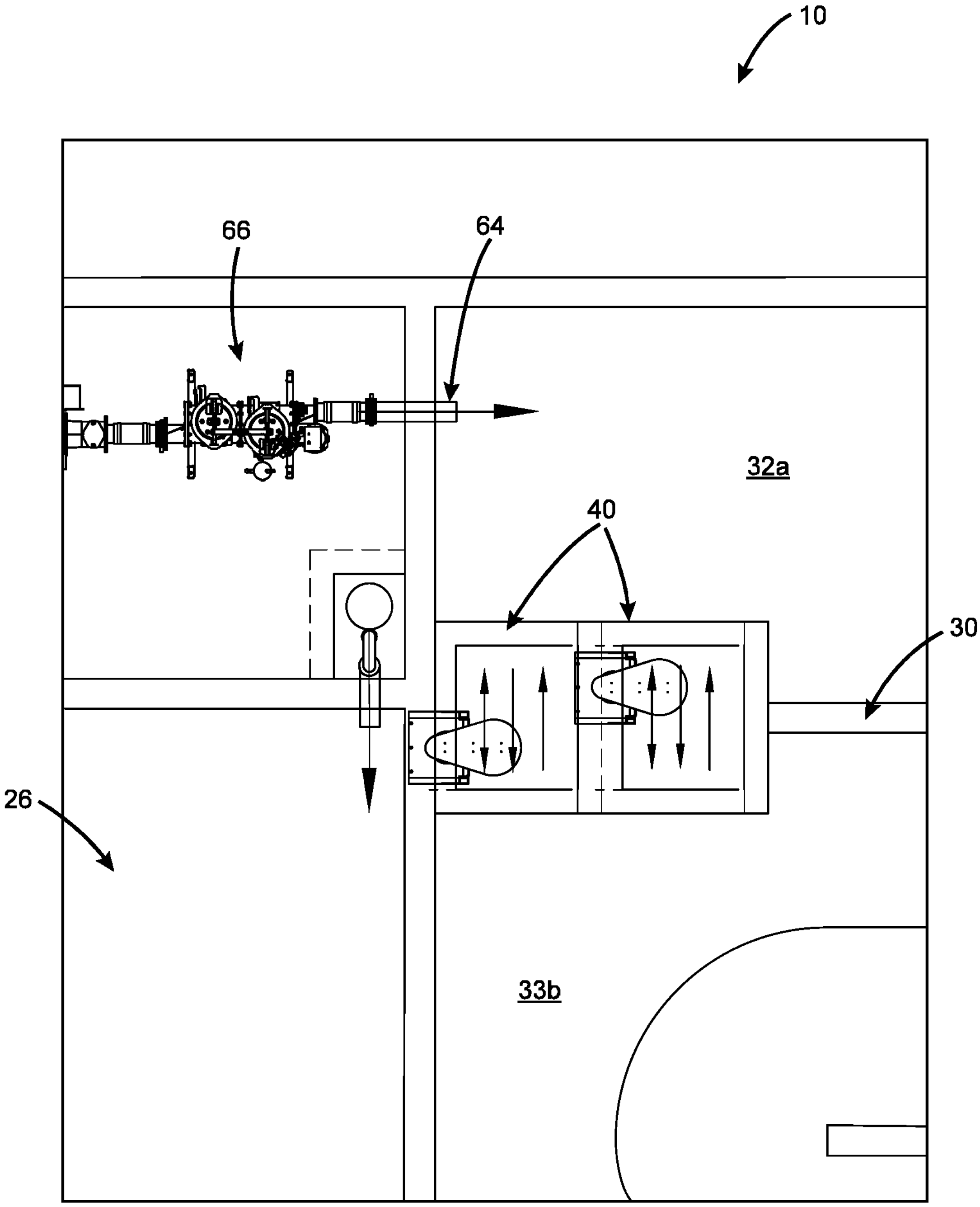

FIG. 6

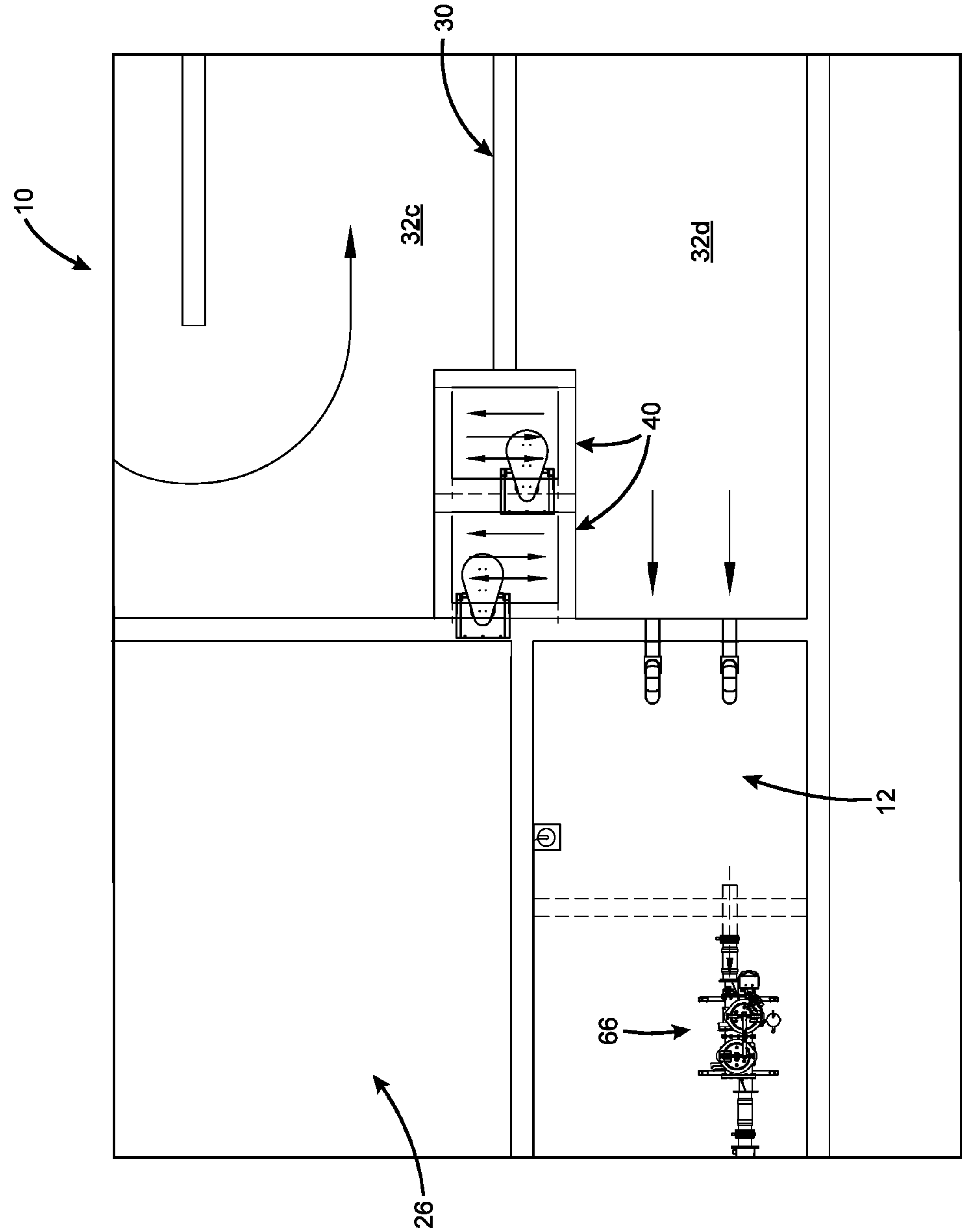

FIG. 7

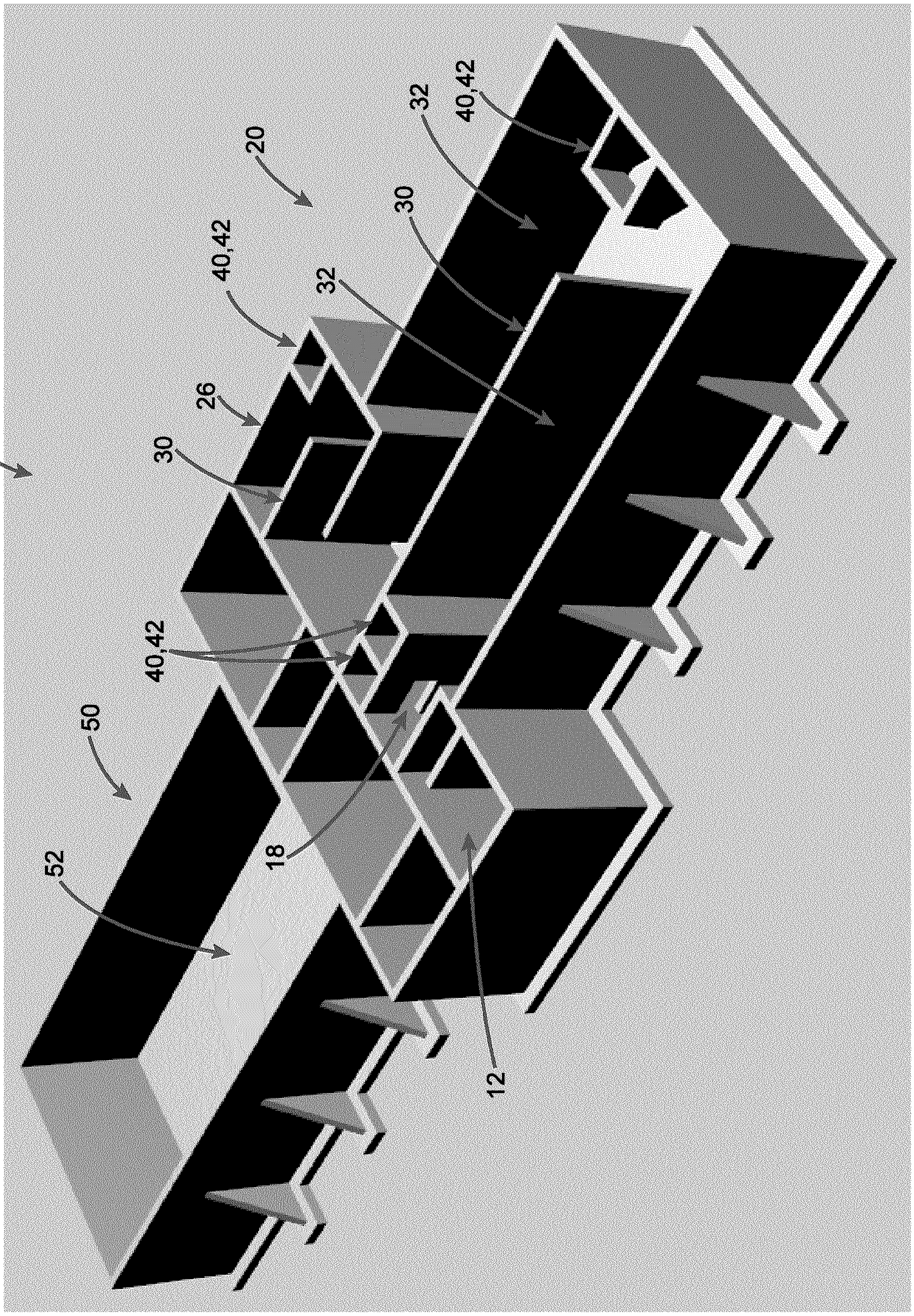

FIG. 8

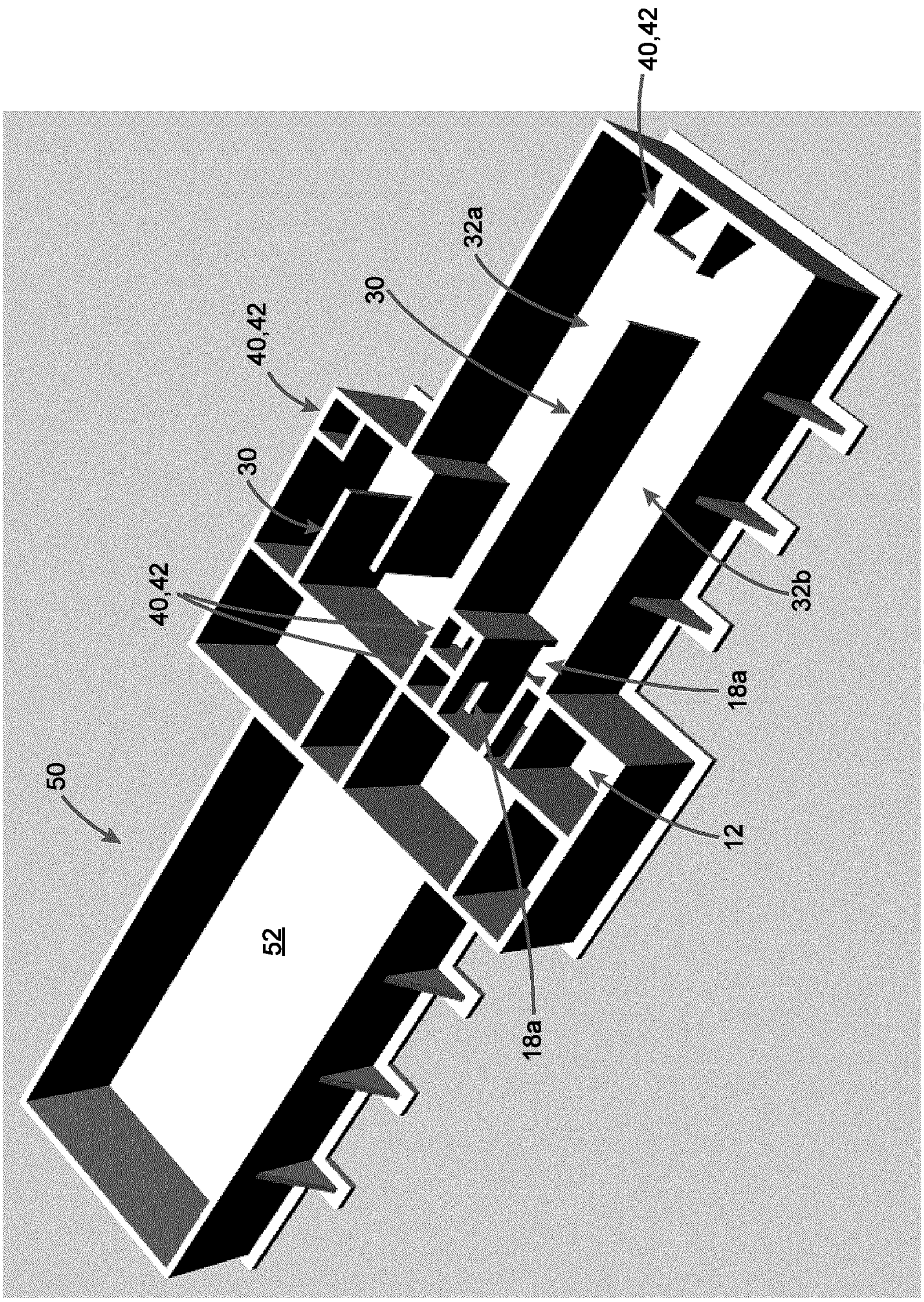

FIG. 9

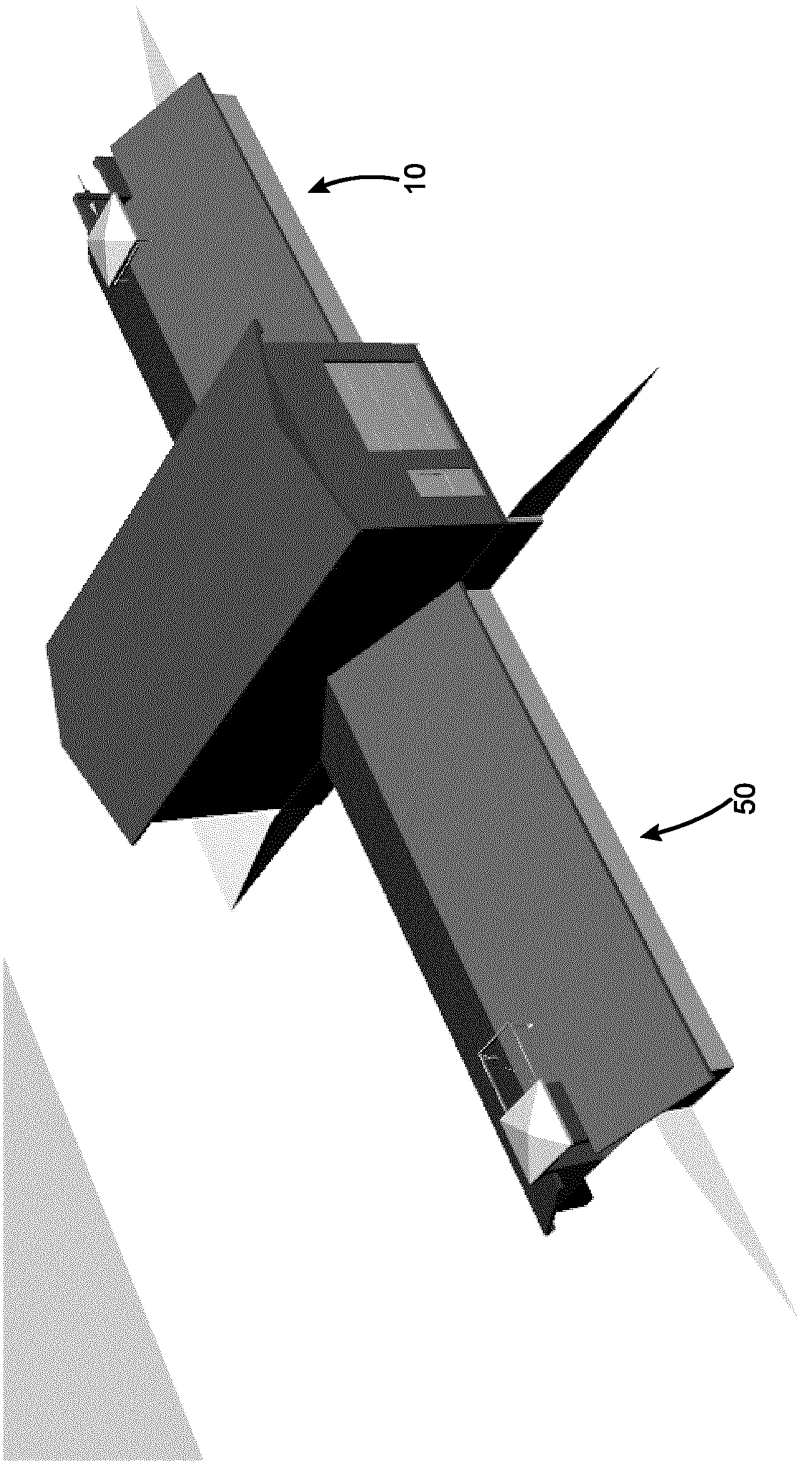

FIG. 10

INTERNATIONAL SEARCH REPORT	International application No. PCT/CA2013/050879

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***C12M 1/02*** (2006.01) , ***C02F 11/04*** (2006.01) , ***C12P 5/02*** (2006.01) , ***F24D 3/00*** (2006.01) , ***F28D 20/00*** (2006.01)
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)
IPC: ***C12M 1/02*** (2006.01) , ***C02F 11/04*** (2006.01) , ***C12P 5/02*** (2006.01) , ***F24D 3/00*** (2006.01) , ***F28D 20/00*** (2006.01), ***C02F 3/30*** (2006.01), ***C02F 3/06*** (2006.01), ***C02F 3/28*** (2006.01), ***C12M 1/107*** (2006.01) ,

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
TotalPatent, Canadian Patent Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP0213691A2, (McCARTY, P.L.) 11 March 1987 (11-03-1987) (Whole document, particularly columns 3, 4, 5 and 9 and Figure 6.)	1-53
Y	US6926830B2, (HO, K.M. et al) 09 August 2005 (09-08-2005) (Whole document, partuicularily column 11 and Figure 6)	1-53
P, X	WO2013144703A1, 03 October 2013 (03-10-2013) (whole document)	1-53

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :
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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 February 2014 (07-02-2014)	18 February 2014 (18-02-2014)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	Authorized officer Marcin Kaminski (819) 934-7933

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
EP0213691A2	11 March 1987 (11-03-1987)	AU4443585A	08 January 1987 (08-01-1987)
		AU589898B2	26 October 1989 (26-10-1989)
		CA1294070C	07 January 1992 (07-01-1992)
		DE3686107D1	27 August 1992 (27-08-1992)
		DE3686107T2	04 March 1993 (04-03-1993)
		EP0213691A3	08 June 1988 (08-06-1988)
		EP0213691B1	22 July 1992 (22-07-1992)
		JPS6232876A	12 February 1987 (12-02-1987)
		JPH0730B2	11 January 1995 (11-01-1995)
		US5091315A	25 February 1992 (25-02-1992)
US6926830B2	09 August 2005 (09-08-2005)	AU2003280444A1	19 January 2004 (19-01-2004)
		CN1678536A	05 October 2005 (05-10-2005)
		CN100360439C	09 January 2008 (09-01-2008)
		HK1082493A1	16 May 2008 (16-05-2008)
		MY136835A	28 November 2008 (28-11-2008)
		US2004206699A1	21 October 2004 (21-10-2004)
		WO2004002904A1	08 January 2004 (08-01-2004)
WO2013144703A1	03 October 2013 (03-10-2013)	ITMI20120516A1	30 September 2013 (30-09-2013)

US 20100206791A1

(19) **United States**

(12) **Patent Application Publication**

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Lee et al.

(43) **Pub. Date: Aug. 19, 2010**

(54) **APARTMENT-SHAPED ANAEROBIC DIGESTER FOR PRODUCING BIOGAS**

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(21) Appl. No.: **12/705,859**

(22) Filed: **Feb. 15, 2010**

(30) **Foreign Application Priority Data**

Feb. 16, 2009 (KR) 10-2009-0012435

Publication Classification

(51) **Int. Cl.**
C02F 3/28 (2006.01)

(52) **U.S. Cl.** **210/151**; 210/176

(57) **ABSTRACT**

Disclosed herein is an anaerobic digester. More specifically, disclosed is an apartment-shaped anaerobic digester configured to include a first input reactor **3** into which livestock wastewater or food waste (hereinafter, 'inflow') is introduced; a second input reactor **4** into which the inflow passing through the first input reactor is introduced; a first region **5**, a second region **6**, a third region **7**, and a fourth region **8** of an anaerobic digestion reactor designed for the inflow passing through the second input reactor **4** to perform methane fermentation in a first-in and first-out order to produce and transfer biogas simultaneously into the next anaerobic digestion region; an inlet pipe **41** in a lower layer portion of the fourth region **8** of the anaerobic digestion reactor, into which sludge liquid is drawn in from the lower layer; an inlet pipe **42** in an upper layer portion of the forth region of the anaerobic digestion reactor, into which activated liquid is drawn in from the upper layer; a biogas capturing device which is connected to a gas layer in the fourth region **8** of the anaerobic digestion reactor; a first heat exchange **2** tube provided inside the first input reactor **3** to allow the sludge liquid drawn in from the inlet pipe **41** in the lower layer portion to perform heat exchange with a new inflow; a first region **11**, a second region **12**, a third region **13**, and a fourth region **14** of a subsequent treatment reactor provided on the upper layer of the anaerobic digestion reactor, to allow the sludge liquid whose heat exchange is completed to be introduced in a first-in and first-out order, and to treat gas odor components generated from the sludge liquid; and a liquid-composting reactor in which the emitted sludge whose odor components have been removed is stored.

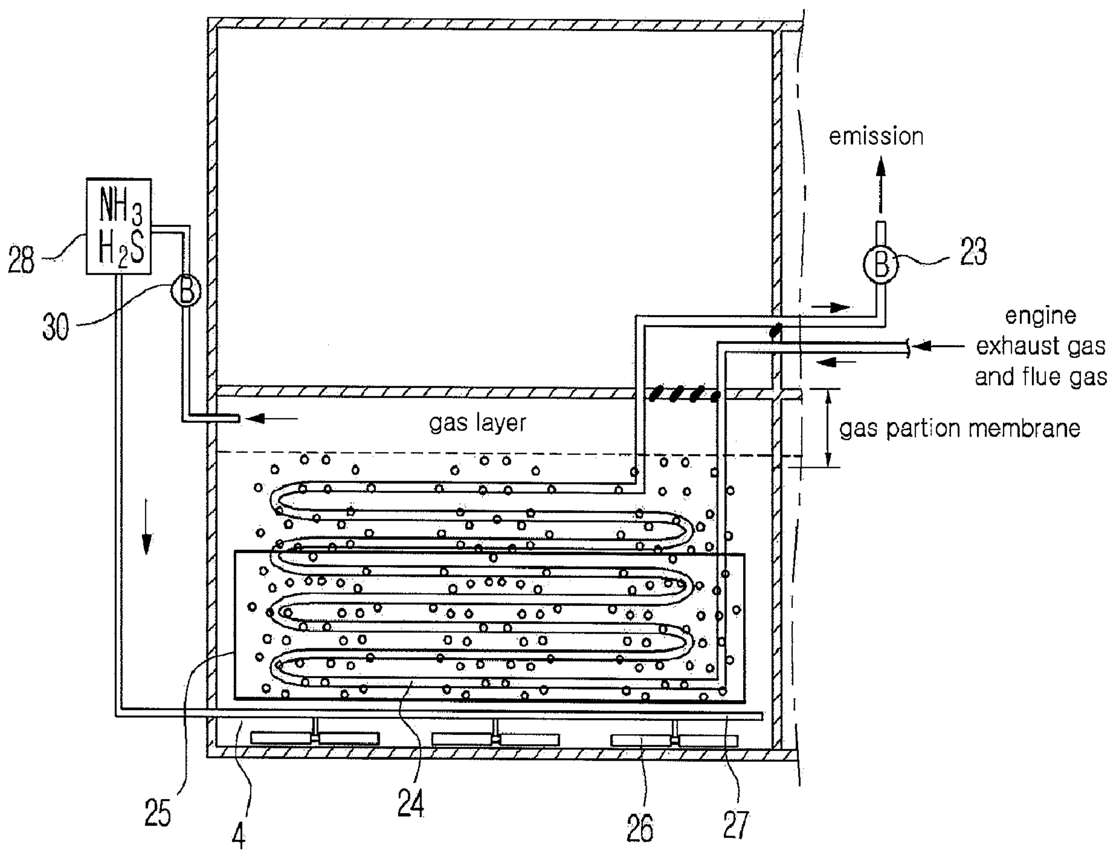


Fig. 1

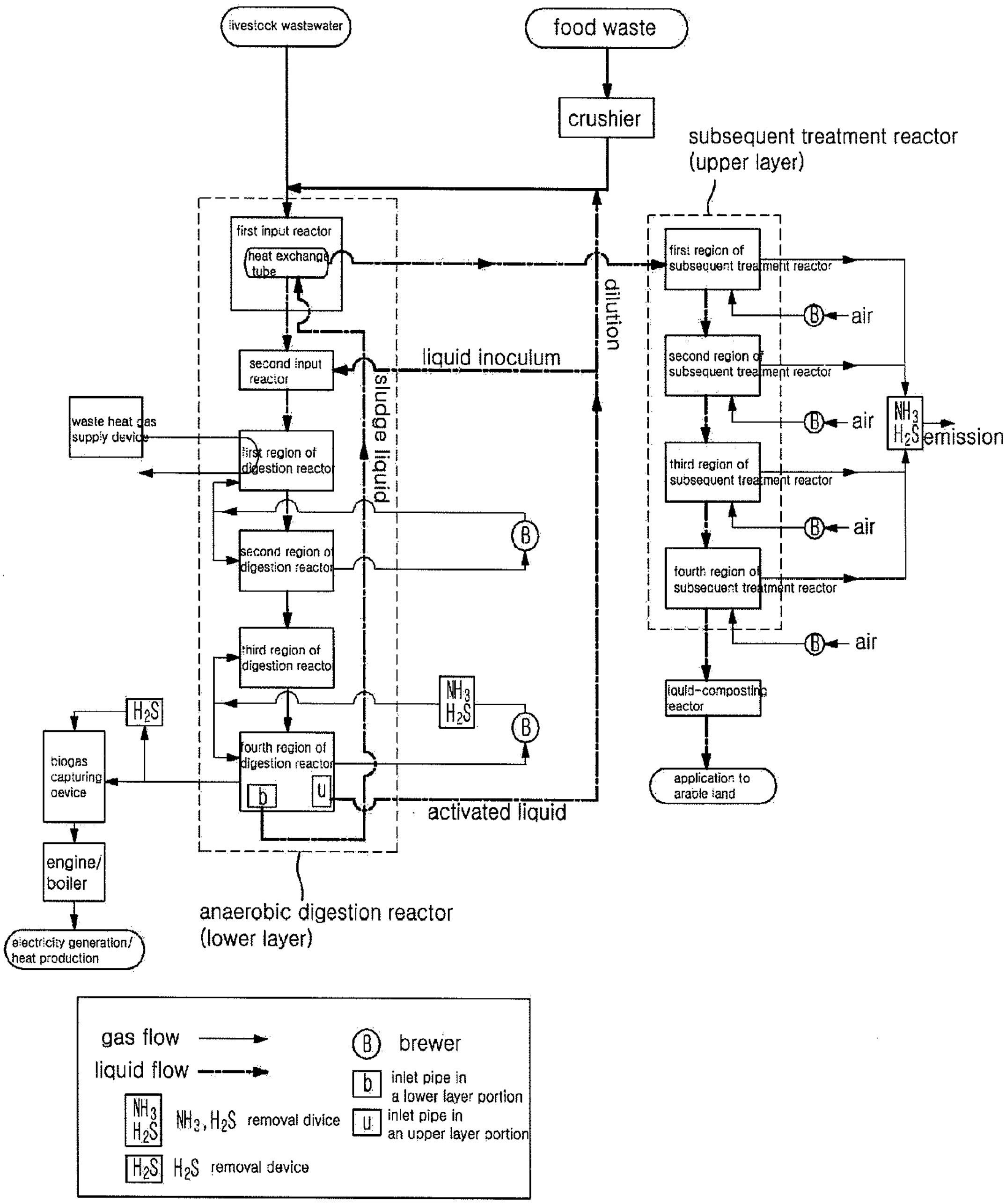

livestock wastewater
food waste
crushier
subsequent treatment reactor
(upper layer)
first input reactor
heat exchange tube
second input reactor
liquid inoculum
dilution
sludge liquid
waste heat gas supply device
first region of digestion reactor
second region of digestion reactor
third region of digestion reactor
fourth region of digestion reactor
b
u
activated liquid
first region of subsequent treatment reactor
second region of subsequent treatment reactor
third region of subsequent treatment reactor
fourth region of subsequent treatment reactor
air
air
air
air
emission
liquid-composting reactor
application to arable land
biogas capturing device
engine/boiler
electricity generation/heat production
anaerobic digestion reactor
(lower layer)
gas flow
liquid flow
NH3, H2S removal divice
H2S removal device
brewer
inlet pipe in a lower layer portion
inlet pipe in an upper layer portion

Fig. 2

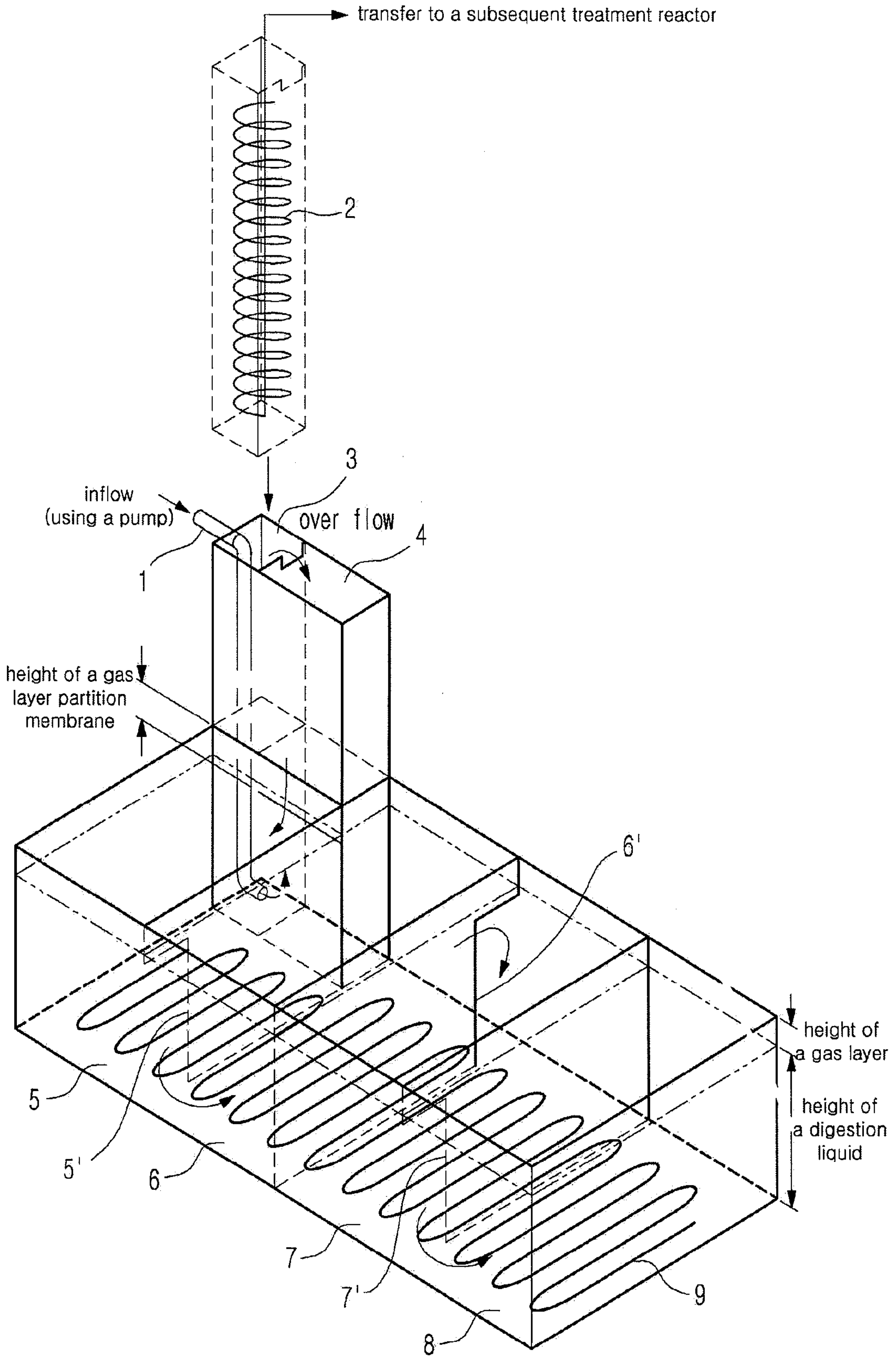

transfer to a subsequent treatment reactor
2
3
inflow
(using a pump)
over flow
4
1
height of a gas
layer partition
membrane
6'
height of
a gas layer
height of
a digestion
liquid
5
5'
6
7
7'
9
8

Fig. 3

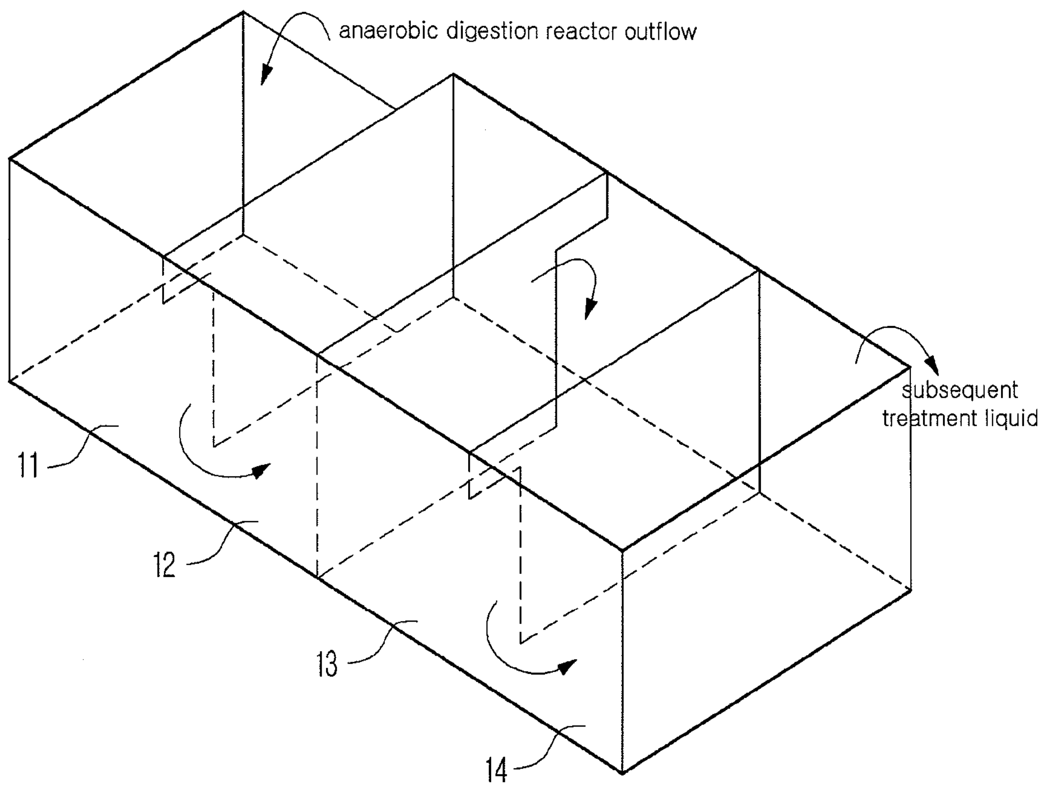

anaerobic digestion reactor outflow
subsequent
treatment liquid
11
12
13
14

Fig. 4

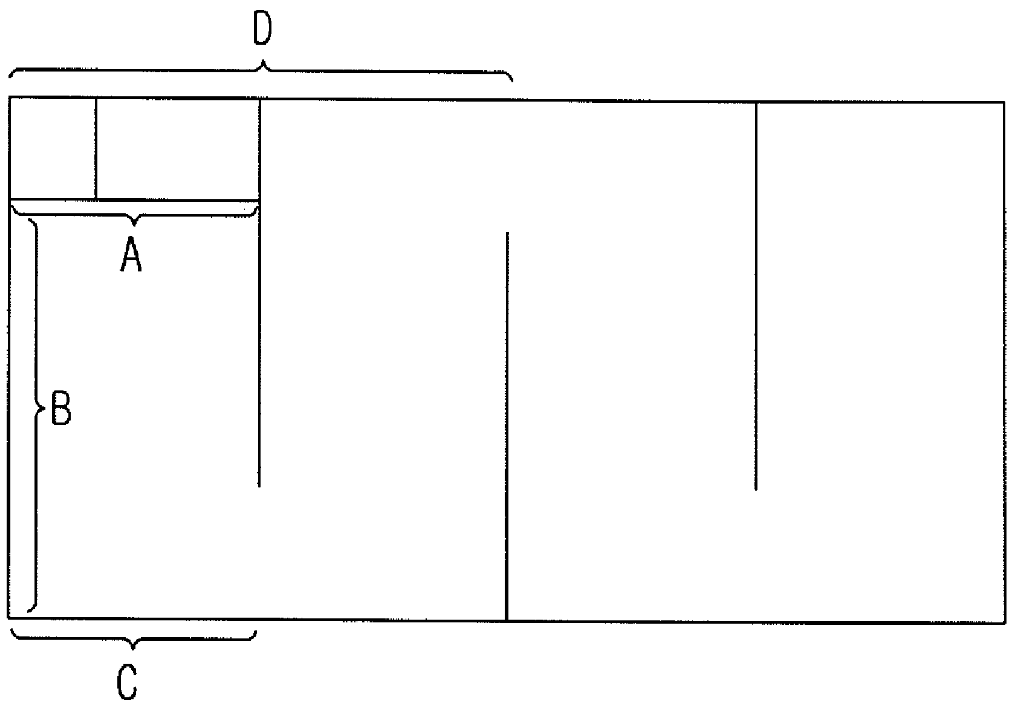


Fig. 5

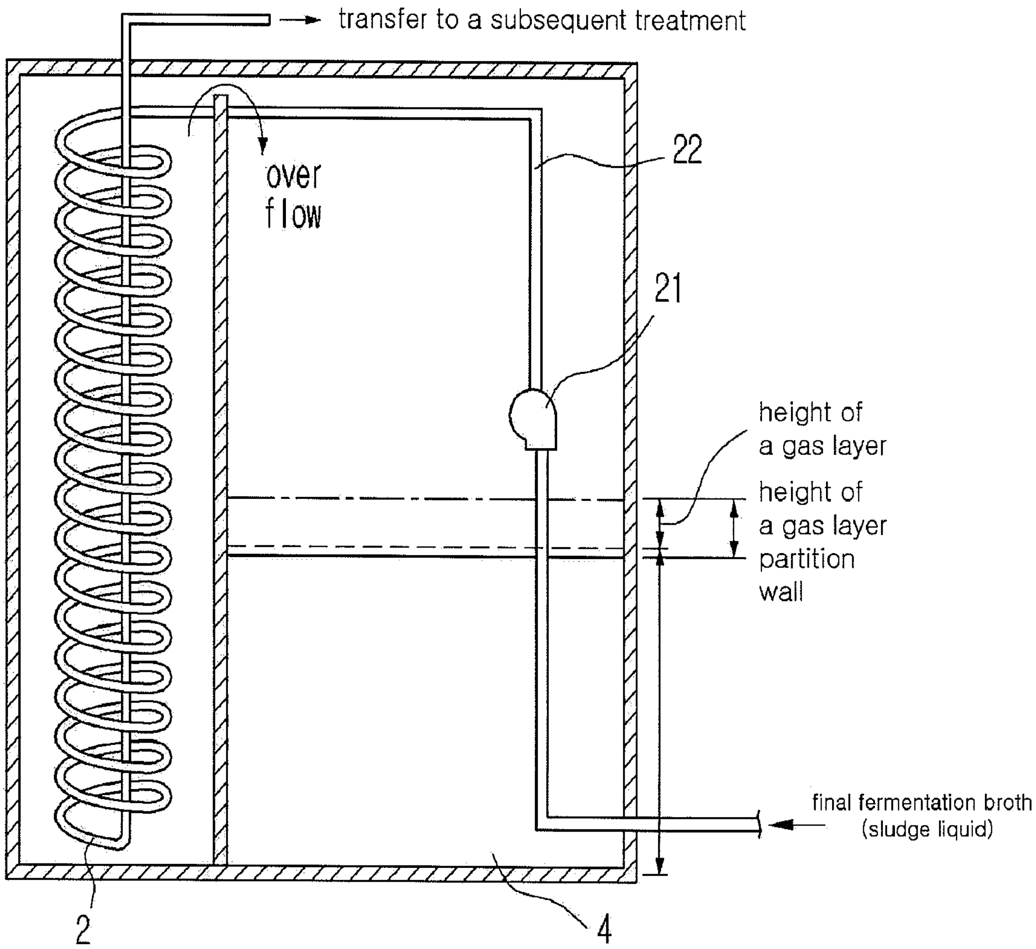
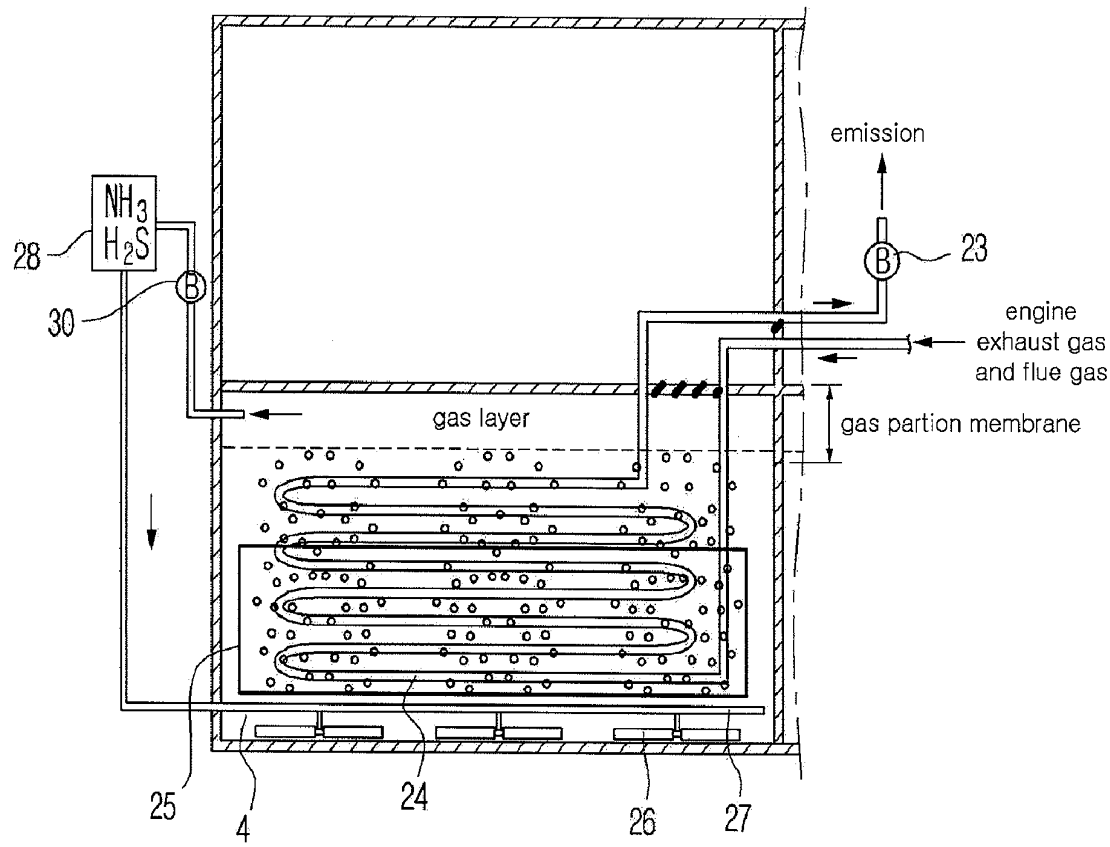

transfer to a subsequent treatment
over flow
22
21
height of a gas layer
height of a gas layer partition wall
final fermentation broth (sludge liquid)
2
4

Fig. 6



emission
NH_3
H_2S
28
30
B
B
23
engine
exhaust gas
and flue gas
gas layer
gas partion membrane
25
4
24
26
27

Fig. 7

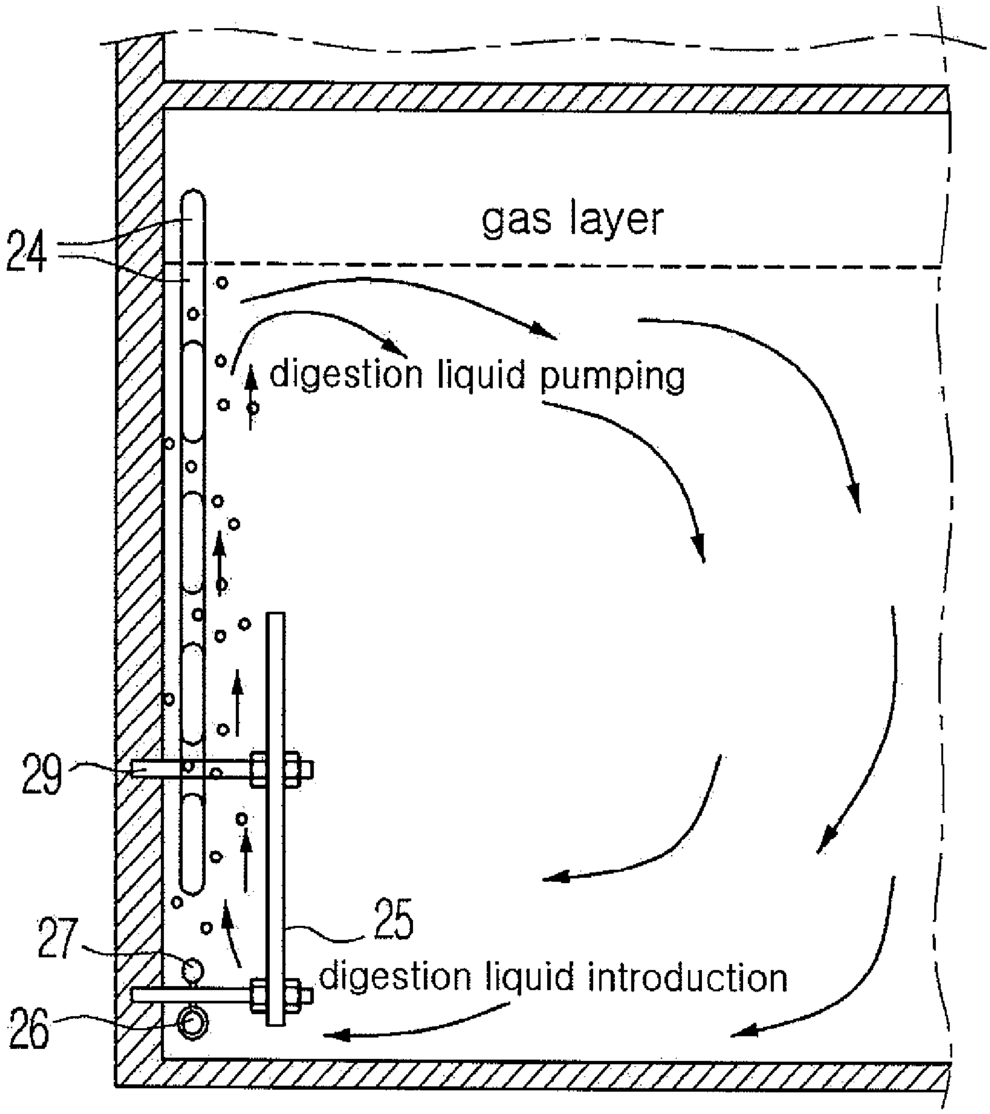

gas layer
24
digestion liquid pumping
29
27
25
digestion liquid introduction
26

Fig. 8

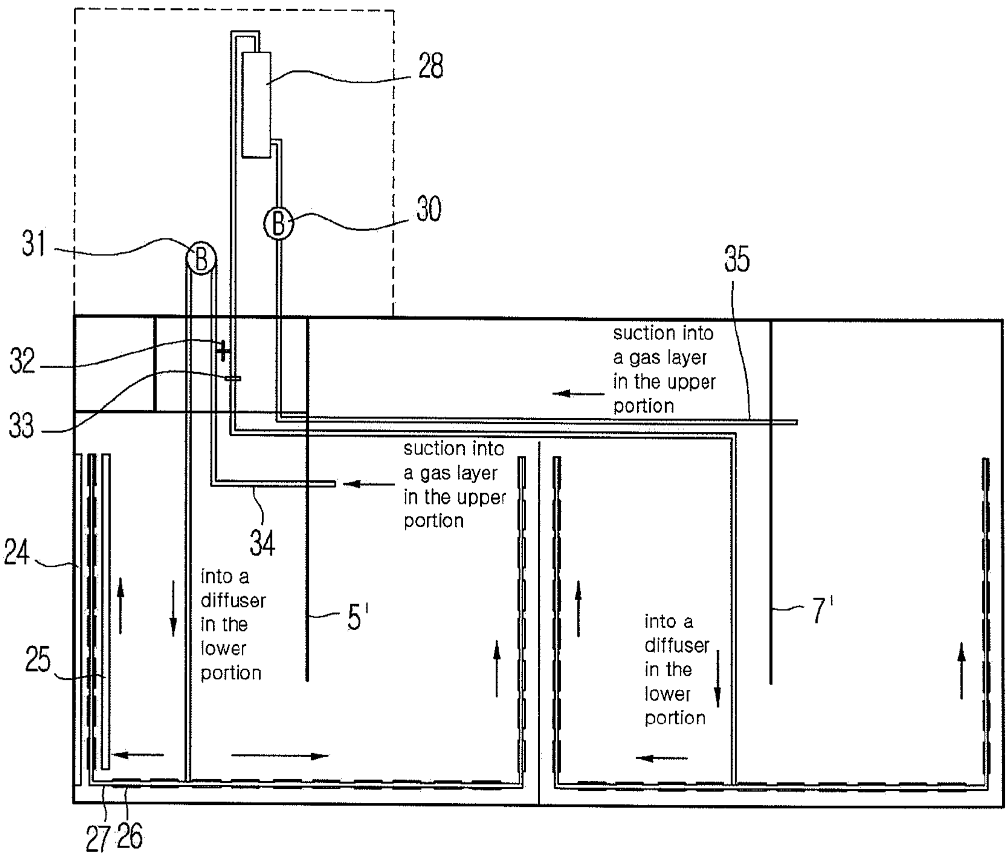

28
30
31
35
suction into
a gas layer
in the upper
portion
32
33
suction into
a gas layer
in the upper
portion
34
24
into a
diffuser
in the
lower
portion
5'
into a
diffuser
in the
lower
portion
7'
25
27
26

Fig. 9

(a)

(b)

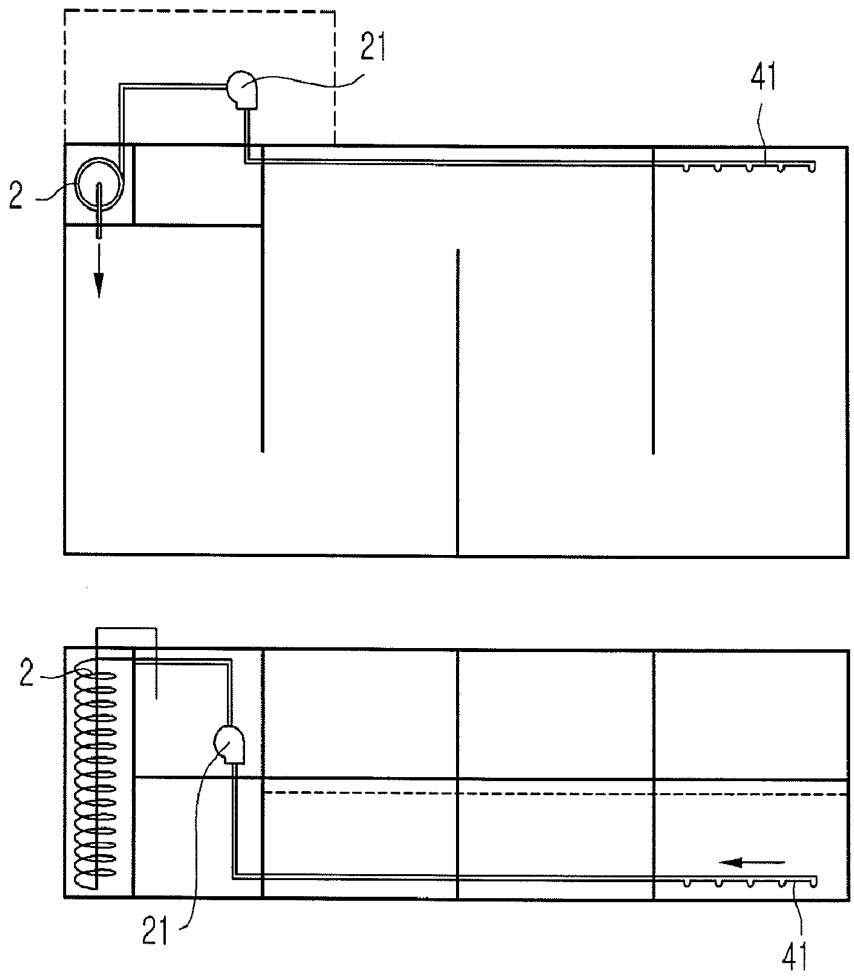
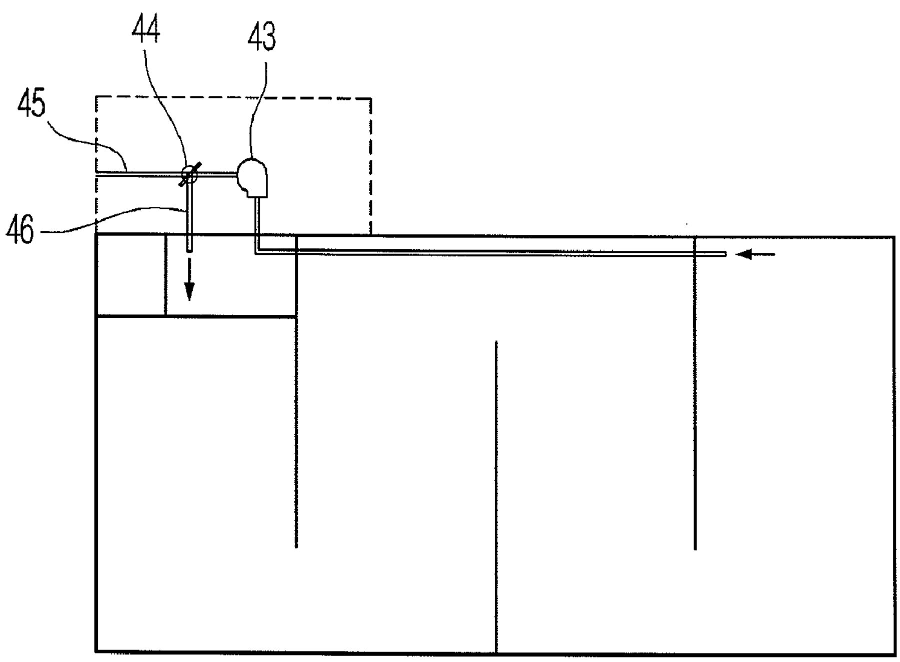


Fig. 10

(a)



(b)

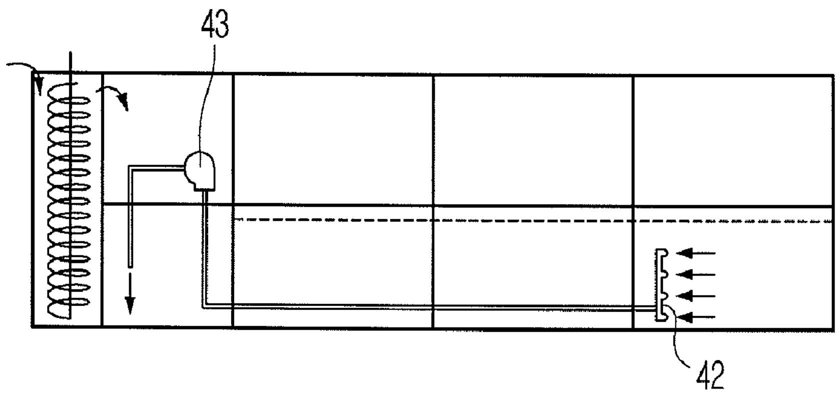


Fig. 11

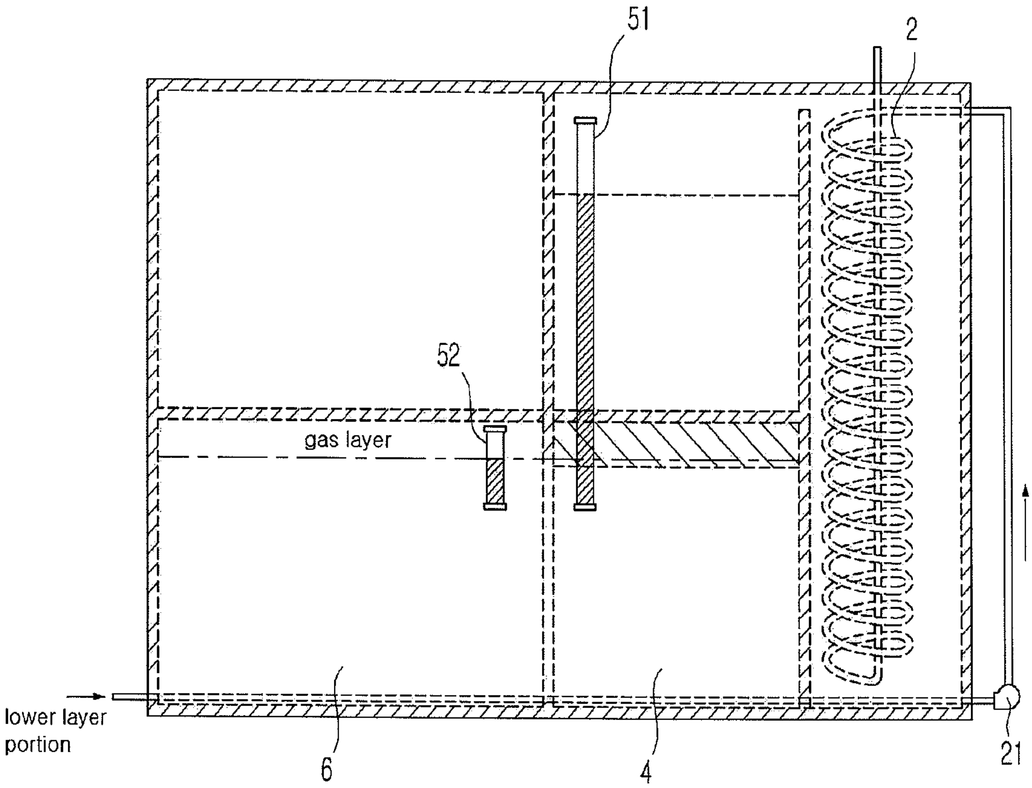


Fig. 12

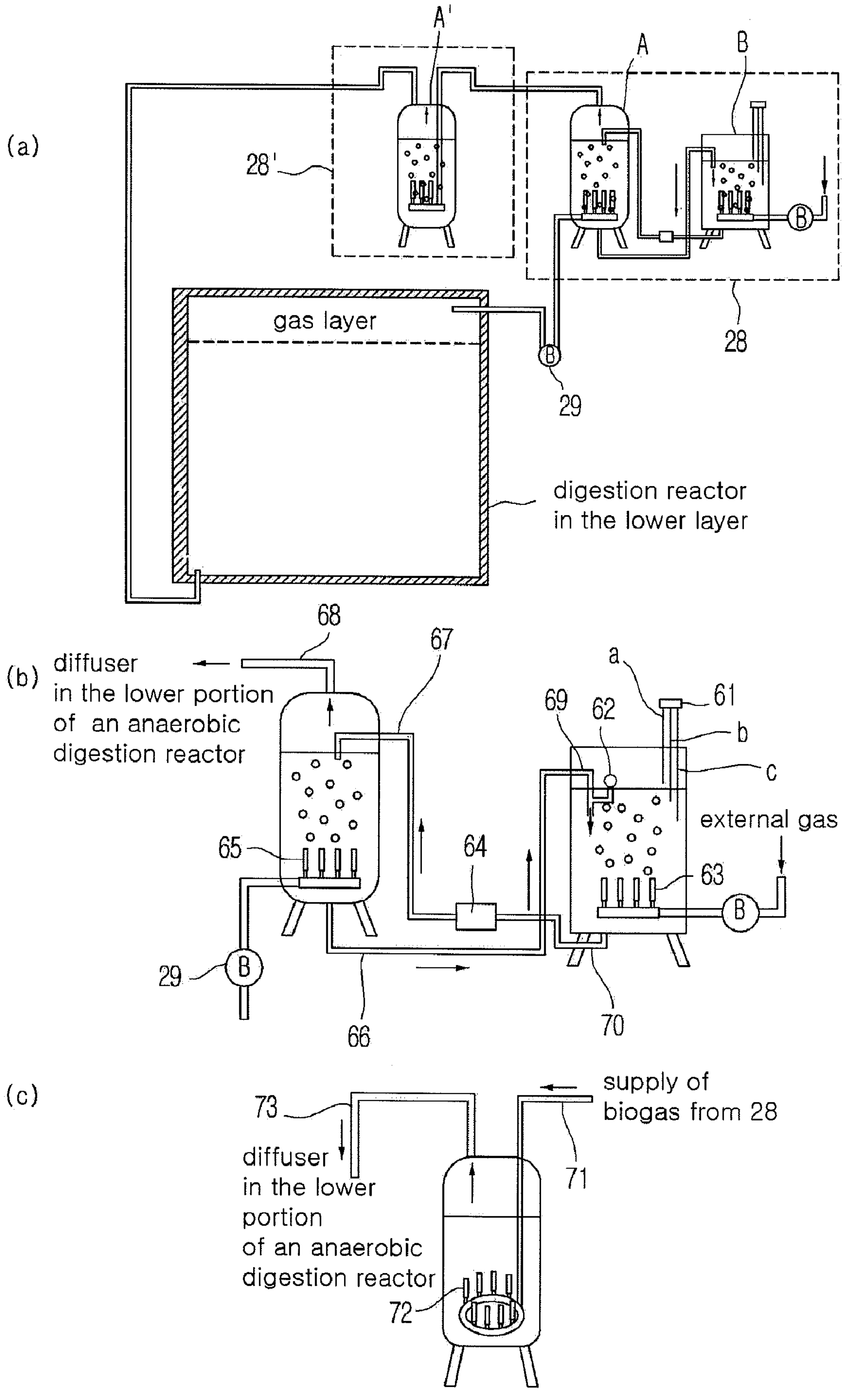
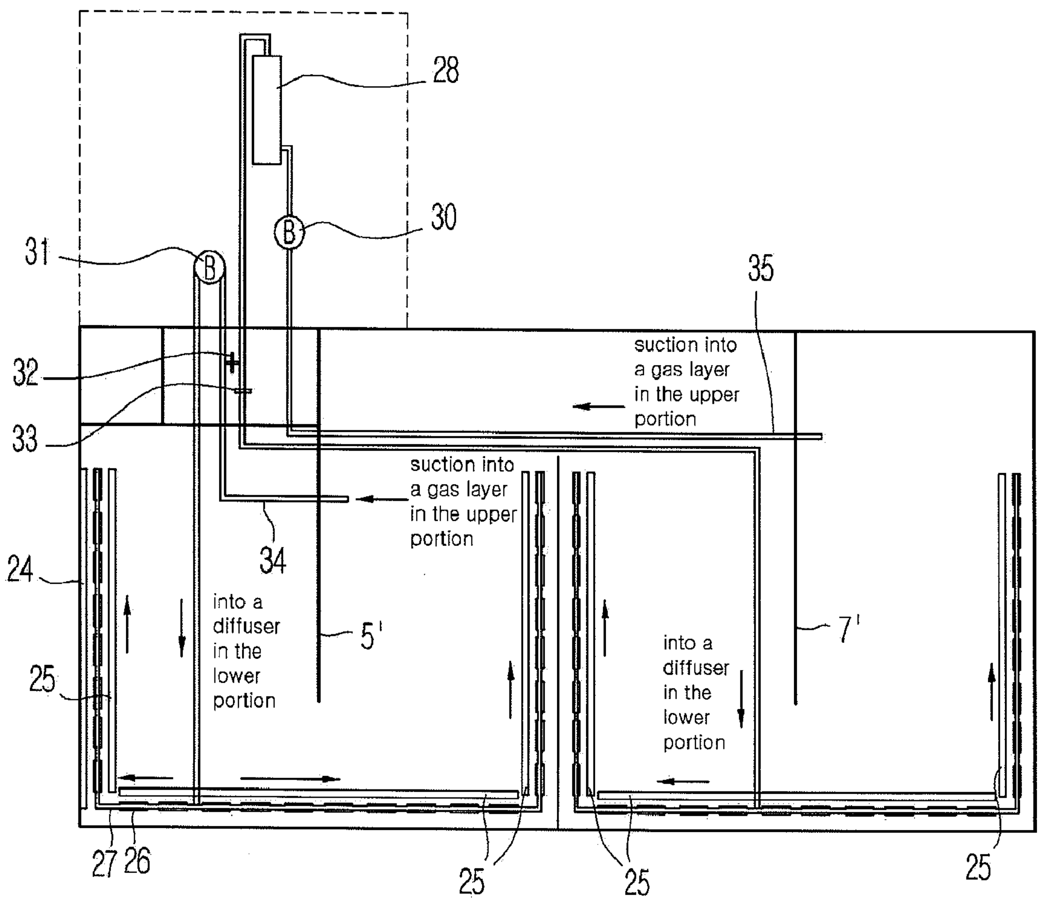

(a)
A'
A
B
28'
28
gas layer
29
digestion reactor
in the lower layer
(b)
diffuser
in the lower portion
of an anaerobic
digestion reactor
68
67
a
61
69
62
b
c
external gas
65
64
63
29
66
70
(c)
73
supply of
biogas from 28
diffuser
in the lower
portion
of an anaerobic
digestion reactor
71
72

Fig. 13


28
30
31
35
32
33
suction into
a gas layer
in the upper
portion
suction into
a gas layer
in the upper
portion
34
24
into a
diffuser
in the
lower
portion
5'
into a
diffuser
in the
lower
portion
7'
25
27
26
25
25
25

APARTMENT-SHAPED ANAEROBIC DIGESTER FOR PRODUCING BIOGAS

CROSS-REFERENCES TO RELATED APPLICATION

[0001] This patent application claims the benefit of priority from Korean Patent Application No. 10-2009-0012435, filed on Feb. 16, 2009, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present disclosure relates to an apartment-shaped anaerobic digester for producing biogas.

[0004] 2. Description of the Related Art

[0005] Anaerobic digestion, also known as “methane fermentation”, is a biological treatment method for stabilizing organic waste such as food waste, livestock waste, sewage sludge, manure, etc., and a treatment method for hydrolyzing high-molecular organic materials in the presence of facultative and obligate anaerobes under anaerobic conditions, producing volatile fatty acids such as acetic, propionic, butyric acids, etc., and finally gasifying them into methane, hydrogen, carbon dioxide, ammonia, and hydrogen sulfide.

[0006] These anaerobic digestions have not been actively used due to widespread adoption of activated sludge methods, but since the mid-1970’s oil crisis many studies have been actively conducted on forms of petroleum replacement energy due to their advantages such as availability of recovered gases (CH_4 60-70%, CO_2 30-40%) for fuel, lower power consumption compared to activated sludge methods that require venting large volumes of air, significantly lower biological sludge generation per unit of organic matter compared to aerobic treatment methods, high value as a fertilizer due to the abundance of nitrogen, phosphorus, humus, etc., in the digested sludge, and an environment-friendly resource renewal method for producing fuel and fertilizer in addition to a simple waste decomposition and treatment function.

[0007] An anaerobic digestion process is basically divided into the two steps of acid production and methanogenesis. Because microbes in each step are very different in physiological characteristics and nutritional requirements, a balance between two biological groups is offset to inhibit the efficiency of the overall process when external conditions are changed. As an alternative, a two-step fermentation process (two-phase method), which divides a reactor into two reactors for acid production and methanogenesis steps, was suggested. Because acid production and methanogenesis occur simultaneously in a reactor in the traditional first step reaction process (one-phase method), there are limitations in that it is impossible to optimally control the acid production and methanogenesis steps, and stability is not maintained due to its sensitivity to changes in externally-introduced waste. On the contrary, the two-phase method is advantageous in that environmental conditions suitable for each step may be easily maintained, the loading rate into the methane reactor may be appropriately controlled, and inhibition of methane fermentation may be prevented in advance due to its prevention of rapid pH decrease by accumulation of lower fatty acids. However, these two-phase methods are disadvantageous in terms of costs because reactors must be separately provided, thereby requiring a system for transfer from a first reactor to a second reactor, and are complicated in that reaction conditions in each reactor must be separately controlled.

[0008] Thus, the present inventors have conducted studies on a novel one-phase method for performing the acid production and methanogenesis steps in one anaerobic digestion reactor instead of the conventional two-phase methods and improving upon the difficulties in simultaneously satisfying optimal conditions for acid production and methanogenesis, which have been identified as problems in conventional one-phase methods, and have developed an apartment-type anaerobic digester for transferring an inflow such as animal manure or food waste within one anaerobic digestion reactor in a first-in and first-out manner and in which optimal conditions may be appropriately provided according to the process flow, thereby leading to completion of the present invention.

SUMMARY OF THE INVENTION

[0009] One object of the present invention is to provide an anaerobic digester which is structurally simple and maximizes the production efficiency of biogas by providing optimal anaerobic digestion conditions.

[0010] In order to solve the object, the present invention provides an apartment-shaped anaerobic digester, including a first input reactor into which livestock wastewater or food waste (hereinafter, ‘inflow’) is introduced; a second input reactor into which the inflow passing through the first input reactor is introduced; first, second, third, and fourth regions of an anaerobic digestion reactor designed for the inflow passing through the second input reactor to perform methane fermentation in a first-in and first-out order to produce and transfer biogas simultaneously into the next anaerobic digestion region; a diffusing gas supply tube and a diffuser giving fluidity to the inflow of the first, second, third, and fourth regions; an inlet pipe in a lower layer portion of the fourth region of the anaerobic digestion reactor, into which sludge liquid is drawn in from the lower layer portion; an inlet pipe in an upper layer portion of the forth region of the anaerobic digestion reactor, into which activated liquid is drawn in from the upper layer portion; a biogas capturing device which is connected to a gas layer in the fourth region of the anaerobic digestion reactor; a first heat exchange tube provided inside the first input reactor to allow the sludge liquid drawn in from the inlet pipe in the lower layer portion to perform heat exchange with a new inflow; first, second, third, and fourth regions of a subsequent treatment reactor provided on the upper layer of the anaerobic digestion reactor, to allow the sludge liquid whose heat exchange is completed to be introduced in a first-in and first-out order, and to treat gas odor components generated from the sludge liquid; and a liquid-composting reactor in which an emitted sludge whose odor components have been removed is stored.

EFFECTS

[0011] An anaerobic digester according to the present invention does not require a separate gas storage unit and a complex pretreatment when inflow is introduced, may control the temperature of the inflow throughout the entire process using waste heat to provide optimal conditions for growth and development of methanogen, allows for anaerobic digestion of fermentation broth in a first-in and first-out manner to remove factors which may deteriorate the removal efficiency of odor components in the subsequent treatment process when unfermented broth subsequently introduced is first emitted, and may slowly transfer the inflow such that floatation and homogenization of deposits in the inflow may be induced by purification or without purification of self-produced biogas for recycling without a stirrer that is complex and involves high costs. In addition, the present invention may provide an anaerobic digester which is excellent in terms of economy and purity of biogas produced due to the use of a low-cost ammonia and hydrogen sulfide removal device that may prevent a sustained concentration of ammonia and hydrogen sulfide that inhibits the growth and development of methanogen, which has been identified as a disadvantage of conventional gas anaerobic digestion reactors, and can remove 99% or more of ammonia and hydrogen sulfide generated to produce a biogas whose methane content is 80% or more, which is the level of municipal gas, by lowering carbon dioxide content in the biogas to 20% or less.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0013] FIG. **1** is a flowchart of a livestock wastewater or food waste treatment process with an apartment-type anaerobic digestion reactor according to the present invention;

[0014] FIG. **2** is a perspective view illustrating a first-floor digestion reactor of an apartment-type anaerobic digestion reactor according to the present invention;

[0015] FIG. **3** is a perspective view illustrating a second-floor subsequent treatment reactor of an apartment-type anaerobic digestion reactor according to the present invention;

[0016] FIG. **4** is a top view schematically illustrating observation sections dividing an apartment-type anaerobic digestion reactor according to the present invention;

[0017] FIG. **5** is a cross-sectional, frontal view of observation section A in FIG. **4**;

[0018] FIG. **6** is a cross-sectional, frontal view of the observation section B in FIG. **4**;

[0019] FIG. **7** is a cross-sectional, frontal view of the observation section C in FIG. **4**;

[0020] FIG. **8** illustrates observation section D in FIG. **4** as observed from above;

[0021] FIG. **9** illustrates (a) a top view and (b) a side view of the arrangement of a pipe that draws in the final fermentation broth in the lower portion of an apartment-shaped anaerobic digestion reactor according to the present invention;

[0022] FIG. **10** illustrates (a) a top view and (b) a side view of the arrangement of a pipe that draws in a liquid inoculum and a diluent in the upper layer portion of an apartment-shaped anaerobic digestion reactor according to the present invention;

[0023] FIG. **11** is a side view of the observation section D in FIG. **4**;

[0024] FIG. **12** is a set of drawings illustrating an ammonia/hydrogen sulfide removal device provided in an apartment-shaped anaerobic digestion reactor according to the present invention, showing (a) a schematic connective view of an ammonia/hydrogen sulfide removal device and an anaerobic digestion reactor; (b) an ammonia/hydrogen sulfide removal device in which an A-type tank and a B-type tank are connected; and (c) a hydrogen sulfide removal device in which only an A' type tank is configured; and

[0025] FIG. **13** illustrates one embodiment of a diffusing gas partition wall of the present invention in FIG. **4** as observed from above.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] Features and advantages of the present invention will be more clearly understood by the following detailed description of the present preferred embodiments by reference to the accompanying drawings. It is first noted that terms or words used herein should be construed as meanings or concepts corresponding to the technical spirit of the present invention, based on the assumption that the inventor has appropriately define the concepts of the terms to best describe the present invention. Also, it should be understood that detailed descriptions of well-known functions and structures related to the present invention are not provided so as not to unnecessarily obscure the essence of the present invention.

[0027] The present invention provides an apartment-shaped anaerobic digester which may increase the production efficiency of biogas by providing optimal anaerobic digestion conditions under which acid production and methanogenesis steps may be simultaneously performed in one anaerobic digestion reactor.

[0028] Hereinafter, according to one aspect of embodiments of the present invention, an anaerobic digester will be described in detail with reference to the accompanying figures.

[0029] According to one aspect of embodiments of the present invention, the anaerobic digester is configured to include:

[0030] a first input reactor **3** into which livestock wastewater or food waste (hereinafter, 'inflow') is introduced;

[0031] a second input reactor **4** into which the inflow passing through the first input reactor is introduced;

[0032] a first region **5**, a second region **6**, a third region **7**, and a fourth region **8** of an anaerobic digestion reactor designed for the inflow passing through the second input reactor **4** to perform methane fermentation in a first-in and first-out order to produce and transfer biogas simultaneously into the next anaerobic digestion region;

[0033] a diffusing gas supply tube and a diffuser giving fluidity to the inflow of the first, second, third, and fourth regions;

[0034] an inlet pipe **41** in a lower layer portion of the fourth region **8** of the anaerobic digestion reactor, into which sludge liquid is drawn in from the lower layer;

[0035] an inlet pipe **42** in an upper layer portion of the forth region of the anaerobic digestion reactor, into which activated liquid is drawn in from the upper layer;

[0036] a biogas capturing device which is connected to a gas layer in the fourth region **8** of the anaerobic digestion reactor;

[0037] a first heat exchange tube **2** provided inside the first input reactor **3** to allow the sludge liquid drawn in from the inlet pipe **41** in the lower layer portion to perform heat exchange with a new inflow;

[0038] a first region **11**, a second region **12**, a third region **13**, and a fourth region **14** of a subsequent treatment reactor provided on the upper layer of the anaerobic digestion reactor, to allow the sludge liquid whose heat exchange has been completed to be introduced in a first-in and first-out order, and to treat gas odor components generated from the sludge liquid; and

[0039] a liquid-composting reactor in which the emitted sludge whose odor components have been removed is stored.

[0040] According to one aspect of embodiments of the present invention, an anaerobic digester includes a floor-heating piping **9** on the floors of the first region **5**, the second region **6**, the third region **7**, and the fourth region **8** of the anaerobic digestion reactor to maintain the optimal methane fermentation temperature (See FIG. **2**).

[0041] The floor-heating piping **9** provides about 35° C. to about 55° C., an optimal temperature range for production of methane by methanogen in the anaerobic digestion reactor. Because the temperatures of initially introduced inflow are about 18° C. in summer and about 8° C. in winter, respectively, the floor-heating piping **9** may minimize a temperature variation between the optimal fermentation temperature for methanogenesis and the temperature of initially introduced inflow.

[0042] According to one aspect of embodiments of the present invention, the fifth, sixth, seventh, and eighth regions of the anaerobic digestion reactor of the anaerobic digester are characterized in that they have a structure in which a space for storing biogas produced by methane fermentation is secured between an upper portion of the inflow introduced in each region and a ceiling in each region (See FIG. **2**).

[0043] When biogas is produced as a result of methane fermentation, the gas produced is stored between a ceiling and an upper portion of the inflow in each region. As a result, the anaerobic digester according to one aspect of embodiments of the present invention requires no separate biogas storage device.

[0044] In the first region **5** of the anaerobic digestion reactor and the external wall of the second input reactor **4**, water level measurement tubes **51** and **52** are provided to measure the levels of inflow in the first region **5** and the second input reactor **4**. An inflow level difference may be generated between the first region **5** and the second input reactor **4** by pressure exerted by biogas produced as a result of methane fermentation. That is, when a big pressure is generated in a gas layer of the first region **6** due to a large amount of biogas produced, it is possible to control the time point to stop the input of the inflow because the water level in the second input reactor **4** into which inflow is introduced is increasing (See FIG. **11**).

[0045] According to one aspect of embodiments of the present invention, the fifth, sixth, seventh, and eighth regions of the anaerobic digestion reactor has a structure in which the regions are divided each other by separation walls **5'**, **6'**, and **7'**. In this case, the terminal portion of each separation wall **5'**, **6'**, and **7'** is opened in the form of ']', from the internal wall of the anaerobic digestion reactor except for an upper space in which biogas is stored. The inflow is transferred into the next region through the opened space (See FIG. **2**).

[0046] In the separation walls **5'**, **6'**, and **7'** of the anaerobic digestion reactor, the separation wall **5'** between the first and second regions and the separation wall **7'** between the third and fourth regions are opened in the same direction while the separation wall **6'** between the second and third regions has a structure in which the terminal portion is opened in the direction opposite to the openings of the separation wall **5'** between the first and second regions and the separation wall **7'** between the third and fourth regions. As a result, the inflow is transferred in a zig-zag manner throughout the whole regions of the anaerobic digestion reactor.

[0047] The first region **5** of the anaerobic digestion reactor is a region in which acid production is performed, producing pH which is much lower than about 7.2 to about 7.4, an optimal pH range for methanogen. Therefore, control of pH lowered by the inflow to the optimal pH range is required. Such control may be regulated by ammonia components included in a gas introduced by a diffusing gas supply tube **27** and a diffuser **26** which will be below described. As the inflow whose pH is regulated passes through the long distance in a zig-zag manner, pH is controlled within a range appropriate for methane fermentation. That is, the separation membranes **5'**, **6'**, and **7'** give the buffering capability to the inflow itself by increasing the moving distance of the inflow so that optimal methane fermentation conditions may be provided as the inflow comes closer to the fourth region **8**.

[0048] According to one aspect of the present invention, the fifth, sixth, seventh, and eighth regions of the anaerobic digestion reactor each have a structure in which a diffusing gas supply tube **27** and a diffuser **26** giving fluidity to the inflow are installed along the perimeter of the wall on the floor of the other walls except for a wall in the direction where the first input reactor **3** and the second input reactor **4** are installed, the separation wall **5'** between the first and second regions, and the separation wall **7'** between the third and fourth regions (See FIG. **8**).

[0049] An anaerobic digestion reactor according to the present invention does not include a separate stirrer. In stead of a stirrer, a gas introduced through the diffusing gas supply tube **27** and the diffuser **26** to provide fluidity to the inflow serves as a stirrer.

[0050] In particular, a diffusing gas partition wall **25** in the first region **5** of the anaerobic digestion reactor is installed in front of a second heat exchange tube **24** which will be below described to induce the flow of the diffusing gas introduced from the diffuser **26** installed on the floor of the wall in the vertical direction, and then the diffusing gas passing through the partition wall provides stirring and fluidity to the inflow passing through the first region **5** by giving clockwise rotation to the inflow (See FIG. **7**). The diffusing gas introduced may be one which is subjected to a different treatment process in each different region of the anaerobic digestion reactor. This will be more specifically described in the following corresponding part.

[0051] Furthermore, a diffusing gas partition wall, installed in an anaerobic digestion reactor according to one embodiment of the present invention may be installed in front of a wall in which a diffusing gas supply tube and a diffuser were installed on the floor from the first region to the fourth region of the anaerobic digestion reactor without being limited to the first region to further give fluidity to the inflow passing through each region (See FIG. **13**).

[0052] According to one aspect of embodiments of the present invention, a second heat exchange tube **24** to exchange heat supplied from an external heat source is provided on the surface of the wall opposite to the separation wall **5'** in the first region **5** of the anaerobic digestion reactor for the purpose of minimizing a temperature variation between the temperature of initially introduced inflow and the optimal fermentation temperature for methanogenesis to maximize the methane fermentation efficiency in the second to the forth regions of a subsequent anaerobic digestion reactor (See FIG. **6**). The heat supplied from the external source may increase the energy efficiency by using waste heat produced by a boiler flue gas or an engine exhaust gas.

[0053] According to one aspect of embodiments of the present invention, the second region **6** of the anaerobic digestion reactor includes a gas piping **34** to recover biogas from the upper gas layer produced as a result of anaerobic digestion through a second suction brewer **31** in the upper gas layer and provide a gas for providing stirring and fluidity to a diffusing gas supply tube **27** and a diffuser **26** which are included in the first region **5** and the second region **6**. In addition, a gas piping **35** in the fourth region **8** of the anaerobic digestion reactor is provided to recover biogas from the upper gas layer, produced as a result of the anaerobic digestion through a first suction brewer **30** in the upper gas layer and provide a gas for providing stirring and fluidity to a diffusing gas supply tube **27** and a diffuser **26** which are included in the third region **7** and the fourth region **8** (See FIG. **8**).

[0054] The biogas drawn in through the gas piping **34** may be not only supplied directly to the first region **5** and the second region **6** without a separate purification of ammonia and hydrogen sulfide, but also supplied in the form of purified ammonia and hydrogen sulfide by manipulating a simple on/off valve of an ammonia and hydrogen sulfide removal device **28** which is selectively connected to an adjacent gas piping **35**.

[0055] As previously described, the first region **5** of the anaerobic digestion reactor has a relatively low pH environment because an acid production step is performed, and requires a process for maintaining pH appropriate for methane fermentation when the inflow is sequentially transferred to the next region. For this purpose, the present invention may control a lowered pH of the inflow within a pH range appropriate for methane fermentation by introducing intact ammonia included in biogas drawn in through a gas piping **34** of the second region **6** of the anaerobic digestion reactor into a diffusing gas supply tube **27** and a diffuser in the first region without a separate purification process.

[0056] Because pH of the inflow through the processes in the third region **7** and the fourth region **8** of the anaerobic digestion reactor is controlled at an optimal pH for methane fermentation, a gas for providing stirring and fluidity may be preferably supplied with ammonia removed from the biogas such that these methane fermentation conditions may not be disturbed. Furthermore, the gas may be preferably supplied with even hydrogen sulfide removed from the biogas to increase the purity of a finally produced biogas. For this purpose, it is necessary to remove ammonia and hydrogen sulfide through an ammonia and hydrogen sulfide removal device **28**. An ammonia and hydrogen sulfide removal device will be below described in more detail with reference to FIG. **12**.

[0057] According to one aspect of embodiments of the present invention, an ammonia and hydrogen removal device **28** includes:

[0058] a closed-type tank (hereinafter, 'A-type tank') including:

- [0059] a diffuser **65** to which a biogas including ammonia and hydrogen sulfide transferred from a gas layer in an anaerobic digestion reactor is supplied;
- [0060] water in which the biogas supplied from the diffuser **65** is dissolved;
- [0061] a drain pipe **66** through which the water in which the biogas is dissolved is emitted by water level and gas pressure in a lower portion;
- [0062] an inlet pipe **67** through which water in which the ammonia and hydrogen sulfide is removed is introduced into an upper portion; and
- [0063] an exhaust pipe **68** through which the gas with the ammonia and hydrogen sulfide removed is returned to the anaerobic digestion reactor; and

[0064] an open-type tank (hereinafter, 'B-type tank') which includes a *Thiocapsa roseopersicina* culture including:

- [0065] a water pipe **69** through which the water drained from a lower portion of the A-type tank is introduced in an upper portion;
- [0066] a ball tap for water level control **62** connected to and supported by the water pipe **69**;
- [0067] a level sensor **61** which senses water level;
- [0068] a diffuser **63** to which external air is supplied;
- [0069] a drain pipe **70**, through which water with ammonia and hydrogen sulfide removed is drained in a lower portion; and
- [0070] a drain pump **64** which is connected to the drain pipe **70** and performs an on/off function according to a water level sensing information of the level sensor,

[0071] wherein the A-type tank is connected each other to the B-type tank.

[0072] According to one aspect of embodiments of the present invention, the A-type tank of the ammonia and hydrogen sulfide removal device **28** supplies ammonia and hydrogen sulfide dissolved in water to the B-type tank, in which the ammonia and hydrogen sulfide are reacted with oxygen supplied from the external air, and removes the ammonia and hydrogen sulfide in the form of ammonium sulfate ($(NH_4)_2SO_4$) as indicated in the following Formula 1.

$$2NH_3+H_2S+2O_2\rightarrow(NH_4)_2SO_4 \quad \text{[Formula 1]}$$

[0073] The A-type tank of the removal device **28** is a closed-type one. The tank may preferably maintain an appropriate internal pressure and water level such that water in which the gas introduced from a gas layer of the anaerobic digestion reactor is dissolved may be supplied to the B-type tank and that the internal pressure may be maintained more preferably at about 0.4 kg/cm^2 to about 0.6 kg/cm^2.

[0074] According to one aspect of embodiments of the present invention, the A-type and B-type tanks of the ammonia and hydrogen sulfide removal device **28** may preferably include a *Thiocapsa roseopersicina* culture. As indicated in the following Formula 2, some enzymes in the *Thiocapsa roseopersicina* culture may convert carbon dioxide and hydrogen sulfide in the biogas into the forms of formaldehyde (CH_2O) and sulfuric acid (H_2SO_4) salt to increase the purity of the biogas. It is thought that the converted sulfuric acid is additionally reacted with ammonia to be converted into the form of ammonium sulfate as indicated in the following Formula 3.

$$2\beta O_2+H_2S+2H_2O\rightarrow2(CH_2O)+H_2SO_4 \quad \text{[Formula 2]}$$

$$H_2SO_4+2NH_3\rightarrow(NH_4)_2SO_4 \quad \text{[Formula 3]}$$

[0075] As a result of the reaction, hydrogen sulfide included in the biogas may be additionally decreased with some carbon dioxide. In particular, in the conditions under which ammonia and hydrogen sulfide are not removed, the accumulation of ammonia and hydrogen sulfide in a conventional gas stirring type anaerobic digestion reactor in which anaerobic digestion liquid is stirred has been identified as a factor which has adverse effects on biogas production environments (growth and development of methanogen). However, according to the removal device of the present invention, a gas with hydrogen sulfide and ammonia removed, that is, a purified biogas in the upper layer portion may be used for the stirring of the anaerobic digestion liquid, and as a result, carbon dioxide and hydrogen may be supplied as a substrate for methanogenesis to methanogen in the anaerobic digestion liquid. This means that carbon dioxide as an impurity may be combined with extra hydrogen to lead to a decrease in methane concentration and an increase in carbon dioxide concentration in a total biogas produced and as a result, the purity of the biogas may be increased.

[0076] When the concentration of hydrogen sulfide introduced into the ammonia and hydrogen sulfide removal device is high, the hydrogen sulfide may be converted into the form of pure sulfur (S) at a rapid rate and removed. That is, when the concentration of hydrogen sulfide is high, the oxidation of hydrogen sulfide (H_2S) into sulfur (S) by *Thiocapsa roseopersicina* proceeds relatively more rapidly than that of sulfur (S) into sulfate anion (SO_4^{2-}), and thus a large amount of sulfur is accumulated in solution in the removal device and some is precipitated and suspended on the surface of a container or in solution.

[0077] Furthermore, the B-type tank of the ammonia and hydrogen sulfide removal device **28** may be preferably supplied with oxygen dissolved in water from the external air. Through the supply, oxygen input not only into the biogas in which ammonia and hydrogen sulfide are to be removed, but also into an anaerobic digestion reactor requiring extreme anaerobic conditions will be blocked in advance.

[0078] According to one aspect of embodiments of the present invention, the level sensor **61** in the B-type tank of the ammonia and hydrogen sulfide removal device **28** includes three sensor rods a, b, and c which are different each other in length. When the water level of the B-type tank touches the shortest sensor rod a, a drain pump **64** is operated to supply water with ammonia and hydrogen sulfide removed to the A-type tank. When the water level of the B-type tank touches the middle-length sensor rod b, the drain pump **64** stops its operation. A removal reaction of ammonia and hydrogen sulfide is continuously performed without any supply of gas-phase oxygen to the A-type tank while the solution is circulating in the A-type and B-type tanks.

[0079] According to one aspect of embodiments of the present invention, an ammonia and hydrogen sulfide removal device **28** transfers a dissolved biogas with ammonia and hydrogen sulfide removed through the B-type tank to the A-type tank and supplies the biogas through an exhaust pipe in the upper portion of the A-type tank to a diffusing gas supply tube **27** and a diffuser **26** in the lower portion of the anaerobic digestion reactor. More specifically, ammonia (NH_4) and hydrogen sulfide (H_2S), gasses which are easily dissolved in water, in the biogas which has been transferred to the A-type tank has been dissolved in water while methane (CH_4), hydrogen (H), some of carbon dioxide (CO_2) are emitted through an exhaust pipe in the upper portion of the A-type tank and supplied to a diffusing gas supply tube **27** and a diffuser **26** in the lower portion of the A-type tank of the present invention. Water in the A-type tank is supplied to the B-type tank while a reaction represented by $2CO_2+H_2S+2H_2O \rightarrow 2(CH_2O)+H_2SO_4$ is performed. As described above in the B-type tank, the rate of oxidation by purple bacteria (*Thiocapsa roseopersicina*) of H_2S groups into S proceeds faster than that of oxidation of S into SO_4^{2-}, and thus the application of a transient mass accumulation of S leads to conversion of S groups into SO_4^{-2} by dissolved oxygen which has been supplied to the B-type tank. The binding of SO_4^{-2} with dissolved NH_4^- leads to a fast reaction of ammonia into the form of ammonium sulfate (See Reaction Formula 3). That is, these reactions continuously occur while water is circulating between the A-type tank and the B-type tank.

[0080] According to one aspect of embodiments of the present invention, the B-type tank of the ammonia and hydrogen sulfide removal device **28** may be used without liquid phase replacement for about 6 months to about 1 year only by replenishing evaporated moisture. The liquid phase replacement time of the removal device **28** depends on the saturated concentration of ammonium sulfate as a produced material, and the liquid phase may be preferably replaced in terms of removal efficiency when the saturated concentration of the solution in the removal device reaches about 40%.

[0081] According to one aspect of embodiments of the present invention, a separate hydrogen sulfide removal device **28'** may be additionally connected to the ammonia and hydrogen sulfide removal device **28** in order to increase the removal efficiency of hydrogen sulfide in the ammonia and hydrogen sulfide removal device **28**.

[0082] One preferable aspect of embodiments of the hydrogen sulfide removal device **28'** may be provided in the form of a closed-type tank, including: an inlet pipe **71** into which a biogas with some hydrogen sulfide removed is introduced through a removal device **28**; a diffuser **72** which diffuses the biogas introduced from the inlet pipe **71**; water including iron hydroxide (II) or iron hydroxide (III) reacting with hydrogen sulfide in the biogas supplied from the diffuser **72**; and an exhaust pipe **73** which emits a biogas with hydrogen sulfide removed.

[0083] Specifically, 99% or more of ammonia supplied through the exhaust pipe **68** in the upper portion of the A-type tank and the biogas with some hydrogen sulfide removed are dissolved through the diffuser **65** and iron hydroxide (II) or iron hydroxide (III) included in the removal device **28'** is reacted with a residual hydrogen sulfide to remove the residual hydrogen sulfide in the form of iron sulfide and water. The hydrogen sulfide removal device **28'** may be serially connected to the A-type tank of the ammonia and hydrogen sulfide removal device **28**.

[0084] More preferably, iron hydroxide (II) or iron hydroxide (III) prepared by a method for preparing mineral hydroxide described in 'Method for preparation of organic chelate' (KR patent No. 0481326 and U.S. Pat. No. 7,087,775) filed by and granted to the present inventors may be used.

[0085] The iron sulfide (II) or iron sulfide (III) in the present invention is a material in the form of $Fe(OH)_2$ or $Fe(OH)_3$ obtained by equivalent reaction of conventional bivalent or trivalent iron such as $FeCl_2$, $FeCl_3$, etc., with NaOH in an aqueous solution. A product obtained as in the following Formula 4 may be centrifuged and NaCl may be removed to yield the $Fe(OH)_2$ or $Fe(OH)_3$.

$$FeCl_2+2NaOH \rightarrow Fe(OH)_2+2\beta NaCl$$

$$FeCl_3+3NaOH \rightarrow Fe(OH)_3+3NaCl \qquad \text{[Formula 4]}$$

[0086] Because the iron hydroxide (II) or iron hydroxide (III) is fully reacted with hydrogen sulfide, a gas component dissolved into a solution removal system in a removal device by a diffuser in a reaction tank of the present invention, the removal efficiency depends on the gas dissolution capability of the diffuser. The present invention is much more excellent than a method for venting air under high pressure into a conventional desulfurization device and performing an adsorption reaction of FeO(OH) as an iron hydroxide (III) and Fe_2O_3 as an iron oxide (III) with a gas-phase hydrogen sulfide to remove the hydrogen sulfide in terms of air venting rate (gas processing capability). In terms of reaction efficiency, the present invention is also much better than conventional desulfurization devices which depend on purity of iron hydroxide (III) and surface area of pellet.

[0087] Specifically, a conventional desulfurization device ("The Study of Biogas Production and Energy Use by High-rate Two Phase Anaerobic Treatment of Swine Wastewater (Final report)", p. 151, September, 2006, Department of Industry and Resources, Korea) may adsorb 130 g of hydrogen sulfide per kg of Fe_2O_3, while a removal device according to the present invention may adsorb about 478 g of hydrogen sulfide per kg of $Fe(OH)_3$, indicating that the present invention is much better than the conventional device by about 3.7 fold in terms of removal efficiency. Because the present invention has an air venting rate of about 4 Nm^3/min, a much better value than 2.5 Nm^3/min of the conventional desulfurization device in terms of gas processing, the present invention is also considered to be excellent in processing capability.

[0088] As described above, an ammonia and hydrogen sulfide removal device **28** according to the present invention may significantly decrease carbon dioxide content in biogas because an enzyme produced in a *Thiocapsa roseopersicina* culture included therein consumes carbon dioxide during the removal of hydrogen sulfide. Biogas produced in a conventional anaerobic digestion reactor for producing biogas contains only 60% to 70% or less of methane and 35% to 45% or less of carbon dioxide.

[0089] On the contrary, when the removal device **28** and/or removal device **28'** according to the present invention is used, the removal device **28'** may be independently applied for the purpose of removing hydrogen sulfide from a biogas produced by an anaerobic digestion reactor. Furthermore, when the removal device **28** is combined with the removal device **28'** for use, optimal anaerobic digestion conditions (prevention of ammonia and hydrogen sulfide accumulation in digestion liquid) may be maintained by supplying a high-purity biogas to an aerobic digestion reactor as a gas for stirring the anaerobic digestion liquid and carbon dioxide content may be decreased to 20% or less, thus leading to an increase in methane content in a total biogas produced to 80% or more by performing a reaction of $2CO_2+H_2S+2H_2O \rightarrow 2\ (CH_2O)+H_2SO_4$ and supplying residual carbon dioxide and hydrogen as a substrate for methanogen in the digestion liquid to convert carbon dioxide as an impurity into methane. Methanogen species and available substrates are summarized in the following Table 1.

TABLE 1

Methanogen species	Available substrate
Methanobacterium, thermoautotrophicum	$H_2 + CO_2$, CO
Methanobrevibacter arboriphilus	$H_2 + CO_2$
Methanococcus vanniellii	$H_2 + CO_2$, HCOOH
Methanospirillum hungatei	$H_2 + CO_2$, HCOOH
Methanosarcina barkeri	$H_2 + CO_2$, CH_3OH, CH_3COOH, methylamines
Methanosarcina mazei	CH_3OH, CH_3COOH, methylamines
Methanothrix soehngenii	CH_3COOH
Methanolobus tindarius	CH_3COOH, methylamines

TABLE 1-continued

Methanogen species	Available substrate
Methanococcoides methylutens	CH_3COOH, methylamines
Methanoplanus limicola	$H_2 + CO_2$, HCOOH

[0090] Because the removal efficiency by the removal device depends on the solubility of a gas to be removed which is transferred to a removal device, it is desirable to increase the gas input rate slowly into the removal device in order to increase the solubility. A better removal efficiency may be achieved in terms of purity increase by increasing the circulation frequency of the gas to be removed in the removal device.

[0091] According to one aspect of embodiments of the present invention, a first input reactor **3** in the anaerobic digestion reactor includes a first heat exchange tube **2**. Because a sludge pump **21** may be used to introduce a final fermentation broth (sludge liquid) in the lower portion of the fourth region **8** in which the final anaerobic digestion is completed into an inlet pipe **41**, installed on the floor of the fourth region **8**, transfer it to a first heat exchange tube **2**, and circulate it in the first input reactor **3**, a new cold inflow may be warmed (See FIGS. **5** and **9**).

[0092] As described above, because the temperature of an inflow introduced into the anaerobic digestion reactor is about 18° C. in summer and about 8° C. in winter, a significant temperature variation occurs compared to 35° C. to 42° C., a temperature range for mesophilic temperature anaerobic digestion.

[0093] The temperature of a final fermentation broth (sludge liquid) in which a final anaerobic digestion is completed becomes about 35° C. Because heat corresponding to the temperature is recovered to the inflow as waste heat, the final fermentation broth is transferred to a subsequent treatment reactor on the upper layer of the anaerobic digestion reactor, and the fermentation step has been completed, no additional temperature control is necessary.

[0094] Therefore, the present invention may allow a new inflow to minimize a variation between the temperatures of an actual methane fermentation and an optimal methane fermentation by introducing a first heat exchange pipe **2** connected to an inlet pipe **41** in the lower portion as above to provide a waste heat generated from a relatively high temperature final fermentation broth to the new inflow in a relatively low temperature first input reactor **3**.

[0095] According to one aspect of embodiments of the present invention, the fourth region **8** of the anaerobic digestion reactor includes an inlet pipe **42** in the upper portion, which draws in an activated liquid in the upper portion. The activated liquid is drawn in through a sludge pump **43**. The activated liquid is used as a liquid inoculum when an inflow is a livestock wastewater, while the liquid is used for dilution according to the concentrations of the inflow when the inflow is a food waste. When it is used as a liquid inoculum, it may be introduced into a second input reactor **4** by manipulating a simple on/off valve **44** (See FIG. **10**).

[0096] According to one aspect of embodiments of the present invention, the anaerobic digestion reactor may further include a hydrogen sulfide removal device between a biogas layer in an upper portion of the fourth region **8** and a biogas capturing device connected thereto in order to increase the removal efficiency of hydrogen sulfide (See FIG. **1**). The hydrogen sulfide removal device may use a hydrogen sulfide removal device **28'** as mentioned in FIG. **12** (*c*).

[0097] According to one aspect of embodiments of the present invention, the anaerobic digestion reactor includes a subsequent treatment reactor in the upper layer (See FIG. **3**). The subsequent treatment reactor is divided into a first region **11**, a second region **12**, a third region **13**, and a fourth region **14** and has a structure in which the regions are divided each other by separation walls in the same form of the separation walls **5'**, **6'**, and **7'** installed in the first region **5**, second region **6**, third region **7**, and fourth region **8** of the anaerobic digestion reactor in the lower layer. The treatment reactor also includes a diffusing gas supply tube (not shown) and a diffuser (not shown) in the same form of those in the lower layer.

[0098] In each region **11**, **12**, **13**, and **14** of the subsequent treatment reactor, external air including oxygen is supplied through a brewer (not shown) to a diffusing gas supply tube and a diffuser, and the air sprayed through the diffuser gives the fluidity to an inflow in each region to be transferred in a first-in and first out order. This means that the treatment reactor is operated in the same manner as the anaerobic digestion reactor in the lower layer except that external air is used as a diffusing gas.

[0099] In order to remove odor components generated by a final fermentation broth (sludge liquid) of the anaerobic digestion reactor, regions **11**, **12**, **13**, and **14** of the subsequent treatment reactor may be connected to an odor component removal device which purifies and emits a gas produced from an upper gas layer of the regions **11**, **12**, **13**, and **14** externally (See FIG. **1**).

[0100] As the odor component removal device, an open type B tank may be alone connected to a gas layer of the subsequent treatment reactor for use. The B-type tank includes water containing a *Thiocapsa roseopersicina* culture, dissolves gas drawn in from a gas layer in each region of the subsequent treatment reactor in the water by using a diffuser in the removal device, removes ammonia and hydrogen sulfide as odor components in the form of ammonium sulfate or sulfate salt, and then emits the gas from which the odor components have been removed into the air.

[0101] Subsequently, a final fermentation broth in which odor components have been removed may be transferred to a liquid-composting reactor and used as a fertilizer for application to arable land.

[0102] Hereinafter, the operating state of an anaerobic digester having the structure will be described with reference to FIG. **1**.

[0103] An inflow such as livestock wastewater, food waste, etc. is introduced into a first input reactor and warmed by heat from a heat exchange pipe (a first heat exchange pipe) included in the first input reactor. The inflow whose heat exchange has been completed to be warmed is overflown into a second input reactor, introduced into a first region of the anaerobic digestion reactor in the lower layer, and passes through a second region, a third region, and a fourth region of the anaerobic digestion reactor in sequence in a first-in and first-out manner. As a result of an anaerobic digestion, biogas is produced and stored in the upper portion of each region. In the side wall of the first region of the anaerobic digestion reactor, a heat exchange pipe (a second heat exchange pipe) in which an engine exhaust gas or a boiler flue gas supplied from an external waste heat gas supply device may be circulated is included to minimize a variation between the temperatures of the inflow and the optimal anaerobic digestion. A floor-heating piping which is installed on the floor from the first region to the fourth region supplies heat to the inflow in order to achieve the same purpose.

[0104] A diffusing gas supply tube and a diffuser are installed on the floor of the first, second, third, and fourth regions of the anaerobic digestion reactor, stir the inflow passing through each region, and provide fluidity to the inflow. The gas draws in a biogas in the upper portion of the second and fourth regions through an external brewer, and ammonia and hydrogen sulfide included in the biogas are supplied to the diffusing gas supply tube and the diffuser from the first region to the fourth region with or without removal of the ammonia and hydrogen sulfide. The biogas which does not pass through the ammonia and hydrogen sulfide removal device is usually transferred to a diffusing gas supply tube, a diffuser, and a diffusing gas separation wall in the first region, and as a result, the lowered pH value of the inflow in the first region by performing an acid production step will satisfy pH conditions of the inflow appropriate for the next region to perform methane fermentation with the help of stirring and fluidity by providing the biogas including ammonia. The biogas passing through the ammonia and hydrogen sulfide removal device is usually supplied to the third to fourth regions, and as a result, a high-purity biogas in which ammonia and hydrogen sulfide are maximally removed is accumulated in a gas layer of the fourth region, in which a final biogas is stored. If necessary, the accumulated biogas may pass through a hydrogen sulfide removal device to be used as a fuel for electricity generation/heat production in the state that almost all the residual hydrogen is removed.

[0105] A final fermentation broth (sludge liquid) which reaches the fourth region of the anaerobic digestion reactor and completes the anaerobic digestion is collected in the lower portion of the fourth region. The final fermentation broth is drawn in through an inlet pipe in the lower portion, transferred to a first heat exchange pipe included in a first input reactor, and moved into a subsequent treatment reactor in an upper layer of the anaerobic digestion reactor after heat generated as a result of a final fermentation is provided to a new inflow to be introduced. Activated liquid is present in the upper layer portion of the fourth region of the anaerobic digestion reactor except for a final fermentation broth in the lower layer. Some of the liquid is supplied through an inlet pipe in the upper layer portion to a second input reactor and used as a liquid inoculum and a pH adjusting liquid, and the other is used as a diluent for livestock wastewater or food waste to be introduced into a first input reactor.

[0106] The final fermentation broth (sludge liquid) transferred to a subsequent treatment reactor in the upper layer of the anaerobic digestion reactor moves in a first-in and first out manner into first, second, third, and fourth regions of the subsequent treatment reactor having the same structure as the first, second, third, and fourth regions of the anaerobic digestion reactor in the lower layer. The process for providing stirring and fluidity to the final fermentation broth is performed in the same manner as in the anaerobic digestion reactor. However, external air including oxygen is injected into the diffusing gas supplied through a diffusing air supply tube and a diffuser unlike the anaerobic digestion reactor. The final fermentation broth moving into each region of the subsequent treatment reactor generates odor components such as ammonia, hydrogen sulfide, etc. to a gas layer in the upper portion, and these odor components are again transferred to the ammonia and hydrogen sulfide removal device to be removed and externally emitted. The final residual fermentation broth is transferred to a liquid-composting reactor and used as a fertilizer for application to arable land, thereby completing an anaerobic digestion process through an anaerobic digester according to the present invention.

[0107] Because a gas layer in the upper portion of the anaerobic digestion reactor serves as a gas storage unit as well in the anaerobic digester according to the present invention, a separate gas storage unit is not required. The water level of an input reactor may be also controlled by gas pressure in a gas layer, and the operation of an additional apparatus such as an engine for electricity generation connected to the anaerobic digestion reactor may be controlled through a digestion liquid level measurement tube.

[0108] In the anaerobic digester according to the present invention, the oxidation and reduction potential (ORP) of the first and fourth regions of the anaerobic digestion reactor is measured at −330 mV to −460 mV, respectively, satisfying bacteria culture conditions of anaerobic digestion reactors requiring −300 mV or less.

[0109] Furthermore, the anaerobic digester according to the present invention does not require pretreatment when an inflow is introduced and provides optimal conditions for growth and development of methanogen by controlling the temperature of the inflow throughout the whole process including an initial input step, an anaerobic digestion step, etc. using waste heat.

[0110] When unfermented liquid which is subsequently introduced is firstly out, the anaerobic digester according to the present invention may remove factors which may deteriorate the removal efficiency of odor components in the subsequent treatment by allowing the inflow to move in a first-in and first-out manner.

[0111] Furthermore, the anaerobic digester according to the present invention does not require a separate stirring unit inside the anaerobic digestion reactor and may slowly transfer the inflow such that floatation and homogenization of deposits in the inflow may be induced with or without purification of a self-produced biogas for recycling.

[0112] In addition, the anaerobic digester according to the present invention may draw in biogas from a gas layer in the anaerobic digestion reactor and recirculate it through an ammonia and hydrogen sulfide removal device to produce a high-purity biogas. Through the removal device, a sustained concentration of ammonia and hydrogen sulfide, which has been identified as a disadvantage of conventional gas stirring-type anaerobic digestion reactors and inhibits the growth and development of methanogen, may be prevented.

[0113] Furthermore, when it is a combined A-type and B-type tank **28**, the ammonia and hydrogen sulfide removal device according to the present invention may remove 99% or more of ammonia and 30% or more of hydrogen sulfide to be produced, and a removal device **28'** which is connected to the combined removal device **28** and includes iron hydroxide (II) or iron hydroxide (III) may remove 99% or more of hydrogen sulfide produced by increasing the passing frequency into the removal device.

[0114] In addition, the ammonia and hydrogen sulfide removal device **28** according to the present invention may consume carbon dioxide, when an enzyme produced in a *Thiocapsa roseopersicina* culture included therein removes hydrogen sulfide, to decrease carbon dioxide content in biogas primarily. Furthermore, residual carbon dioxide and hydrogen in biogas as described above may be provided as a substrate for methanogen in the digestion liquid to convert carbon dioxide as an impurity into methane and decrease the carbon dioxide content secondarily. Conventional anaerobic digestion reactors for biogas production only contain 65% or less of methane and 35% or more of carbon dioxide. However, the removal device according to the present invention may be used in the anaerobic digestion reactor to produce biogas whose methane content is 80% or more, the level of municipal gas, by lowering carbon dioxide content in the biogas to 20% or less (See FIG. **2**).

TABLE 2

	H_2S (ppm)		CO_2 (%)		NH_3 (ppm)		Passing frequency
Measurement	Measurement position 1	Measurement position 2	Measurement position 1	Measurement position 2	Measurement position 1	Measurement position 2	into a removal device
1	5000	1600	23	18	25	—	1
2	1600	320	20	17	25	—	2
3	600	40	20	18	40	—	3

[0115] Table 2 is a measurement result of the removal efficiency of ammonia, hydrogen sulfide, and carbon dioxide by a removal device according to the present invention. Specifically, Table 2 is a result of the ingredient and content of a biogas measured at a GASTEC Detector (manufacturer: Japan) tube (measurement position 1) between a brewer **29** and an A-type tank in FIG. **12** (*a*) by increasing the passing frequency into the removal device from 1 to 3, and measured at a position (measurement position 2) out of the A'-type tank of the removal device **28'** in FIG. **12** (*a*). Referring to Table 2, ammonia was fully removed only by an initial one time passing while about 68%, about 80%, and about 94% of hydrogen sulfide was removed by one, two, and three passing frequencies, respectively. It can be seen that carbon dioxide may be included at 20% or less in biogas and a high-purity biogas may be produced from an anaerobic digestion reactor including a removal device according to the present invention.

[0116] It is apparent to those skilled in the art to which the present invention pertains that various modifications and changes can be made without departing the spirit and scope of the present invention and all these modifications and changes are intended to be contained with the accompanying claims.

[0117] For example, an anaerobic digester according to the present invention includes an anaerobic digester which has structures of a monolayer type with an upper layer and a lower layer separated as well as of a double layer of an upper layer and a lower layer described in the Detailed Description and Claims, and technical features of the upper layer and the lower layer embodied in one monolayer. The ammonia and hydrogen sulfide removal device **28** or hydrogen sulfide removal device **28'** according to the present invention is not limited to the use only for the anaerobic digester according to the present invention. Rather, the removal device **28** or the removal device **28'** may be appropriately modified according to the structure of the device as long as it is a device provided for the purpose of removing gasses such as ammonia, hydrogen sulfide, carbon dioxide, etc, and obtaining a high-purity biogas. Furthermore, it may be applied to a device for removing sulfur, ammonia, carbon dioxide, etc, as well as a device for producing biogas.

What is claimed is:

1. An apartment-shaped anaerobic digester, comprising:

a first input reactor into which livestock wastewater or food waste (hereinafter, 'inflow') is introduced;

a second input reactor into which the inflow passing through the first input reactor is introduced;

first, second, third, and fourth regions of an anaerobic digestion reactor designed for the inflow passing through the second input reactor to perform methane fermentation in a first-in and first-out order to produce and transfer biogas simultaneously into the next anaerobic digestion region;

a diffusing gas supply tube and a diffuser giving fluidity to the inflow of the first, second, third, and fourth regions;

an inlet pipe in a lower layer portion of the fourth region of the anaerobic digestion reactor, into which sludge liquid is drawn in from the lower layer portion;

an inlet pipe in an upper layer portion of the forth region of the anaerobic digestion reactor, into which activated liquid is drawn in from the upper layer portion;

a biogas capturing device which is connected to a gas layer in the fourth region of the anaerobic digestion reactor;

a first heat exchange tube provided inside the first input reactor to allow the sludge liquid drawn in from the inlet pipe in the lower layer portion to perform heat exchange with a new inflow;

first, second, third, and fourth regions of a subsequent treatment reactor provided on the upper layer of the anaerobic digestion reactor, to allow the sludge liquid whose heat exchange is completed to be introduced in a first-in and first-out order, and to treat gas odor components generated from the sludge liquid; and

a liquid-composting reactor in which an emitted sludge whose odor components have been removed is stored.

2. The digester as set forth in claim **1**, wherein the floor of the first, second, third, and fourth regions of the anaerobic digestion reactor comprises a floor-heating piping to maintain a temperature for methane fermentation.

3. The digester as set forth in claim **1**, wherein each region of the anaerobic digestion reactor has a structure in which a space for storing biogas produced by methane fermentation is secured.

4. The digester as set forth in claim **1**, wherein each region of the anaerobic digestion reactor has a structure in which the regions are divided each other by separation walls, in each of which the terminal portion is opened in the form of the '⌉', and the inflow and biogas move through the open space into the next region.

5. The digester as set forth in claim **4**, wherein the separation wall of each region of the anaerobic digestion reactor has a structure in which a separation wall between a first region and a second region and a separation wall between a third region and a fourth region are opened in the same direction, a separation wall between the second region and the third region is opened in the direction opposite to the openings of the separation wall between the first region and the second region and the separation wall between the third region and the fourth region, and an inflow moves in a zig-zag manner throughout the whole regions of the anaerobic digestion reactor.

6. The digester as set forth in claim **1**, wherein the diffusing gas supply tube and the diffuser include a diffusing gas supply tube and a diffuser in a first region and a second region provided around the perimeter of a wall on the floor of a side wall in the direction of the second region of a separation wall installed between the second and a third regions, on the floor of an inner side wall from the first region to the second region, which is vertical to the separation wall, and on the floor of an inner side wall in the first region, which is vertical to an inner side wall from the first region to the second region, and a diffusing gas supply tube and a diffuser in a third and a fourth region provided around the perimeter of a wall on the floor of a side wall in the direction of the third region of a separation wall installed between the second and the third regions, on the floor of an inner side wall from the third region to the fourth region, which is vertical to the separation wall, and on the floor of an inner side wall in the fourth region, which is vertical to an inner side wall from the third region to the fourth region.

7. The digester as set forth in claim **1**, wherein the first region of the anaerobic digestion reactor has a second heat exchange tube which is formed on the surface of the side wall opposite to a separation wall in the first region and may exchange a heat supplied from an external source to maximize the methane fermentation efficiency by minimizing a temperature variation between the temperature of initially introduced inflow and the optimal fermentation temperature for methanogenesis.

8. The digester as set forth in claim **7**, wherein the heat supplied form the external source is a waste heat produced by a boiler flue gas or an engine exhaust gas.

9. The digester as set forth in claim **7**, wherein the first region of the anaerobic digestion reactor has a diffusing gas partition wall in front of the second heat exchange tube and a diffusing gas supply tube and a diffuser are installed on the floor between the wall on which the second heat exchanger is installed and the diffusing gas partition wall, and wherein the diffusing gas partition wall induces the flow of the diffusing gas exiting from the diffuser in the vertical direction, and then allows the diffusing gas passing through the diffusing gas partition wall to provide clockwise fluidity to the inflow passing through the first region.

10. The digester as set forth in claim **1**, wherein the second region of the anaerobic digestion reactor comprises a gas piping to recover a gas produced as a result of anaerobic digestion and supply the gas to a diffusing gas supply tube and a diffuser in the first region and the second region, provided around the perimeter of a wall on the floor of a side wall in the direction of the second region of a separation wall installed between the second and the third regions, on the floor of an inner side wall from the first region to the second region, which is vertical to the separation wall, and on the floor of an inner side wall in the first region, which is vertical to an inner side wall from the first region to the second region, and wherein the fourth region of the anaerobic digestion reactor comprises a gas piping to recover a gas produced as a result of anaerobic digestion and supply the gas to a diffusing gas supply tube and a diffuser in the third region and the fourth region provided around the perimeter of a wall on the floor of a side wall in the direction of the third region of a separation wall installed between the second and the third regions, on the floor of an inner side wall from the third region to the fourth region, which is vertical to the separation wall, and on the floor of an inner side wall in the fourth region, which is vertical to an inner side wall from the third region to the fourth region.

11. The digester as set forth in claim **10**, wherein the gas piping comprised in the fourth region of the anaerobic digestion reactor is connected to a device for removing ammonia and hydrogen sulfide comprised in a gas produced as a result of anaerobic digestion and supplies a gas with ammonia and hydrogen sulfide removed to a diffusing gas supply tube and a diffuser comprised in the third region and the fourth region to maintain an optimal pH for methane fermentation and increase the purity of a biogas finally produced.

12. The digester as set forth in claim **10**, wherein the gas piping comprised in the second region of the anaerobic digestion reactor is connected to a gas piping comprised in the fourth region of the anaerobic digestion reactor, into which a gas passing through an ammonia and hydrogen sulfide removal device moves, and selectively supplies or blocks the gas with ammonia and hydrogen sulfide removed to a diffusing gas supply tube and a diffuser comprised in the first and second regions.

13. The digester as set forth in claim **11**, wherein the ammonia and hydrogen removal device comprises

a closed-type tank (hereinafter, 'A-type tank') comprising:

- a diffuser to which a biogas comprising ammonia and hydrogen sulfide transferred from a gas layer in an anaerobic digestion reactor is supplied;
- water in which the biogas supplied from the diffuser is dissolved;
- a drain pipe through which the water in which the biogas is dissolved is emitted by water level and gas pressure in a lower portion;
- an inlet pipe through which water in which ammonia and hydrogen sulfide is removed is introduced into an upper portion; and
- an exhaust pipe through which the gas with the ammonia and hydrogen sulfide removed is returned to the anaerobic digestion reactor; and

an open-type tank (hereinafter, 'B-type tank') which comprises a *Thiocapsa roseopersicina* culture comprising:

- a water pipe through which the water drained from a lower portion of the A-type tank is introduced in an upper portion;
- a ball tap for water level control connected to and supported by the water pipe;
- a level sensor which senses water level;
- a diffuser to which external air is supplied;
- a drain pipe, through which water with ammonia and hydrogen sulfide removed is drained in a lower portion; and
- a drain pump which is connected to the drain pipe and performs an on/off function according to a water level sensing information of the level sensor,

wherein the A-type tank is connected each other to the B-type tank.

14. The digester as set forth in claim **13**, wherein the A-type tank of the ammonia and hydrogen sulfide removal device supplies ammonia and hydrogen sulfide dissolved in water to the B-type tank, in which the ammonia and hydrogen sulfide are reacted with oxygen supplied from the external air, and removes the ammonia and hydrogen sulfide in the form of ammonium sulfate ($(NH_4)_2SO_4$).

15. The digester as set forth in claim **13**, wherein the B-type tank of the ammonia and hydrogen sulfide removal device uses a *Thiocapsa roseopersicina* culture to remove carbon dioxide or hydrogen sulfide in the biogas in the form of formaldehyde (CH_2O), sulfuric acid (H_2SO_4) salt or pure sulfur (S).

16. The digester as set forth in claim **13**, wherein the B-type tank of the ammonia and hydrogen sulfide removal device is supplied with oxygen dissolved in water from the external air to block the oxygen input into the anaerobic digestion reactor.

17. The digester as set forth in claim **13**, wherein a level sensor in the B-type tank of the ammonia and hydrogen sulfide removal device comprises three sensor rods which are different each other in length, operates a drain pump to supply water with ammonia and hydrogen sulfide removed to the A-type tank when the water level of the B-type tank touches the shortest sensor rod, and stops the operation of the drain pump when the water level of the B-type tank touches the middle-length sensor rod to perform a removal reaction of the ammonia and hydrogen sulfide.

18. The digester as set forth in claim **13**, wherein the ammonia and hydrogen removal device transfers a dissolved biogas with ammonia and hydrogen sulfide removed through the B-type tank to the A-type tank and supplies it through an exhaust pipe in an upper portion of the A-type tank to a diffusing gas supply tube and a diffuser in the lower portion.

19. The digester as set forth in claim **13**, wherein the ammonia and hydrogen sulfide removal device dissolves a biogas with ammonia and hydrogen sulfide removed through a diffuser in the upper portion of the A-type tank and further connects a hydrogen sulfide removal device which removes a residual hydrogen sulfide in the form of iron sulfide and water by reacting iron hydroxide (II) or iron hydroxide (III) with the residual hydrogen sulfide to the A-type tank, in order to increase the removal efficiency of hydrogen sulfide.

20. The digester as set forth in claim **19**, wherein the hydrogen sulfide removal device is a closed type tank ("A type tank"), comprising:

- an inlet pipe into which a biogas with some hydrogen sulfide removed is introduced through the ammonia and hydrogen sulfide removal device of claim **13**;
- a diffuser which diffuses the biogas introduced from the inlet pipe;
- water comprising iron hydroxide (II) or iron hydroxide (III) reacting with hydrogen sulfide in the biogas supplied from the diffuser; and
- an exhaust pipe which emits a biogas with hydrogen sulfide removed.

21. The digester as set forth in claim **1**, wherein a sludge liquid which is drawn into an inlet pipe in the lower portion of the fourth region of the anaerobic digestion reactor provides heat generated as a result of a temperature increase by anaerobic digestion to a new inflow while being circulated in a first heat exchange tube of the first input reactor and minimizes a temperature variation between the temperatures of an optimal methane fermentation and the new inflow.

22. The digester as set forth in claim **1**, wherein some of the activated liquid which is drawn into an inlet pipe in the upper layer portion of the anaerobic digestion reactor is introduced into a second input reactor and used as a liquid inoculum when an inflow is a livestock wastewater.

23. The digester as set forth in claim **1**, wherein some of the activated liquid which is drawn into an inlet pipe in the upper layer portion is used for dilution according to the concentrations of the inflow before the inflow is introduced into a first input reactor.

24. The digester as set forth in claim **1**, wherein in order to increase the removal efficiency of hydrogen sulfide, between a biogas layer of the fourth region of the anaerobic digestion reactor and a biogas capturing device connected thereto, a hydrogen sulfide removal device is comprised to supply a biogas from the biogas layer through a diffuser in the tank comprising water into which iron hydroxide (II) or iron hydroxide (III) is added and to be reacted with a residual hydrogen sulfide in the biogas to remove the residual hydrogen sulfide in the form of iron sulfide.

25. The digester as set forth in claim **1**, wherein a first region, a second region, a third region, and a fourth region of a subsequent treatment reactor comprised in the upper layer of the anaerobic digestion reactor are divided each other by separation walls in the same form of the separation walls installed in the first region, second region, third region, and fourth region of the anaerobic digestion reactor in the lower layer and comprise a diffusing gas supply tube and a diffuser in the same form.

26. The digester as set forth in claim **25**, wherein an external air comprising oxygen is supplied through a brewer to a diffusing gas supply tube and a diffuse in each region of the subsequent treatment reactor, and the air sprayed through the diffuser gives the fluidity to an inflow in each region to be transferred in a first-in and first out order.

27. The digester as set forth in claim **25**, wherein each region of the subsequent treatment reactor is connected to an odor component removal device which purifies and emits a gas produced in an upper gas layer of each region externally in order to remove odor components generated from the inflow.

28. The digester as set forth in claim **25**, wherein the odor component removal device is an open-type tank which comprises water containing a *Thiocapsa roseopersicina* culture, dissolves a gas drawn in from a gas layer of each region in the subsequent treatment reactor through a diffuser in the removal device into the water to remove ammonia and hydrogen sulfide as a odor component in the form of ammonium sulfate or sulfuric acid salt, and then emits the gas with odor components removed into the air.

* * * * *

United States Patent [19]

Paton

[11] **4,429,043**

[45] **Jan. 31, 1984**

[54] **ANAEROBIC DIGESTION OF ORGANIC WASTE FOR BIOGAS PRODUCTION**

[75] Inventor: **Robert Paton**, Ponce, P.R.

[73] Assignee: **Biorganic Energy Inc.**, Hato Rey, P.R.

[21] Appl. No.: **337,250**

[22] Filed: **Jan. 5, 1982**

[51] **Int. Cl.**[3] **C12P 5/02**

[52] **U.S. Cl.** **435/167**; 435/801; 71/10; 210/603; 426/55

[58] **Field of Search** .... 435/801, 167, 813; 210/603, 218, 613, 320; 48/197 A, 197 FM; 426/55, 56; 71/10

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[57] **ABSTRACT**

A low solids aqueous suspension of organic waste is treated in at least four, e.g., six serial anaerobic zones at a temperature of less than 40° C. and under quiescent conditions to provide methane, fertilizer and a clean liquid effluent.

16 Claims, 3 Drawing Figures

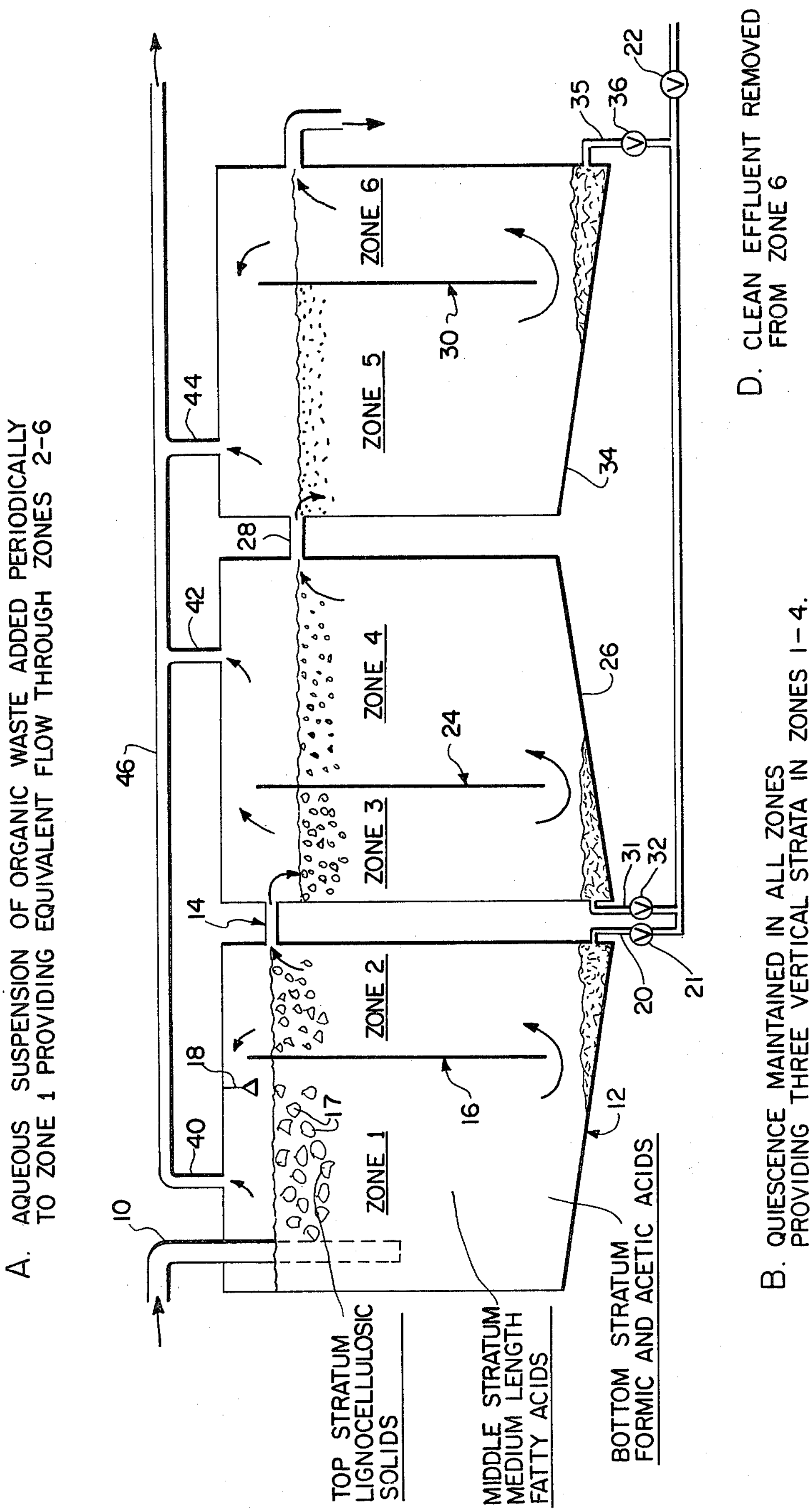
A. AQUEOUS SUSPENSION OF ORGANIC WASTE ADDED PERIODICALLY TO ZONE 1 PROVIDING EQUIVALENT FLOW THROUGH ZONES 2-6
B. QUIESCENCE MAINTAINED IN ALL ZONES PROVIDING THREE VERTICAL STRATA IN ZONES 1-4.
C. METHANE COLLECTED FROM TOP OF EACH ZONE; FERTILIZER REMOVED PERIODICALLY FROM BOTTOM OF ZONES 2,3 AND 6
D. CLEAN EFFLUENT REMOVED FROM ZONE 6
TOP STRATUM LIGNOCELLULOSIC SOLIDS
MIDDLE STRATUM MEDIUM LENGTH FATTY ACIDS
BOTTOM STRATUM FORMIC AND ACETIC ACIDS
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
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FIG. 1

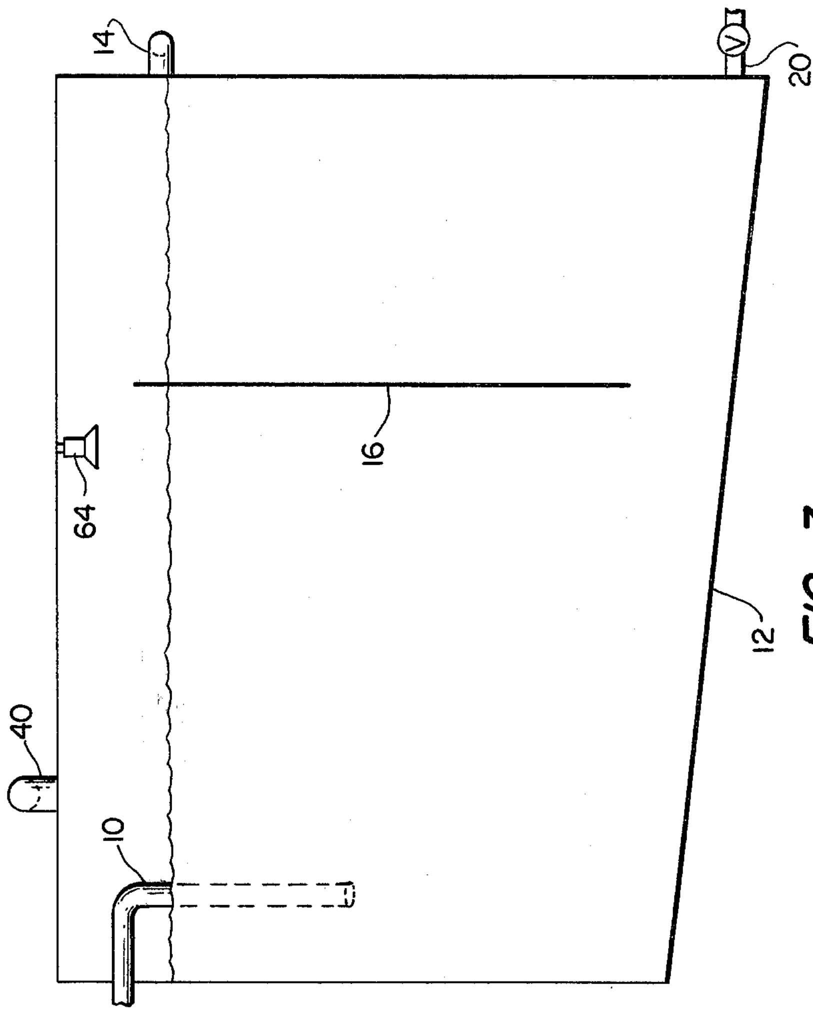
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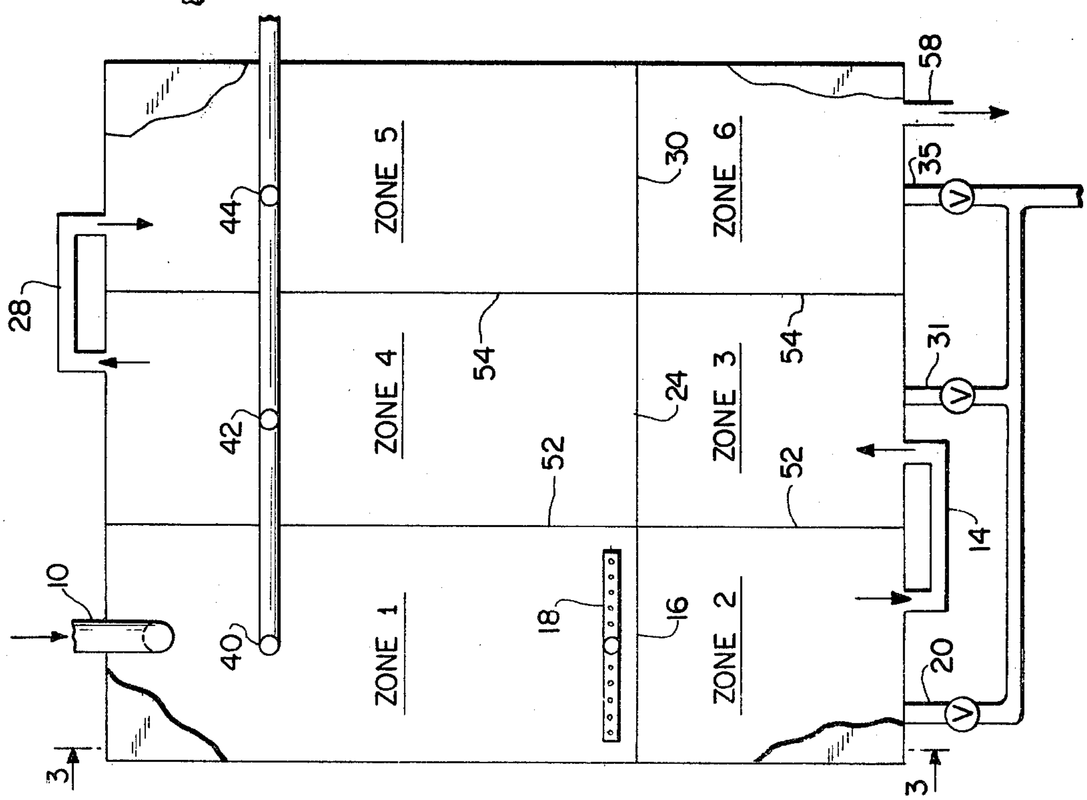
FIG. 3


ZONE 1
ZONE 2
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ZONE 4
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3

FIG. 2

ANAEROBIC DIGESTION OF ORGANIC WASTE FOR BIOGAS PRODUCTION

BACKGROUND OF THE INVENTION

This invention relates to a process for converting organic waste material into methane and other useful products such as fertilizer. More specifically, this invention relates to an anaerobic digestion process which is conducted in several zones.

Organic waste such as straw, paper and particularly animal wastes, i.e., manure, have long been considered a potential resource for the production of methane gas. Substantial amounts of money and effort have been directed towards providing a practical process for utilization of this resource. Typical methods involve both aerobic and anaerobic degradation of the waste within a complex system.

Most prior art systems involve treating an aqueous suspension of the waste having a solids content of about 10% or greater in a fermentative system which requires heating of at least part of the system. Such systems also typically require intermittent or continuous mixing and frequent periodic maintenance. Recirculation of microbe-rich or activated sludge is often an essential part of the system and operation normally requires nontrivial technological expertise. Initial capital investment to acquire such systems is generally prohibitive.

SUMMARY OF THE INVENTION

A simple and economical process for the conversion of organic waste material and particularly animal wastes into substantial amounts of methane has now been found. The process can be operated with little or no expertise and requires little or no maintenance. In accordance with the invention, organic waste material is anaerobically treated. A low solids aqueous suspension of organic waste is periodically passed into the first of at least four, e.g., six serially arranged anaerobic zones. The zones communicate with one another in a manner such that addition of liquid to the first zone, when six zones are employed, causes: liquid flow from the lower portion of the first anaerobic zone to the lower portion of the second anaerobic zone; liquid flow from the upper portion of the second anaerobic zone to the upper portion of the third anaerobic zone; liquid flow from the lower portion of the third anaerobic zone to the lower portion of the fourth anaerobic zone; liquid flow from the upper portion of the fourth anaerobic zone to the upper portion of the fifth anaerobic zone; liquid flow from the lower portion of the fifth anaerobic zone to the lower portion of the sixth anaerobic zone; and liquid flow out of the upper portion of the sixth anaerobic zone. Such serial liquid communication constitutes the only liquid communication between these zones. All of the zones are maintained at substantially quiescent conditions. This provides three vertically arranged strata in at least each of the first four zones. The upper stratum includes an aqueous suspension of lignocellulosic solids. The intermediate stratum includes an aqueous solution of acids which are predominantly medium length fatty acids such as valeric and propionic acids. The lower stratum includes an aqueous solution of acids which are predominantly formic and acetic acids. Each of the zones is maintained at an ambient temperature that can range from 26° to 34° C., thus the system normally needs no energy input unless faster degradation is required in which case the temperature can be increased up to 40° C. in the first zone only. Methane gas is collected from the top of the zones and fertilizer solids can be periodically removed from a lower portion of the zones 2, 3 and 6. The liquid effluent removed from the sixth zone requires little or no further treatment to meet environmental standards.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings which form part of the original disclosure of the invention:

FIG. 1 is a flow diagram illustrating one preferred embodiment of the invention;

FIG. 2 is a top plan view shown in partial cutaway and illustrates one preferred arrangement of the various zones; and

FIG. 3 is a side view of the arrangement shown in FIG. 2, taken at line 3—3.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 diagrammatically illustrates one advantageous embodiment of the method. A low solids aqueous suspension of organic waste is periodically passed via line **10** into zone **1**. The organic waste can be straw, paper or other lignocellulosic material and is advantageously an animal waste, i.e., manure. The solids will constitute less than about 4% by weight of the aqueous suspension added by line **10** and are preferably less than 3% by weight, most preferably about 2% by weight. The size of the first zone is dependent upon the BOD and/or COD content of the material which is to be treated in the process. There should be sufficient liquid space in the first zone that there is at least 10 gallons of liquid space per pound of BOD or COD which is added to the system in any eight hour period. The liquid depth of zone **1**, which is determined by the bottom of zone **12** and the location of exit pipe **14**, should be within the range of about 10 to about 30 feet, preferably between about 10 and about 18 feet in order to provide stratification in the zone and to allow methogenic bacteria to flourish.

Zone **1** is defined by side walls (not shown), a front wall and baffle **16** which extends the width of the entire zone, i.e., from side wall to side wall. The height of the baffle is adjusted so that it terminates at the top at least about 10 inches above the water level which is defined by pipe **14**. The top of the baffle preferably terminates below the roof of the zone so that there is gaseous communication between zones **1** and **2**. The bottom of the baffle should terminate prior to contacting the floor of the zone so that there is liquid communication between the bottom of zone **1** and the bottom of zone **2**. The space between the bottom of the baffle and the bottom of the zone should be about 30 inches, but this can vary to provide a bottom space having a height of from about 18 inches to about 48 inches.

An important aspect of the invention is that the liquid-solid mixture in the zones is maintained under substantially quiescent or undisturbed conditions. This promotes stratification of the mixture. A top layer which can have a depth of up to about two feet will be floating lignocellulosic solids, **17**. As anaerobic bacteria degrade this material, medium length fatty acids such as valeric, butyric and propionic acids are formed and these will be located predominantly as an intermediate layer in the zone. As these intermediate acids are degraded, formic and acetic acids are formed and will be located in the bottom stratum of the zone. Methane and carbon dioxide are formed from the bacterial degradation of these simple acids in the bottom of the zone.

To maintain quiescense, it is necessary that the solid-liquid suspension added via line **10** to zone **1**, be added in a manner so that the force of entry is relatively low. This is partially accomplished by submerging the entry pipe **10** into the liquid in the first zone to a depth which is below the level of floating solids, e.g., about five feet. Additionally, the diameter of the entry pipe should be large, thus assuring that the force of the entering material will be spread over a larger area.

Sprinkler **18** is provided at a location close to the baffle. Water pressure and the design of the sprinkler are adjusted so that water issuing from the sprinkler will merely wet floating solids and cause no turbulence. Depending on temperature, location and the particular organic waste, it is possible that the uppermost portion of the floating organic wastes **17** will form a dry, hard, matted layer and will not be acted upon by bacteria. Accordingly, a sprinker such as **18** can be provided to wet the floating wastes causing at least some to gently sink, thus causing the hardened mat of solids to be broken.

The bottom floor **12** of zone **1**, or as shown in FIG. **1**, zones **1** and **2**, is preferably sloped in a direction away from the entering materials. Such slope can be varied as desired and it has been found that a slope of about 7° is suitable. Some degraded solids will sink to the bottom of the zone and flow down the slope. These solids can be removed periodically via line **20** by opening valves **21** and **22** and are useful as fertilizer. When too great an amount of solids have accumulated on the floor of the tank there will be a noticeable decrease in methane production. Solids should be removed via line **20** at that time. The solids have little malodorous quality when fully degraded. When solids which have not been fully degraded are allowed to pass out of the system, a highly noticeable and aromatic smell of organic acids will be apparent and at this point valves **22** and **21** should be closed.

Zone **2** is preferably of a size which is about one-half the size of zone **1**. Thus, when zones **1** and **2** are located in a single tank as shown in FIG. **1**, zone **2** should constitute about one-third the length of the tank. The upper portion of zone **2** communicates with the upper portion of zone **3** via line **14**. It is preferred that the water level in zone **3** be somewhat lower, e.g., about 10 inches, than the water level in zone **2**. This insures that materials passing via pipe **14** from zone **2** to zone **3** will drop as they pass out of pipe **14** and will be submerged. Thus the floating solid will be wetted upon entry into zone **3**.

The size of zone **3** is preferably about the same size as zone **2**. The location and spacing of baffle **24**, between zones **3** and **4**, is about the same as between zones **1** and **2**. However, the size of zones **3** and **4** can be varied, as desired, so long as the bottoms of the zones communicate from one to the other. As indicated previously, the size of zones **1** and **2** is most important to proper operation of the process.

The bottom of zone **3** communicates with the bottom of zone **4** beneath the bottom of baffle **24** which, as with baffle **16**, is preferably spaced about 30 inches from the bottom **26** of zones **3** and **4**. The top of zone **4** communicates via line **28** with the top of zone **5**. Zone **5** communicates with zone **6** via the space underneath baffle **30** which is arranged preferably in the same manner as baffles **24** and **16**.

The direction of the slope of the bottom **26**, of zones **3** and **4** can be in any direction desired. It is preferred that there be some slope to facilitate removal of solids via line **31** and valve **32** as shown. Likewise, the direction of slope of the bottom **34**, of zones **5** and **6** can be as desired and the slope facilitates removal of solids via line **35** and valve **36**.

It will be appreciated that as material passes through the serial zones, a greater amount of degradation takes place. By maintaining quiescent conditions in all zones, there will be strata formed in all zones. The amount of solids passing through zones **1**, **2**, **3** and **4** will be such that there will be a layer of solids in each of the zones. By the time the material reaches zones **5** and **6**, there may be little, if any, floating solids. However, even in these zones there will be acid strata. In most cases, there will be floating solids also in zone **5** and a small amount of solids in zone **6**.

Methane is collected from the zones via lines **40**, **42** and **44** and is passed via line **46** to storage. The gas can be stored in any conventional system or manner. One preferred method of storage is through the use of a water sealed gas holder in which the gas is collected beneath a tank floating in water. Such water sealed gas holders are known to those skilled in the art. By using such a system, there is a continuous back pressure kept on the gas which is preferably about 0.4 psi above atmospheric pressure. This causes some gases to be redissolved in the system and is believed to promote the growth of various bacteria. If the gas is collected by means of a system other than a water sealed gas holder, back pressure in the system can be effected by means known to those skilled in the art such as through the use of a pressure reduction valve provided in line **46**. The stored gas can be used as desired to provide useable energy, e.g., in the form of electricity.

The system is maintained at ambient temperature and in many areas of the world will need no added heat. This is because the system has been designed to utilize mesophilic, methogenic bacteria. It is preferred that the system be operated at a temperature of from about 26° C. to about 40° C. and more preferably at a temperature of less than 32° C. It has been found that best results are obtained when the system is operated at a temperature of between 26° and 30° C. When it is desired to operate the system in a colder climate, heat may be provided by any conventional means. One contemplated method of providing heat under such circumstances is to locate the system within an insulated structure wherein a space is provided between the outer walls of the zones and the inner walls of the insulated structure. Exhaust gas from generators used to convert the methane into electricity can then be passed into this space and the waste heat thus efficiently utilized to heat the system.

One preferred arrangement of the various zones is shown in FIGS. **2** and **3**. Zones **1** and **4**, and **2** and **3** share a common side wall **52**. Zones **4** and **5** and **3** and **6** likewise share a common side wall **54**. Baffles **16**, **24** and **30** extend from side to side of the zones and are located in a coplanar arrangement. Material is admitted to the first zone via line **10**. Sprinkler **18** is located close to baffle **16** and above zone **1** for intermittently wetting floating material as necessary. Materials pass beneath baffle **16** and out of the upper portion of zone **2** via line **14** whereupon they enter into the upper portion of zone **3**. Materials are then passed beneath baffle **24** and exit from the upper portion of zone **4** via line **28**. Finally, materials pass beneath baffle **30** and then exit the system via line **58**.

The diameters of pipes **14, 28** and **58** can be varied to help maintain the quiescent conditions in the zones. Thus, the diameter of such pipes should be large enough that they will not be clogged by solid material passing through them; also, by keeping the diameter relatively large, the flow of material from zone to zone will be slowed so as not to cause excess turbulence. It has been found that a diameter of about six inches is the smallest suitable diameter. This can be varied as desired and depending upon types of solids treated, and the like.

Solids are removed from the bottom of the zones via lines **20, 31** and **35** while the methane gas is collected via lines **40, 42** and **44**. The advantageous layout of the system shown in FIGS. **2** and **3** is such that it forms a single modular unit. The slope of the bottom of the unit **12** can advantageously be in a single direction.

It has been found that certain inorganic chemicals can dramatically improve operation of the system. Thus, the addition of sulfate as copper sulfate is recommended in an amount of between about 1 and about 1½ pounds, based on 10,000 gallons, added at intervals of two to three weeks. Iron, in the form of the metal, can be added in an amount of about one ton, based on 230,000 gallons, at a period of about once every two to three years. Molybdenum, added in the form of soluble molybdenum, is added in an amount of between 2 to 3 pounds, based on about 700,000 gallons, every two to three years.

It is believed that the quantity of the methane gas produced can also be increased by recirculating the total gas produced through the last four stages of the series of zones, thereby increasing the amount of dissolved CO_2 which has a favorable effect upon the metabolism of the methogenic bacteria in these stages. Recirculation of the gas can be accomplished by inserting a pipe at a distance of about two feet from the bottom of each of the last four zones and gently circulating gas into the zone through such pipes.

The following example illustrates operation and practice of the invention and constitutes the best mode.

EXAMPLE

A fermentation system such as illustrated in FIGS. **1**, **2** and **3**, together with a biogas storage system, a generating plant and an effluent holding tank were installed on a pig farm having approximately 2,000 pigs. Wastes were pressure washed from the pens twice and passed by gravity flow into the first zone of the digestor. The digestor constituted three tanks, sharing two common walls as shown in FIG. **2** and had a total liquid capacity of about 700,000 gallons. The capacity of such tanks was designed based on a future expectation of about 11,000 animals. The overall length of the tank was 96 feet, and the liquid depth within the tanks was 11 feet at the entrance end and 17 feet at the exit end. The solids constituted 2% of the liquid solid suspension added twice daily to the tanks. The system was operated for six months without removal of solids in order to increase the solid concentration within the system which was required for the efficient operation of the system. Thereafter, solids were removed every 21 days and were used as fertilizer.

Copper sulfate in an amount of approximately 1 lb./10,000 gallons was added periodically every two to three weeks, scrap iron weighing about three tons was added once and molybdenum in an amount of two pounds was added once. The system generated about 10,000 to 11,000 cubic feet of gas per day of which 75% constituted methane gas. The remainder was carbon dioxide. Electricity was generated and used at the farm in an amount of about 600 kilowats per day.

Measurements of BOD and COD were taken of material entering the system and material exiting the system and it was found that BOD and COD had been reduced by 90–95%.

In order to more fully study operation of the system, BOD and COD contents were measured at the following locations:

Location **1**: Solids/liquid suspension prior to introduction into system
Location **2**: Upstream end of zone **1**
Location **3**: Downstream end of zone **1**
Location **4**: Downstream end of zone **2**
Location **5**: Upstream end of zone **3**
Location **6**: Downstream end of zone **4**
Location **7**: Upstream end of zone **5**
Location **8**: Downstream end of zone **5**
Location **9**: Downstream end of zone **6**
Location **10**: Effluent pipe exiting zone **6**

The following results were obtained:

Location Number	BOD[a] (mg/l)	COD[b] (mg/l)	BOD/COD rates
1	2389 ± 241	6352 ± 742	0.36:1
2	480 ± 42	1807 ± 92	0.27:1
3	443 ± 40	1999 ± 88	0.22:1
4	421 ± 40	2090 ± 102	0.20:1
5	212 ± 22	860 ± 52	0.25:1
6	220 ± 33	840 ± 53	0.26:1
7	147 ± 16	599 ± 39	0.25:1
8	141 ± 13	584 ± 43	0.24:1
9	143 ± 18	584 ± 43	0.24:1
10	141 ± 16	576 ± 46	0.24:1

[a]Mean ± standard error; 11 N 16 observations per value.
[b]10 N 15 observations per value.

It can be seen that total BOD and COD reduction was in excess of 90%. Further, since reduction in BOD and COD is directly proportional to the amount of methane gas produced, the above table indicates the relative amounts of methane produced in each of the various zones.

Although the invention has been described in detail with reference to preferred embodiments, variations and modifications can be made without departing from the invention as described in the foregoing specification and defined in the appended claims. Thus, while the system has been specifically described using six anaerobic zones, the number of zones can be reduced to four if COD loads are not very large by eliminating baffles **24** and **30** in the second and third tanks.

What is claimed is:

1. An anaerobic bacterial process for converting manure containing organic waste material into methane and fertilizer, the combination of steps consisting essentially of:

passing a low solids aqueous suspension of manure containing organic wastes having a solids content of less than about 4% by weight into the first of at least four anaerobic zones, the first and second anaerobic zones being located in one tank and the third and fourth anaerobic zones being located in a second tank, the second zone having a liquid space about one half the liquid space of the first zone, said zones being arranged for liquid communication in series such that addition of liquid to the first zone causes;

liquid flow from the lower portion of the first anaerobic zone to the lower portion of the second anaerobic zone;

liquid flow from the upper portion of the second anaerobic zone to the upper portion of the third anaerobic zone;

liquid flow from the lower portion of the third anaerobic zone to the lower portion of the fourth anaerobic zone;

liquid flow out of the upper portion of the last anaerobic zone;

said serial liquid communication being the only liquid communication between zones, there being no passing of the settled solids from the second anaerobic zone to the third anaerobic zone,

maintaining quiescent conditions in each of said anaerobic zones whereby a three layer stratification of the mixture occurs,

maintaining ambient temperature of up to about 40° C. in each of said zones; and

collecting methane from the top of said zones and periodically removing fertilizer solids from said zones.

2. An anaerobic bacterial process for converting manure containing organic waste material into methane and fertilizer, the combination of steps consisting essentially of:

passing a low solids aqueous suspension of manure containing organic wastes having a solids content of less than about 4% by weight into the first of six anaerobic zones, the first and second anaerobic zones being located in one tank, the third and fourth anaerobic zones being located in a second tank and the fifth and sixth anaerobic zones being located in a third tank, the second zone having a liquid space about one half of the liquid space in the first zone, said zones being arranged for liquid communication in series such that addition of liquid to the first zone causes;

liquid flow from the lower portion of the first anaerobic zone to the lower portion of the second anaerobic zone;

liquid flow from the upper portion of the second anaerobic zone to the upper portion of the third anaerobic zone;

liquid flow from the lower portion of the third anaerobic zone to the lower portion of the fourth anaerobic zone;

liquid flow from the upper portion of the fourth anaerobic zone to the upper portion of the fifth anaerobic zone;

liquid flow from the lower portion of the fifth anaerobic zone to the lower portion of the sixth anaerobic zone; and

liquid flow out of the upper portion of the sixth anaerobic zone,

said serial liquid communication being the only liquid communication between zones, there being no passing of settled solids from the second anaerobic zone to the third anaerobic zone or from the fourth anaerobic zone to the fifth anaerobic zone,

maintaining quiescent conditions in each of the six anaerobic zones whereby a three layer stratification of the mixture occurs,

maintaining ambient temperature of up to about 40° C. in each of said zones; and collecting methane from the top of said zones and periodically removing fertilizer solids from a lower portion of three of said zones.

3. The process of claims 1 or 2 wherein said quiescent conditions provide in each of the first four zones, said three layer strata which are:

an upper stratum comprising an aqueous suspension of lignocellulosic solids,

an intermediate stratum comprising an aqueous solution of acids which are predominantly medium length fatty acids; and

a lower stratum comprising an aqueous solution of acids which are predominantly formic acid and acetic acids.

4. The process of claim 3 wherein the liquid depth in each of said zones is between about 10 and about 30 feet.

5. The process of claim 4 wherein the liquid space in the first zone is greater than about 10 gallons per pound of BOD or COD which is added to the system per eight hours.

6. The process of claim 5 wherein the communication for liquid flow between the first and the second zones consists of an opening between said zones extending substantially from side to side of said zones and substantially from the bottoms of said zones to a height of about 30 inches above the bottom of said zones.

7. The process of claim 6 wherein said low solids aqueous suspension of organic waste solids has a solids content of less than about 3% by weight.

8. The process of claim 7 wherein the liquid depth in each of said zones is between about 10 and about 18 feet.

9. The process of claim 8 wherein said low solids aqueous suspension of organic waste solids has a solids content of about 2% by weight.

10. The process of claim 8 wherein solids passed from the second to the third zone are submerged upon entry into the third zone.

11. The process of claim 10 wherein said fourth and third anaerobic zones are about the same size as said first and second anaerobic zones, respectively.

12. The process of claim 11 wherein said fifth and sixth anaerobic zones are about the same size as said first and second anaerobic zones, respectively.

13. The process of claim 12 wherein the temperature of said six zones is maintained at less than 32° C.

14. The process of claim 13 further comprising periodically adding to said first zone one or more compositions selected from the group consisting of iron, copper sulfate and soluble molybdenum.

15. The process of claim 14 wherein the temperature of said six zones is maintained in the range of between about 26° C. and about 30° C.

16. The process of claim 15 wherein gas pressure above said six zones is maintained above atmospheric pressure.

* * * * *

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[Fortsetzung auf der nächsten Seite]

(54) Title: FERMENTER FOR A BIOGAS PLANT

(54) Bezeichnung : FERMENTER FÜR EINE BIOGASANLAGE

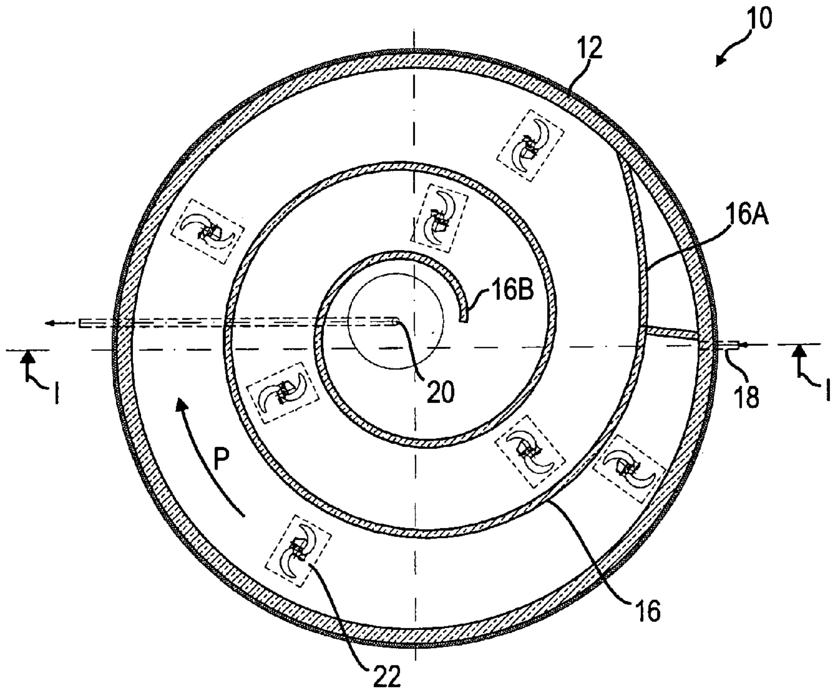

Fig. 2

[Fortsetzung auf der nächsten Seite]

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SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Veröffentlicht:

— *mit internationalem Recherchenbericht (Artikel 21 Absatz 3)*

(57) Abstract: A fermenter (10) for a wet fermentation biogas plant, comprising a fixed jacket (12) which surrounds a reaction space, an inlet (18) for biomass and an outlet (20) for the fermentation residue, is characterized in that a wall (16) separating the inlet (18) from the outlet (20) is arranged inside the jacket (12).

(57) Zusammenfassung: Ein Fermenter (10) für eine Biogasanlage, die mit Nassvergärung arbeitet, mit einem feststehenden Mantel (12), der einen Reaktionsraum umgibt, einem Einlass (18) für Biomasse und einen Auslass (20) für den Gärrest, ist dadurch gekennzeichnet, dass innerhalb des Mantels (12) eine Wand (16) angeordnet ist, die den Einlass (18) vom Auslass (20) trennt.

Fermenter für eine Biogasanlage

Die Erfindung betrifft einen Fermenter für eine Biogasanlage, die mit Nassvergärung (bis 15% Trockensubstanz) arbeitet, mit einem feststehenden Mantel, der einen Reaktionsraum umgibt, einem Einlass für Biomasse und einem Auslass für den Gärrest.

Im Fermenter wird die Biomasse unter anaeroben Bedingungen vergoren, wobei Biogas entsteht. Im Hinblick auf einen optimalen Wirkungsgrad ist es wünschenswert, wenn die in den Fermenter eingebrachte Biomasse diesen erst dann verlässt, wenn sie vollständig vergoren ist. Dies lässt sich in der Praxis aber nur sehr schwer erreichen. So besteht bei den üblicherweise verwendeten Fermentern, die im Nassvergärungs-Verfahren arbeiten, das Problem, dass bei der Entnahme des Gärrests immer auch ein Teil unvergorene Biomasse den Fermenter verlässt („Frischmasseverlust"). Dieser Frischmasseverlust konnte bei den bisher üblichen Fermentern, die im Topfverfahren arbeiten, nicht vermieden werden.

Die Aufgabe der Erfindung besteht darin, einen Fermenter der eingangs genannten Art dahingehend zu verbessern, dass der Frischmasseverlust verringert oder gar vollständig vermieden wird.

Zur Lösung dieser Aufgabe ist bei einem Fermenter der eingangs genannten Art vorgesehen, dass innerhalb eines Mantels eine Wand angeordnet ist, die den Einlass vom Auslass trennt. Dies verhindert, dass frisch in den Fermenter eingebrachte Biomasse unmittelbar zum Auslass gelangt und dadurch den Fermenter verlassen kann, ohne vollständig vergoren zu sein.

Vorzugsweise ist vorgesehen, dass die Wand spiralförmig verläuft. Auf diese Weise kann innerhalb des Fermenters ein vergleichsweise langer Weg vorgegeben werden, den die Biomasse vom Eingang bis zum Ausgang zurücklegen muss.

Gemäß einer bevorzugten Ausführungsform der Erfindung ist vorgesehen, dass die Wand einen spiralförmigen Gang für die Biomasse innerhalb des

Reaktionsraums vorgibt, wobei der Einlass an einem Ende des Gangs und der Auslass am anderen Ende angeordnet ist. Bei dieser Gestaltung kann, wenn die Biomasse kontinuierlich zugeführt wird, eine langsame Bewegung der Biomasse entlang des Gangs hin zum Auslass eingestellt werden, wobei die Verweilzeit der Biomasse im Fermenter so bestimmt ist, dass die Biomasse vollständig vergoren ist, wenn sie den Auslass erreicht. Auf diese Weise ergibt sich ein optimaler Wirkungsgrad, da zum einen keine unvergorene Biomasse den Fermenter verlassen kann und zum anderen bereits vergorene Biomasse nicht übermäßig lange im Fermenter verbleibt und dort Volumen belegt, welches ansonsten für den Vergärungsprozess genutzt werden könnte.

Vorteilhafte Merkmale der Erfindung ergeben sich aus den Unteransprüchen.

Die Erfindung wird nachfolgend anhand einer bevorzugten Ausführungsform beschrieben, die in den beigefügten Zeichnungen dargestellt ist. In diesen zeigen:

- Figur 1 einen Querschnitt durch einen erfindungsgemäßen Fermenter; und
- Figur 2 einen Schnitt entlang der Ebene II-II von Figur 1.

In den Figuren 1 und 2 ist ein Fermenter 10 gezeigt, der Teil einer Biogasanlage ist. Der Fermenter ist gebildet durch einen feststehenden Mantel 12, der auf einem Fundament 14 angeordnet ist. Der Mantel 12 ist zylindrisch, wobei die Mittelachse des Zylinders vertikal auf dem Fundament 14 steht. Im Inneren des Mantels 12 ist eine Wand 16 angeordnet, die spiralförmig verläuft. Ein außenliegendes Ende 16A der Wand berührt den Mantel 12, während das innenliegende Ende 16B in der Nähe der Mittelachse des zylindrischen Mantels 12 endet. Durch die spiralförmige Wand 16 ist ein Gang gebildet, der schneckenförmig von außen, also vom Mantel 12, zur Mitte hin verläuft. Dieser Gang erstreckt sich dabei in vertikaler Richtung von der Oberkante der Wand 16 bis zum Fundament 14. Auf der Oberseite des Mantels 12 ist ein Deckel 15 angeordnet, so dass im Inneren des Mantels ein abgeschlossener Reaktionsraum gebildet ist. Der Deckel 15 befindet sich im Abstand von der Oberkante der Wand 16, so dass im oberen Bereich des Fermenters ein durchgehender Gas-Sammelraum gebildet ist.

Sowohl der Mantel 12 als auch die spiralförmige Wand 16 können aus Metall und/oder Beton bestehen. Der Deckel 15 ist hier ebenfalls massiv ausgeführt. Alternativ kann auch eine Kunststoff-Haube verwendet werden.

In der Nähe des außenliegenden Endes 16A der spiralförmigen Wand 16 ist ein Einlass 18 für Biomasse angeordnet, der durch den Mantel 12 hindurchtritt. Etwa in der Mitte des vom Mantel 12 umschlossenen Reaktionsraumes des Fermenters und damit im Inneren der von der Wand 16 gebildeten Spirale ist ein Auslass 20 für den Gärrest angeordnet, also für die vergorene Biomasse. Aufgrund der spiralförmigen Wand 16 bewegt sich die Biomasse entlang eines vorgegebenen Weges durch den Fermenter, um vom Einlass 18 zum Auslass 20 zu gelangen. Entlang des Gangs sind mehrere Rührwerke 22 angeordnet, die für eine gleichmäßige vertikale Durchmischung sorgen. Ferner ist der Fermenter mit einer (nicht dargestellten) Heizung versehen, die eine gleichbleibende Temperatur im Inneren des Fermenters gewährleistet.

Im Betrieb wird dem Fermenter über den Einlass 18 Biomasse zugeführt. Entsprechend der zugeführten Menge wird vollständig vergorene Biomasse als Gärrest durch den Auslass abgeführt. Es stellt sich daher eine sehr langsame Strömung der Biomasse vom Einlass 18 zum Auslass 20 in der Richtung des Pfeils P von Figur 2 ein. Die sich dabei einstellenden, unterschiedlichen Niveaus der Biomasse entlang dem gebildeten Gang sind in Figur 1 mit den Pfeilen N angedeutet. Während des Fortschreitens vom Einlass 18 zum Auslass 20 wird die Biomasse durch die Rührwerke 22 regelmäßig in vertikaler Richtung umgewälzt, so dass der Vergärungsprozess gleichmäßig abläuft. Das beim Vergären entstehende Biogas wird über einen Gasabzug 24 entnommen.

Patentansprüche

1. Fermenter (10) für eine Biogasanlage, die mit Nassvergärung arbeitet, mit einem feststehenden Mantel (12), der einen Reaktionsraum umgibt, einem Einlass (18) für Biomasse und einen Auslass (20) für den Gärrest, dadurch gekennzeichnet, dass innerhalb des Mantels (12) eine Wand (16) angeordnet ist, die den Einlass (18) vom Auslass (20) trennt.

2. Fermenter nach Anspruch 1, dadurch gekennzeichnet, dass die Wand (16) spiralförmig verläuft.

3. Fermenter nach Anspruch 2, dadurch gekennzeichnet, dass die Wand (16) einen spiralförmigen Gang für die Biomasse innerhalb des Reaktionsraums vorgibt, wobei der Einlass (18) an einem Ende des Gangs und der Auslass (20) am anderen Ende angeordnet ist.

4. Fermenter nach Anspruch 3, dadurch gekennzeichnet, dass der Einlass (18) am äußeren Ende des Gangs angeordnet ist.

5. Fermenter nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass der Auslass (20) etwa mittig am Boden des Fermenters angeordnet ist.

6. Fermenter nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass der Mantel (12) und die Wand (16) sich vertikal erstrecken.

7. Fermenter nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass entlang des Gangs mehrere Rührwerke (22) angeordnet sind.

8. Fermenter nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass eine Heizung vorgesehen ist.

9. Fermenter nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass der Mantel (12) zylindrisch ist.

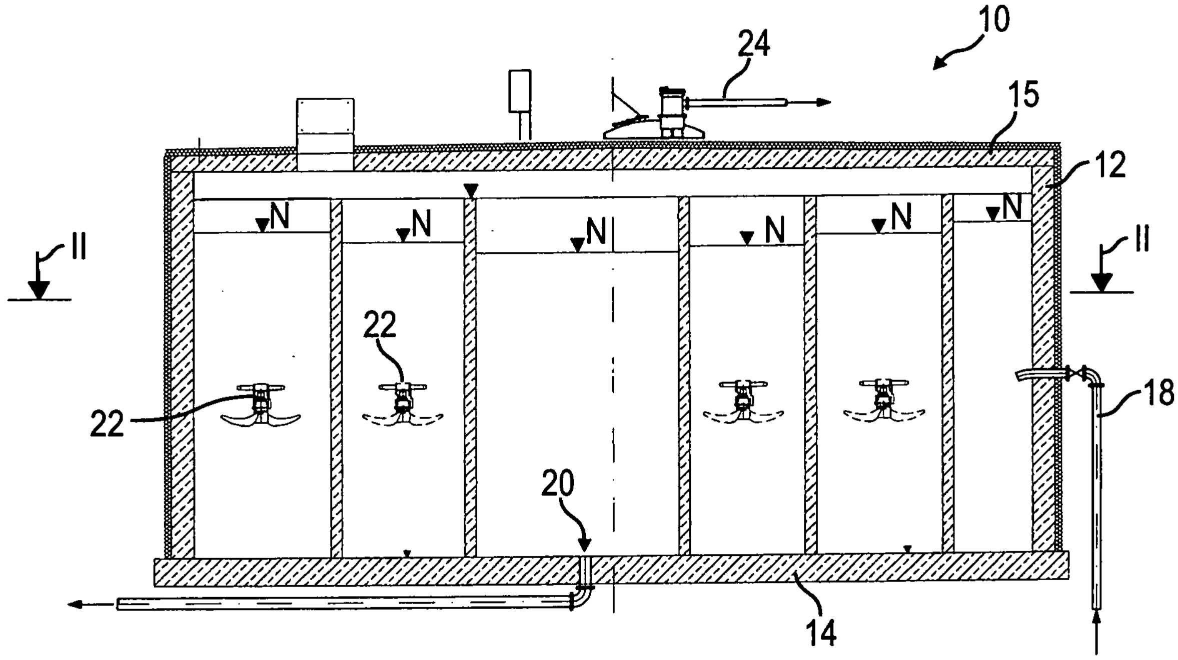

Fig. 1

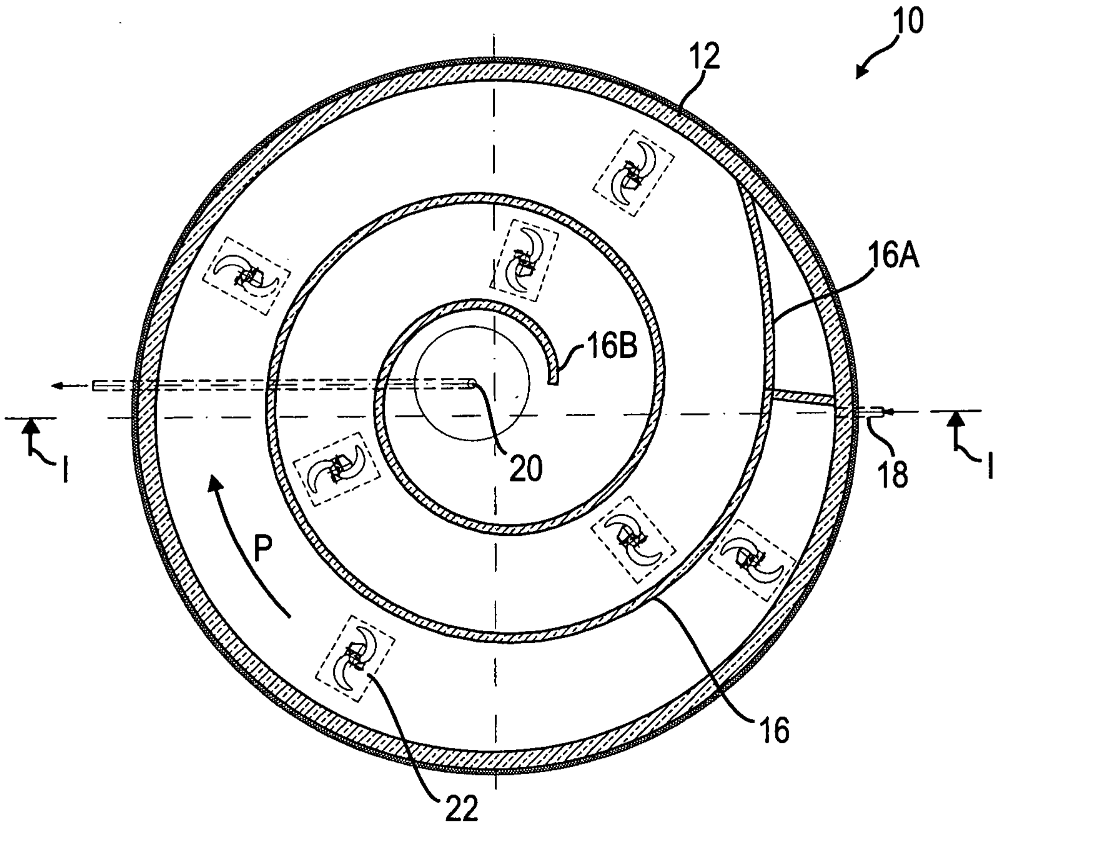

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/001321

A. CLASSIFICATION OF SUBJECT MATTER
INV. C12M1/107
ADD.

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 C12P

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	CA 2 259 673 A1 (LEVIN ANDREY [CA]) 14 July 2000 (2000-07-14) the whole document	1-9
X	EP 0 213 691 A2 (UNIV LELAND STANFORD JUNIOR [US]) 11 March 1987 (1987-03-11) column 3, line 9 - line 28 column 4, line 37 - column 5, line 36 figures 1-4	1
X	DE 36 04 415 A1 (CARO THOMAS) 13 August 1987 (1987-08-13) column 4, line 22 - line 41 column 4, line 51 - column 5, line 9 column 6, line 26 - column 7, line 14 figures 1-3	1

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 June 2010	28/06/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cubas Alcaraz, Jose

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/001321

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/154982 A1 (IRANI MAYYAR F [US]) 12 August 2004 (2004-08-12) paragraphs [0003], [0026], [0037] figures 1-3 -----	1
X	WO 2007/054193 A1 (GANTEFORT WILHELM [DE]) 18 May 2007 (2007-05-18) page 20 - page 24 figures 1-4 -----	1,5
X	DE 10 2007 005069 A1 (UTS BIOGASTECHNIK GMBH [DE]) 31 July 2008 (2008-07-31) paragraphs [0030], [0031], [0037] - [0040] figures 1,5,8 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2010/001321

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
CA 2259673	A1	14-07-2000	NONE			
EP 0213691	A2	11-03-1987	AU	589898	B2	26-10-1989
			CA	1294070	C	07-01-1992
			DE	3686107	D1	27-08-1992
			DE	3686107	T2	04-03-1993
			JP	1971981	C	27-09-1995
			JP	7000030	B	11-01-1995
			JP	62032876	A	12-02-1987
DE 3604415	A1	13-08-1987	NONE			
US 2004154982	A1	12-08-2004	NONE			
WO 2007054193	A1	18-05-2007	CA	2629207	A1	18-05-2007
			DE	102005054323	A1	24-05-2007
			EA	200801024	A1	30-12-2008
			EP	1945751	A1	23-07-2008
			US	2009305376	A1	10-12-2009
DE 102007005069	A1	31-07-2008	NONE			

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/EP2010/001321

A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
INV. C12M1/107
ADD.

Nach der Internationalen Patentklassifikation (IPC) oder nach der nationalen Klassifikation und der IPC

B. RECHERCHIERTE GEBIETE

Recherchierter Mindestprüfstoff (Klassifikationssystem und Klassifikationssymbole)
C12M C12P

Recherchierte, aber nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Gebiete fallen

Während der internationalen Recherche konsultierte elektronische Datenbank (Name der Datenbank und evtl. verwendete Suchbegriffe)

EPO-Internal

C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	CA 2 259 673 A1 (LEVIN ANDREY [CA]) 14. Juli 2000 (2000-07-14) das ganze Dokument	1-9
X	EP 0 213 691 A2 (UNIV LELAND STANFORD JUNIOR [US]) 11. März 1987 (1987-03-11) Spalte 3, Zeile 9 - Zeile 28 Spalte 4, Zeile 37 - Spalte 5, Zeile 36 Abbildungen 1-4	1
X	DE 36 04 415 A1 (CARO THOMAS) 13. August 1987 (1987-08-13) Spalte 4, Zeile 22 - Zeile 41 Spalte 4, Zeile 51 - Spalte 5, Zeile 9 Spalte 6, Zeile 26 - Spalte 7, Zeile 14 Abbildungen 1-3	1

-/--

[X] Weitere Veröffentlichungen sind der Fortsetzung von Feld C zu entnehmen [X] Siehe Anhang Patentfamilie

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Datum des Abschlusses der internationalen Recherche	Absendedatum des internationalen Recherchenberichts
21. Juni 2010	28/06/2010

Name und Postanschrift der Internationalen Recherchenbehörde	Bevollmächtigter Bediensteter
Europäisches Patentamt, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016	Cubas Alcaraz, Jose

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/EP2010/001321

C. (Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN		
Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	US 2004/154982 A1 (IRANI MAYYAR F [US]) 12. August 2004 (2004-08-12) Absätze [0003], [0026], [0037] Abbildungen 1-3 -----	1
X	WO 2007/054193 A1 (GANTEFORT WILHELM [DE]) 18. Mai 2007 (2007-05-18) Seite 20 - Seite 24 Abbildungen 1-4 -----	1,5
X	DE 10 2007 005069 A1 (UTS BIOGASTECHNIK GMBH [DE]) 31. Juli 2008 (2008-07-31) Absätze [0030], [0031], [0037] - [0040] Abbildungen 1,5,8 -----	1

Formblatt PCT/ISA/210 (Fortsetzung von Blatt 2) (April 2005)

INTERNATIONALER RECHERCHENBERICHT

Angaben zu Veröffentlichungen, die zur selben Patentfamilie gehören

Internationales Aktenzeichen
PCT/EP2010/001321

Im Recherchenbericht angeführtes Patentdokument		Datum der Veröffentlichung	Mitglied(er) der Patentfamilie			Datum der Veröffentlichung
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			EA	200801024	A1	30-12-2008
			EP	1945751	A1	23-07-2008
			US	2009305376	A1	10-12-2009
DE 102007005069	A1	31-07-2008	KEINE			