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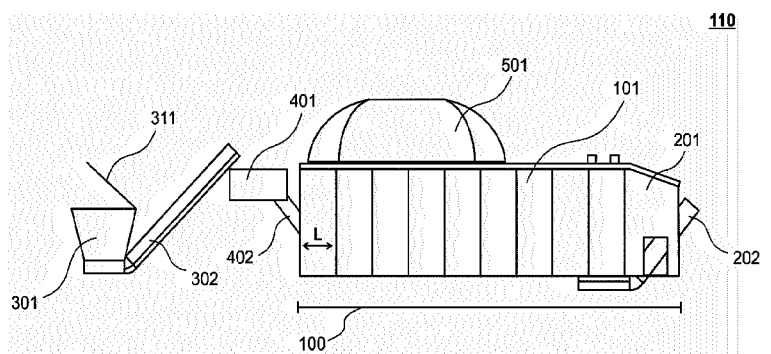
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ANAEROBIC DIGESTION REACTOR AND PLANT

(56) Viitejulkaisut - Anförda publikationer - References cited
GB 2528848 A, US 2010062482 A1, CN 102242052 A, CN 201161981 Y, CN 103881901 A

(57) Tiivistelmä - Sammandrag - Abstract

Tarjotaan käyttöön jatkuvan sekoituksen reaktori (100) biotajavan orgaanisen substraatin anaerobista mädättämistä varten, käsittäen vaakasuuntaisesti ulottuvan reaktiokammion (101), jossa on sisäänvirtausportti tulopäässä ja ainakin kaksi ulosvirtausporttia tulopäätä vastapäätä olevassa lähtöpäässä. Reaktori (100) käsittää lisäksi välineet orgaanisen substraatin sekoittamiseksi jatkuvasti reaktiokammiossa (110) ja orgaaniseen substraattiin suspendoitujen ei-mädätettävissä olevien sedimenttien ja kelluvien epäpuhtauksien erottelemiseksi. Lisäksi tarjotaan käyttöön anaerobinen mädätyslaitteisto (110), joka käsittää ainakin yhden reaktorin (100), esikäsittelytilan (401) ja syöttösäiliön (301).

A continuously stirred reactor (100) for anaerobic digestion of biodegradable organic substrate is provided, comprising a horizontally extended reaction chamber (101) with an influent port at an entrance end and at least two effluent ports at a discharge end opposite to the entrance end. The reactor (100) further comprises means for continuously stirring the organic substrate within the reaction chamber (110) and for sorting indigestible sediments and floating impurities suspended in the organic substrate. An anaerobic digestion plant (110) comprising an at least one reactor (100), a pre-treatment facility (401) and a feed tank (301) is further provided.



ANAEROBIC DIGESTION REACTOR AND PLANT

FIELD OF THE INVENTION

The present invention generally relates to systems and methods for anaerobic biodegradation of organic substrates accompanied by biogas recovery. In particular, the present invention
5 concerns a continuously stirred horizontal reactor for dry anaerobic digestion of organic substrates and a plant facility comprising said reactor(s).

BACKGROUND

Anaerobic digestion (AD), a complex process of organic matter decomposition by methanogenic bacteria, has been reduced to practice in a variety of biorefinery technologies
10 including agricultural and industrial waste disposal. In all instances, anaerobic digestion is further accompanied by production of biogas, which is further upgraded to yield biofuels.

Two types of anaerobic digestion processes are generally distinguished for management of solid waste with varying dry matter (DM) content, which are referred to as “wet” (DM 5-15 wt-%) and “dry” (DM 30-55 wt-%), accordingly. Dry digesters are generally more compact,
15 with an average capacity 950-1000 m³ upgradable to about 2000 m³, as in comparison to wet ones with an average capacity of 2-4000 m³. Generally speaking, any anaerobic digester may be exploited for wet- and dry processes; however, in practice the equipment is designed to meet specific requirements imposed by choice- and/or availability of feed materials, expected outputs, available premises, etc. Further advantages of dry digestion when used in waste
20 disposal relate to enduring the comparatively impure waste, i.e. containing considerable amounts of non-biodegradable matter; thereby expenditures for pretreatment and conditioning of feedstock prior to digestion can be minimized.

Conventional AD plants include a pre-treatment facility, a digester reactor or reactors, and a number of post-processing facilities, including solid separators and hygienization tanks for
25 digested material and recirculation means for reverting part of digested material into a reaction space as inoculum. Common reactor configurations include fixed dome-shaped tanks comprising, in most instances, a wall-integrated mixer or mixers. Dry AD reactors operating at a continuous flow-through basis are generally referred to as plug-flow reactors and are embodied as horizontally extended, narrow tanks with an inlet and an outlet, in where
30 feed is continually decomposed as it advances along the length of the tank. Some plug-flow solutions are complemented with a mixer in the form of a bladed shaft or a mixing screw.

Publication GB 2528848 (Lloyd et al) discloses a composting apparatus for biologically degrading organic materials, which can be operated aerobically and anaerobically. The apparatus comprises an enclosed vessel with an inlet and an outlet. The vessel has two horizontally elongated channels, each of said channels having a curved base. Within each channel, a shaft with a plurality of mixing blades is located. Organic material is processed, while advancing through the entire length of the vessel. Nevertheless, the apparatus contains no means for sorting extracted organic material such, as to separate and remove indigestible residue from the vessel. The apparatus does not include any particular provisions for sanitizing organic material propagating through the vessel.

- 10 Dry anaerobic digester solutions operating at a continuous flow basis are impacted by a number of common drawbacks. In most instances, biodegradable waste obtained from agrarian and municipal sources contains essential amounts of indigestible solids, such as stones, sand, glass and a variety of plastics, that results in floating layers and massive sediments in the digester. In order to deal with weighty sediments, the United States patent
- 15 no. 8241869 (Büchner et al) discloses a dry anaerobic fermenter operating at a plug-flow basis and provided in the form of an elongated tubular container with overlapping stirring blades configured to push sediments towards the discharge end, and a suction socket for removing solid sediments from the reactor via an additional outlet. However, the solution does not account for separation of lightweight impurities; thereby provision of a filtration
- 20 station would be required to handle plastic-rich waste streams.

Publication CN 102242052 (Su et al) discloses a dry anaerobic fermentation reactor that comprises heat transfer tubes located in the base structure of said reactor. Mentioned tubes are not assigned with the functions other than heating the organic material in the reactor. In particular, provision of integrated conduits for withdrawal of digested substrate while sanitising said substrate by heating is not disclosed.

- 25 Further challenge concerns raising the capacity of an AD plant without compromising its economic feasibility in terms of capital investment. Conventional solutions include growing the number of reaction tanks per plant, which is not always possible due to limited area, and/or provision of gear that supports stirring and advancement of material through the extremely long reactors. An exemplary solution according to the United States patent no. 7659108 (Schmid) thus concerns means for detecting and compensating sagging of the agitator shaft within horizontal anaerobic fermenters, in particular those, whose length exceeds 50 meters.
- 30

Furthermore, according to existing requirements set in the national- and EU standards and regulations imposed on the processes of anaerobic digestion of biodegradable feedstocks, including the Finnish Fertilizer Product Act No. 539/2006, the Finnish Decree on fertilizer products No. 24/11, and the Commission Regulation (EU) No. 142/2011 implementing the Regulation (EC) No. 1069/2009 with regard to animal by-products and derived products not intended for human consumption, decomposition products resulted from AD processes must be sanitized prior to being re-introduced into the ecosystems, in the form of fertilizers, compost or soil amendments. In conventional anaerobic digester plants such sanitization is conducted in separate facilities commonly located downstream the digester reactor(s).

- 10 In this regard, a revision of technology related to anaerobic digestion in horizontal, continuously stirred reactors suitable for production of biogas is still desired, in view of addressing challenges associated with the application of AD technology as part of a solid waste management system, and in particular, related to unsatisfactory elimination of contaminants, clogging of effluent pathways, inefficient mixing of the material in the digester and/or low biogas yield.

SUMMARY OF THE INVENTION

- An objective of the present invention is to solve or to at least mitigate each of the problems arising from the limitations and disadvantages of the related art. The objective is achieved by various embodiments of a reactor for anaerobic digestion of biodegradable organic substrate, related uses thereof, and a plant facility comprising said reactor. Thereby, in one aspect of the invention an anaerobic digestion reactor is provided, according to what is defined in the independent claim 1.

- 25 In one preferred embodiment the reactor comprises a horizontally extended reaction chamber with an influent port at an entrance end and at least two effluent ports at a discharge end opposite to the entrance end, wherein said reaction chamber comprises, within an interior thereof, at least two longitudinally extending agitators disposed side by side and configured to convey said organic substrate along the length of the reaction chamber towards the discharge end such, that the digested organic substrate is discharged from the reaction chamber through a primary effluent port, and the indigestible residue is discharged through an at least one auxiliary effluent port.

In some embodiments, the reactor is configured to convey, by means of a discharge appliance, a non-buoyant indigestible residue from the bottom of the reaction chamber, via the first auxiliary effluent port, disposed below the primary effluent port, outside the reactor. In additional embodiments, the reactor is further configured to convey a buoyant indigestible

residue residing at a surface of the organic substrate advancing along the length of the reaction chamber, via the second auxiliary effluent port, disposed above the primary effluent port, outside the reactor.

In preferred embodiments, the reactor is configured such that lateral walls defining, in a longitudinal direction, the interior of the reaction chamber are sloped (have a sloped or inclined profile); thereby a slope element is formed along an entire length of the reaction chamber at intersections between the lateral walls and the bottom.

In some embodiments, each lateral wall is defined by a number of L-shaped profiles with the slope element integrated in each L-shaped profile. Said L-shaped profiles are positioned against each other and joined at the bottom by a base element or elements such, that at least two adjoining subsections are formed within the interior of the reaction chamber, each subsection is configured to receive the agitator.

In some other embodiments, each aforesaid lateral wall is defined as a substantially flat panel or panels with the slope element provided as a separate module.

In preferred embodiments, the reactor further comprises a hygienization system configured to traverse, in a longitudinal direction, through the slope elements formed in the interior of the reaction chamber and comprising an at least one conduit encased in a jacket. Said hygienization system is configured to receive digested substrate discharged from the reaction chamber through the primary effluent port, to mediate advancement of said digested substrate along the at least one conduit from the discharge end to the entrance end, thereupon microorganisms residing in said digested substrate are inhibited and/or inactivated, and to extract hygienized digested substrate through an least one aperture disposed at the entrance end of the reaction chamber.

In further embodiments, the hygienization system is configured to deliver heat to the conduit via the encasing jacket.

In further embodiments, the reactor comprises a temperature regulating arrangement formed by a plurality of internal ducts configured to traverse, in a longitudinal direction, through lateral walls and/or the base element or elements of the reaction chamber and to convey temperature regulating fluid therealong.

In some embodiments, each agitator comprises a drive shaft with a number of blades mounted thereto. In some embodiments, the at least two said agitators are configured to rotate in opposite directions.

In some embodiments, the reactor further comprises, within the reaction chamber, a number of separating devices positioned adjacent to the discharge end and configured as vertical oscillating rods.

5 In another aspect, an anaerobic digestion plant is provided, according to what is defined in the independent claim 15. Said plant comprises an at least one reactor according to the previous aspect and a pre-treatment facility configured to adjust the temperature of organic substrate entering the reactor, as to conform to the temperature maintained in the reaction chamber.

10 In some embodiments, the plant further comprises a heat exchanger for mediating heat transfer between the at least one reactor and the pre-treatment facility.

In a further aspect, use of the reactor is provided for anaerobic digestion of organic waste, according to what is defined in the independent claim 17.

In still further aspect, use of the reactor is provided for production of biogas, according to what is defined in the independent claim 18.

15 The utility of the present invention arises from a variety of reasons depending on each particular embodiment thereof. At first, the invention provides for a compact reactor solution, whose length is reduced at least twice in comparison to conventional AD reactors of the same type, wherein reduction in length is compensated by provision of the at least two reaction sub-zones disposed side-by-side. By reducing length of the reactor, imposing of excessive
20 load on stirring agitators and/or a driving engine is avoided, thereby adding stability and reliability to the reactor, enhancing mixing efficiency, reducing energy demand, and allowing for substantial repair- and maintenance cost savings.

25 Moreover, an efficient effluent/residue sorting- and withdrawal system provided within the reactor allows for processing of a “dirty” feedstock, including organic substrates heavily contaminated with a variety of sediment- and/or lightweight impurities, such as plastic packages and wraps, for example. Efficient sediment withdrawal system further prevents formation of a solid layer on the bottom of the reaction chamber and creates prerequisites for a sustained flow dynamics therein.

30 Due to its prefab construction model, the reactor solution disclosed hereby can be easily and promptly assembled on-site. Additionally, pre-fabricated construction blocks for said reactor are designed, in terms of dimensions thereof, suitable for transportation by a conventional

motorized vehicle or a platform, including transportation under the standard bridges (e.g. motorway bridges) and via the road tunnels; thereby, no special transport is required.

Provision of a hygienization treatment system integrated inside the walls and/or the base of the reactor tank adds to the compactness of the overall solution and naturally eliminates the need for building a separate sanitization facility. Similarly, integrated system of hollow ducts for circulating temperature-regulating fluid inside the walls and/or the base of the reactor tank further allows for fine-tuning reaction conditions therewithin, thus creating the most favorable environment for biodegrading microorganisms residing in the tank. By adjusting temperature inside the reactor, populations of mesophilic and thermophilic bacteria can be regulated such, as to modify biogas production yields, accordingly.

The expression “organic substrate” refers in the present disclosure to substrate materials originating from living beings; whereas the term “biodegradable” refers to (organic) substrates that break down naturally and/or as a result of biological activity of microorganisms. The term “anaerobic” refers in the present disclosure to a biodegradation process that proceeds in an absence of oxygen.

The expression “a number of” is used in the context of the present document to indicate any positive integer starting from one (1). The expression “a plurality of” refers hereby to any positive integer starting from two (2), e.g. to two, three, or four.

Different embodiments of the present invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 schematically illustrates an anaerobic digestion plant 110, according to some aspect of the invention, viewed from the side.

Fig. 2A and 2B are perspective views of the anaerobic digestion reactor 100, according to some embodiments.

Fig. 3 schematically illustrates the reactor 100 and disposition thereof with regard to a pre-treatment facility.

Figs. 4A and 4B schematically illustrate a cross-sectional view of the reactor 100, according to various embodiments.

Fig. 5 is a longitudinal crosscut view of the anaerobic digestion plant 110, according to some embodiment.

DETAILED DESCRIPTION OF THE DRAWINGS

Detailed embodiments of the present invention are disclosed herein with the reference to accompanying drawings. The same reference characters are used throughout the drawings to refer to same members. Following citations are used for the members:

- 100 – an anaerobic digestion reactor,
- 101 – a reaction chamber,
- 201 – a mechanics section,
- 10 202 – a sediment discharge appliance,
- 301 – a feed tank with a lid 311,
- 401 – a pre-treatment facility,
- 302, 402 – first- and second feed supply appliances, accordingly,
- 501 – a rooftop of the reactor,
- 15 110 – an anaerobic digestion plant,
- 10, 10A, 10B – an interior of the reaction chamber,
- 11, 11A, 11B – lateral (wall-) profiles,
- 12, 12A – a base element and its extension, accordingly,
- 13 – external insulation / lining,
- 20 14 – an external foundation element,
- 15 – a cover,
- 16, 17 – entrance- and discharge ends, accordingly,
- 18 – an influent port,
- 19 – primary effluent port for discharge of digested substrate,
- 25 20, 21 – first- and second auxiliary effluent ports, accordingly, for discharge of indigestible residue,
- 22 – an agitator,
- 23 – a drive shaft,
- 24 – blades,
- 30 25 – separating devices,
- 30 – an integrated hygienization system,
- 31 – a flow conduit within the hygienization system,
- 32 – a jacket for the conduit 31,
- 33 – an extraction aperture for hygienized digested substrate.
- 35 40 – a temperature regulating arrangement,
- 50 – a heat exchanger.

Fig. 1 schematically illustrates an anaerobic digestion plant 110 in accordance with some aspect of the present invention. The plant 110 advantageously comprises an anaerobic

digestion reactor 100, a pre-treatment facility 401 and a feed tank 301 interlinked by a number of feed supply appliances 302, 402. For clarity purposes, more detailed description of the plant 110 is provided further below.

5 The reference is made to Figs. 2A and 2B illustrating at 100 a concept underlying various embodiments of an anaerobic digestion reactor, hereafter, the “reactor”, in accordance with an aspect of the present invention. It should be noted that the elements indicated by reference numerals 301, 302 and 401, 402 do not form parts of the reactor tank, but merely serve a purpose of illustrating the connection between the reactor 100 and preceding facilities within a general concept of the plant 110.

10 The reactor 100 is advantageously configured as a horizontally elongated, closed tank and comprises a reaction chamber 101 and, preferably, an adjacent mechanics section 201. In exemplary embodiments, the reactor 100 is dimensioned as follows: $23\text{ m} \times 13\text{ m} \times 6\text{ m}$, as standing for length $\times$ width $\times$ height, accordingly. For the reaction chamber 101 these parameters constitutes: $20\text{ m} \times 12\text{ m} \times 6\text{ m}$, accordingly.

15 The reaction chamber 101 is defined by a horizontally extended, quadrilateral container with an entrance end 16 for receiving organic feedstock and a discharge end 17 for extracting digested slurry (digestate). For clarity purposes, by the terms “digestate” and “digested substrate” we refer, in present disclosure, to any substantially solid by-product of anaerobic digestion apart from biogas. Feedstock, supplied from the feed tank 301 via the pre-treatment
20 facility 401, is received into the reactor 100 through a feed inlet port 18 (influent port) provided at the entrance end 16.

In preferred embodiments, the reaction chamber 101 is rectangular at its' base. In such a case width of the reaction chamber is the same at the entrance- and the discharge ends.

25 In some other embodiments, the reaction chamber 101 and/or the reactor tank 100 can be configured as a quadrilateral body, whose width at the discharge end 17 is greater than that at the entrance end 16. At its' base such configuration forms an isosceles trapezoid set upside down (with its narrower base at the entrance end 16).

30 The reaction chamber 101 further accommodates, within an interior 10 thereof, at least two agitators or mixers 22 positioned side-by-side and extending in longitudinal direction throughout an entire length of the reaction chamber, the latter being defined, in present disclosure, as a distance from the entrance end 16 to the discharge end 17.

The agitators may be disposed strictly in parallel (in case of a “rectangular” reaction chamber 101) or deviate from the longitudinal symmetry axis by preferably no more than 45 degrees in each direction (in case of a “trapezoidal” reaction chamber 101).

Each agitator 22 comprises a drive shaft 23 with a number of blades 24 mounted thereto. In some embodiments blades 24 are configured as blade paddles (vanes) individually fitted to the drive shaft to follow a substantially radial pattern (Figs. 2A, 2B) or a substantially helical pattern (not shown). In some alternative embodiments (not shown), each blade can be configured as an open impeller consisting of a series of vanes attached to a central hub, the latter being fitted to the drive shaft 23. The agitators can be further configured as helical ribbon impellers (not shown).

In an event the reaction chamber 101 follows a trapezoidal shape, the series of blades 24 are preferably configured such, as to gradually increase in diameter in a direction of the discharge end 17.

The shafts 23 are preferably engine-driven, thereby an at least one motor engine, preferably an electric motor (not shown), is set up within the mechanics section 201. It is preferred that an at least one additional drive mechanism is installed outside the reactor 100 adjacent to the entrance “front” end 16 thereof to pair the primary motor engine provided on the “rear” of the reactor within the mechanics section 201. By provision of at least two motors at both ends of the reactor tank, overloading of the agitators can be avoided. The mechanics section 201 further comprises additional gear, such as a variety of controllers, amplifiers and the like.

In order to provide for a most efficient stirring of the reaction substrate within the reaction chamber 101, the agitators 22 are set to rotate in opposite directions (shown by arrows on Figs. 2A, 2B); thereby reaction substrate is directed substantially from the center of the reaction chamber 101 towards its sides and back to the center. Preferred rotation model is further shown on Fig. 4A (directions pictured by arrows), wherein the agitator positioned on the right side of the reactor tank 101 (as viewed from the entrance end 17) is set to rotate clockwise and the agitator on the left side is set to rotate counterclockwise, accordingly. In other configurations the agitators 22 can be set rotating towards one another (right side – counterclockwise; left side – clockwise); or, alternatively, rotating in the same direction.

Disposition of blades 24 on the drive shaft 23 for both radial and helical / spiral patterns is preferably such that intervals between the individual blades 24 at the entrance end 16 are superior to that at the discharge end 17. Increase in blades’ density per a unit of distance along the drive shaft 23 allows for efficient handling, aka mixing, of the reaction substrate, whose density, in turn, decreases upon advancing along the length of the reaction chamber

101 from the entrance end 16 towards a discharge end 17, as organic substrate solubilizes within the reactor as a result of anaerobic digestion.

The reactor 100 is preferably configured as a horizontal plug-flow reactor (PFR), for continuously stirred anaerobic digestion treatment of organic substrates. The term “anaerobic digestion” refers to, in the present disclosure, to a process or processes of organic matter degradation by microorganisms in an absence of oxygen in a wide range of temperatures and accompanied by production of biogas. Based on said temperature range two sub-processes can be generally identified: mesophilic digestion within a range of 30 to 42 °C and thermophilic digestion within a range of 43 to 55 °C. Microorganisms stable and active in the above indicated ranges are referred to mesophilic- and thermophilic microorganisms, accordingly. The latter demonstrate increased efficiency and yield in biogas production; however, thermophilic microorganisms are also more sensitive to changes in temperature, pH level, redox potential, and the presence of inhibitory factors, such as heavy metals, antibiotics and detergents. The reactor 100 provided hereby can be configured, in terms of adjusting the abovementioned parameters to appropriate values, to operate with mesophilic microorganisms, with thermophilic microorganisms, or both types of microorganisms present in the reaction chamber at once. While advancing through the reactor 100, the organic substrate material gradually solubilizes, as a result of microbial activity.

During bacteria-mediated anaerobic digestion biodegradable organic substrate is thus decomposed to yield biogas and substantially solid remnants, generally referred to as digestate. The latter consist of fibrous material (cellulose and lignin), dead bacterial cells and of a sludge-like fraction containing solids and methanogenic liquor. These by-products can be further utilized as fertilizer, compost, low-grade building materials, such as fiberboards, and/or as a feedstock for ethanol production.

Feed input for the reactor 100 is represented primarily by organic waste of plant- or animal origin, such as field (plant) biomass and by-products (bagasse, bran, straw), kitchen- and catering (bio)waste, household- and/or municipal waste, by-products of food industry, forestry, agriculture (farming, animal- and poultry rearing), as well as sewage slurries and wastewater sludge.

It is clear that in terms of purity the abovementioned feedstocks vary greatly. Thus, field biomass and crop by-products, for example, are essentially free of indigestible- or poorly digestible impurities or contains negligible amount thereof in the form of gravel or sand. From the other hand, household- or agricultural bio-waste often contains significant amounts of contaminants represented by indigestible plastics and/or metals, and by a variety of poorly

digestible organic by-products, such as wood- and/or lumber processing industry by-products, for example.

In order to effectively deal with these indigestible fractions present in the reaction substrate advancing through the reactor 100, in particular, from its entrance end 16 along the length of the reaction chamber 101 towards the discharge end 17, the reactor 100 further comprises means for sorting and separating digested substrate from indigestible residue and extracting digestate-containing and residue-containing fractions from the reaction chamber 101 independently from one another.

The reference is further made to Fig. 3, showing the reaction chamber 101 within the reactor 100 (for clarity purposes the mechanics section 201 is not shown). The reaction chamber 101 thus comprises the feedstock receiving influent port 18 at the entrance end 16 and at least two effluent ports 19, 20 at the discharge end 17 opposite to the entrance end 16. Biodegradable organic substrate containing feedstock (F) supplied from the feed tank (not shown), via the pre-treatment facility 401, enters the reaction chamber 101 through said influent port 18. Feedstock (F) comprises a variety of solid, indigestible contaminants suspended therein, as mentioned above.

With an advancement of feedstock (F) along the length of the reaction chamber 101, while being continuously stirred by the at least two agitators 22, biodegradable organic substrate material contained in feedstock undergoes processes of anaerobic digestion by mesophilic- and/or thermophilic microorganisms. At the same time, weighty, non-buoyant indigestible sediment, such as stone, gravel, sand, glass, metal particulate, etc., settles at the bottom of the reaction chamber 101, as dragged down by its own weight, whereas lightweight, buoyant indigestible residue, such as plastics, for example, floats to the surface of the organic substrate material and resides thereat. In conventional digesters, with an inlet and an outlet, such indigestible contaminants must be removed manually upon emptying the reactor(s) to avoid clogging discharge pathways and/or formation of a sediment layer on the bottom of the reaction chamber. Formation of the latter causes rising of the base level and thus alters flow dynamics created upon stirring.

The reactor 100 allows for efficient removal of indigestible contaminants from the reaction space 101 continuously during the digestion process. The reactor 100 is thus configured such, that the digested substrate (digestate), indicated by a capital D on Fig. 3, is discharged from the reaction chamber 101 via a primary effluent port 19, whereas a non-buoyant indigestible residue R1 (sediment) is discharged via a first auxiliary effluent port 20 disposed below the primary effluent port 19. The digested substrate D thus obtained is either free of solid,

indigestible matter or contains meaningless or negligible amounts of indigestible impurities. In any event, the digested substrate D requires no further purification and/or refinement.

In preferred embodiments the reactor 100 further comprises a second auxiliary effluent port 21 disposed above the primary effluent port 19 and configured to receive a lightweight, buoyant indigestible residue R2 (floating matter), such as a variety of non-recyclable plastics (plastic wraps, bubble plastics, etc.). With regard to the primary effluent port 19, said auxiliary effluent ports 20 and 21 can be disposed directly underneath or above, accordingly (see Fig. 3, port 21). Alternatively, any one of said auxiliary ports 20, 21 can be shifted sideways in a horizontal plane related to a position of the primary port 19 (see Fig. 3, port 20).

The reactor 100 further comprises a number of appliances configured to mediate separation and sorting of solid, indigestible matter suspended in organic substrate material subjected to anaerobic digestion upon advancing of the latter along the length of the reaction chamber 101 towards the effluent ports 19, 20 and/or 21.

In preferred embodiments the reactor 100 thus comprises a sediment discharge appliance 202 (Figs. 1, 2A, 2B) configured to convey non-buoyant indigestible residue R1 from the bottom of the reaction chamber 101, via the first auxiliary effluent port 20, outside the reactor 100. The appliance 202 is disposed at the discharge end 17 and it is configured as an at least one conveyor, preferably, a screw conveyor designed to collect solid sediment, e.g. gravel and sand, that accumulates on the bottom of the reaction chamber 101 and advances slowly (as a result of agitator-mediated stirring) towards the discharge end 17. In the embodiments shown on Figs. 2A and 2B the appliance 202 thus comprises a conveying screw provided within the reaction chamber 101 and arranged in a substantially horizontal plane; and a second conveying screw disposed within an ascending tube, thereby sediment residue R1 is conveyed upwards prior to being withdrawn from the reactor 100. After withdrawal from the reactor 100, solid non-buoyant sediment is collected for recovery. Alternative configurations include a single rising- or a non-rising conveyor, preferably a screw conveyor. Provision of the appliance 202 within the reactor 100 and the plant 110 is further shown on Fig. 5.

In some embodiments the reactor 100 further comprises an additional residue discharge appliance (now shown) configured to convey the buoyant indigestible residue R2 residing at a surface of the organic substrate material advancing along the length of the reaction chamber 101, via the second auxiliary effluent port 21, outside the reactor 100. Possible configurations for the additional residue discharge appliance include a conveyor configured to transfer

lightweight plastic residue R2 in a horizontal plane and/or downwards for further collection and recovery.

Fig. 2B shows a configuration, in which the reactor 100 further comprises, within the reaction chamber 101, a number of separating devices 25 for promoting separation of indigestible (both buoyant/floating and non-buoyant/sediment) matter suspended in organic substrate. In exemplary embodiments, the separating devices 25 are configured as vertical rods with lower ends fixed to the bottom of the reaction chamber 101, said rods set to perform vibrational or oscillatory motion. The rods are preferably motor-driven; thereby the motor engine(s) may be disposed within the mechanics section 201. The separating devices 25 are preferably positioned adjacent to the discharge end 17 of the reaction chamber 101 such, as promote separation of the digested (biodegraded) organic products from indigestible solids and to facilitate sorting of the digested products D, and the residue R1 and/or R2 towards the appropriate effluent port 19, 20 and/or 21, accordingly.

Reference is further made to Figs. 4A and 4B illustrating, at a cross-section of the reaction chamber 101, various embodiments of the reactor 100. The reaction chamber 101 is thus defined, in a longitudinal direction, by lateral walls (side walls). In order to achieve more efficient mixing of the reaction substrate within the reaction chamber 101 and to avoid accumulation of sediments in the corners formed at an intersection between (lateral) wall profiles and the bottom, each lateral wall defining, in a longitudinal direction, the interior 10 of said reaction chamber 101 is sloped (inclined). Thereby, a slope element, indicated by a capital S is advantageously formed along an entire length of the reaction chamber 101, at the corners or intersections where lateral walls meet the bottom.

Fig. 4A shows a configuration, in which each lateral wall is defined by a number of L-shaped profiles 11; thereby the slope element S is integrated into each L-shaped profile, accordingly. The slope element S is outlined on Fig. 4A by dashed lines. Fig. 4B shows an alternative configuration, in which each lateral wall comprises a substantially flat vertical panel or panels 11A and the slope element (S) provided as a separate module 11B.

Slope surface may be curved (Fig. 4A) or flat (Fig. 4B). Slope (inclination) angle (θ) may vary within a range of about 35 to about 60 degrees; preferably, the slope angle constitutes about 45 degrees.

In configuration of Fig. 4A the L-shaped profiles 11 forming lateral walls are advantageously positioned against each other and joined at the bottom by a base (central) element or elements 12 such, that at least two adjoining subsections 10A, 10B are formed within the interior 10 of the reaction chamber 101, wherein each subsection 10A, 10B is configured to receive the

agitator 22 (not shown; rotation directions pictured by arrows). Provision of the base element(s) 12 is therefore such, as to form an elevated partition between the subsections 10A, 10B. Said partition may be optionally increased in height by mounting an extension element(s) 12A thereon. In some configurations (not shown) the base element(s) 12 may be provided as substantially flat panel(s), with a separate partition element optionally mounted thereto.

The individual L-profiles 11 are positioned against each other pairwise, as to comply with the principles of mirror-symmetry. L-profiles 11 are configured such, as to externally define the reaction chamber 101 as a tank rectangular at its' base, whereas the internal surfaces of the reaction chamber 101 are curved to accommodate the at least two agitators 22 within the at least two adjoining subsections 10A, 10B, accordingly.

Each L-profile is dimensioned such, as to accommodate into a standard transport vehicle (a trailer or a platform), which vehicle, when loaded by said L-profiles, fits under standard bridge- or road tunnel structures. Thus, for the purposes of unhindered transportation, those (lowermost) faces of the L-profiles that form a base of the reaction chamber 101 do not preferably exceed 3,5 m, considering that the maximum height of a transportable load is 4,4 m and the height of a chassis is 0,8 m. In exemplary embodiments the reaction chamber 101 is formed by 18 L-profiles (9 per side), wherein the distance across each profile (width) constitutes about 2,2 m. Said distance is indicated by a capital L on Fig. 1.

The number of base elements 12 may, in turn, correlate with the number of L-profiles in a relation of 1 to 2; however, provision of a single central element joining together several pairs of L-profiles (e.g. 2 to 5 pairs), is not excluded.

In configuration shown on Fig. 4B the base element 12 is provided as a substantially flat panel (or panels); thereby, the at least two agitators 22 are received within the undivided interior 10. In further configurations (now shown), provision of the base element may be implemented in a manner shown on Fig. 4A. Hence, the reaction chamber as shown on Fig. 4B may further comprise a separate partition element (not shown) to divide the interior 10 into at least two subsections. Each sloped module 11B is, in turn, provided as an elongated block or as a number of sequential blocks that extend through an entire length of the reaction chamber 101.

It is clear to those skilled in the art that an amount of modules 11, 11A, 11B defining lateral walls of the reaction chamber 101 with regard to an amount of base elements 12 and dimensions thereof may vary dependent on the reactor design.

The reactor 100 further advantageously comprises an at least one layer 13 of external lining-and/or insulation (Figs. 4A, 4B). The reaction chamber 101 is further placed onto a foundation element 14 and it is sealed from the top by a flexible or rigid cover 15.

While biogas being an ultimate product of bacterial digestion of organic feedstock entering the reaction space, most of biogas is produced during the middle of digestion, thereby, the reactor 100 is advantageously equipped with the inflatable cover and/or a rooftop for storage of biogas. The flexible cover 15 is provided as an expandable layer or a number of layers, which, when inflated, accommodates in a stationary, rigid dome-shape rooftop structure 501 (Fig. 1). In some instances the cover 15 may be configured as a rigid, stationary structure (dome-shaped or flat), in which case the reactor is advantageously equipped with a biogas extraction system (not shown).

Lateral profiles 11, 11A and/or 11B, and base (central) elements 12 can be realized as precast blocks (formed and hardened before being brought to the construction site), preferably made of concrete. Typical concrete blocks or slabs comprise of powdered Portland cement, water, sand and gravel. In some instances weighty sand and gravel in said concrete blocks may be replaced with lightweight expanded clay or expanded clay aggregate, for example. In some instances, precast cinder blocks may be utilized, in which the aforesaid gravel and sand are replaced by coal and/or cinders.

Additionally or alternatively, the aforesaid profiles can be manufactured from metal. Metal-based configurations include solutions consisting of metal sheets and optionally a core. In some embodiments, the lateral walls 11, 11A are concrete slabs, whereas the slope modules 11B are metal-based blocks. Entirely metal-based configurations are not excluded.

In some embodiments (not shown) the reaction chamber 101 may comprise a number of base (central) elements 12 positioned side-by-side to form at least two partitions extending, in parallel, in a longitudinal direction, thereby at least three adjoining subsections are formed within the interior 10 of the reaction chamber 101. Such configuration allows for accommodating at least three agitators 22, arranged in parallel, within the internal reaction space 10.

In a particularly preferred embodiment, the reactor 100 further comprises a hygienization treatment system 30 (Figs. 3, 4A, 4B) for post-treating digested substrate D via inhibition and/or inactivation (reversible or irreversible deprivation of microbial activity, accordingly) of microorganisms contained in the digested substrate; thereby eliminating or at least reducing epidemiological risks.

The hygienization system 30 is integrated into the slope elements S formed within the interior of the reaction chamber 101.

The hygienization system 30 comprises an at least one conduit 31 encased in a jacket or a sheath 32. In some configurations, the hygienization system comprises the encased conduit or conduits traversing, in a longitudinal direction, through each lateral wall of the reaction chamber 101 defined by a number of L-profiles 11 (Fig. 4A). Whether the L-profiles are formed by concrete slabs, in order to house the hygienization system 30 therewithin, each said slab comprises pre-fabricated through-apertures that form, upon assembling the reactor tank, a hollow, tubular duct or a channel.

In some other embodiments the hygienization system 30 is configured to traverse, in a manner as described above, through the slope modules 11B (Fig. 4B).

Additionally or alternatively, the hygienization system can be integrated into the base (central) element(s) 12.

The hygienization system 30 is thus configured to receive digested substrate D discharged from the reaction chamber 101 through the primary effluent port 19, to mediate advancement of said substrate D along the at least one conduit 31 from the discharge end 17 to the entrance end 16, thereupon microorganisms residing in said digested substrate are inhibited and/or inactivated, and to extract post-treated (hygienized) substrate D1 through an least one aperture 33 disposed at the entrance end of the reaction chamber. Post-treated digested substrate D1, withdrawn from the reactor 100 at the entrance end 16, is further conveyed elsewhere for storage or transportation.

In preferred embodiments, the hygienization system 30 is configured to deliver heat, as a flow of thermal energy, to the conduit 31 via the jacket 32; thereby, attenuation / elimination of microbial activity is thermally-induced.

The hygienization system 30 can comprise a single U- or Y-shaped conduit traversing from the primary effluent port 19 (at the discharge end 17) through both lateral walls, in particular, through slope elements S thereof, towards the apertures 33 arranged at the entrance end 16. Alternatively, the conduits extending through each lateral wall 11 may be provided as separate elements.

Hence, as digested substrate D advances along the hygienization system 30 provided as encased conduits 31 “piercing” the lateral walls 11 in a longitudinal direction, the digested substrate is sanitized by thermal post-treatment. By the way of examples, hygienization

treatment has been conducted at a temperature of 70 °C for 1 hour; and at a temperature of 100 °C for 20 minutes; therefore flow rate through the conduit(s) 31 has been adjusted accordingly.

5 The jackets 32 advantageously comprise heat transfer means optionally communicating with heat-producing equipment. In exemplary embodiments, heating can be implemented via liquid circulation. Additionally or alternatively, heat transfer can be mediated by means of an external heat exchanger or a heat pump. An exemplary heat exchanger 50 arranged at the entrance end 16 is shown on Fig. 3.

10 The reference is made back to Figs. 4A and 4B that illustrate the reactor 100 comprising, in addition to the hygienization system 30, a temperature regulating arrangement 40 configured to maintain temperature within the reaction chamber 101 at a level suitable for the normal functioning of bacterial populations indispensable for anaerobic digestion. The temperature regulating arrangement 40 consists of a plurality of internal ducts configured to traverse, in a longitudinal direction, through lateral walls 11 and/or the base element or elements 12 of
15 the reaction chamber 101 and to convey temperature regulating fluid therealong.

In order to accommodate the temperature regulating arrangement 40 into the reaction chamber 101, the elements 11, 11A forming the lateral walls and/or the base element(s) 12 can be provided as preformed, hollow-core concrete slabs with a plurality of hollow, tubular ducts 40. The ducts forming the arrangement 40 are preferably smaller in diameter than those
20 forming the hygienization system 30. For clarity purposes, a reference number 40 will further refer also to the ducts forming the temperature regulating arrangement.

In some embodiments, the ducts 40 further comprise pipes encased in the concrete slabs forming lateral walls 11, 11A and/or base (central) element(s) 12 or an internal lining / coating to reduce wearing out of the concrete slabs. Coating, such as metal coating, for example, is
25 preferably applied prior to assembling the blocks 11, 11A, 12.

The temperature regulating fluid is a glycol compound, such as ethylene glycol or propylene glycol, for example. Alternatively, the temperature regulating liquid can be water. By circulating heating fluid through the ducts 40, temperature within the reaction chamber 101 is maintained sufficiently high for the mesophilic digestion (30 – 42 °C) or for the
30 thermophilic digestion (43 – 55 °C). In some exceptional instances, fluid can be used as a coolant allowing for cooling down the reaction chamber 101.

The ducts 40 forming the temperature regulating arrangement can be arranged into a substantially closed-loop recirculation path, wherein temperature regulating fluid recirculates

between the ducts 40 and an at least one heat source (not shown). To create the recirculation path, in some configurations the head-end L-profiles may be provided with preformed turns and/or pipe elbows therewithin.

5 The temperature regulating arrangement is preferably set to communicate with the heat exchanger 50 (Fig. 3). Excessive thermal energy released via the temperature regulating arrangement 40 and/or the hygienization system 30 is further supplied to the pre-treatment facility 401 and/or extracted for further utilization.

10 The reactor 100 advantageously comprises recirculation means (not shown) for re-introducing a portion of digested substrate back into the reaction chamber 101. Separation of this portion (inoculum) occurs before the digested substrate enters the hygienization system 30. It is preferred that at least one third of digested substrate is reversed back into the reactor 100 for maintaining stable bacterial populations in the reaction chamber.

15 The reactor 100 is configured for anaerobic digestion treatment of organic substrate, in which the content of dry matter (solid matter) constitutes 0 – 80 percent by weight (wt-%), preferably, 0 – 45 wt-%. In most instances, the organic substrate inside the reaction chamber 101 has DM content within a range of 10 – 35 wt-%; however, the aforementioned range can vary on case-by-case basis. In some embodiments, preferred content of dry matter in feedstock constitutes about 35 wt-%. Organic substrate entering the reaction chamber 101 is kept at a solid state, i.e. in the abovementioned range of 30 – 40 wt-% of dry matter. In 20 exceptional cases, with a content of dry matter being equal or exceeding 50 wt-%, the reaction substrate needs to be diluted. Upon advancing along the length of the reaction chamber 101 the organic substrate with DM about 35 wt-% solubilizes, thereby the digested product D contains approximately 25 wt-% of dry matter.

25 In some aspect of the invention, use of the reactor 100 is provided for anaerobic digestion of organic waste.

In some further aspect, use of the reactor 100 is provided for production of biogas. As mentioned hereinabove the process of anaerobic digestion mediated by microbial activity results in production of biogas. Biogas is a mixture of predominantly methane (50-70%) and carbon dioxide (30-40%) with trace amounts of ammonia (NH₃) and hydrogen sulfide (H₂S). 30 Biogas obtained from the reactor 100 is advantageously directed for further refinement, such as for production of biofuels, for example.

The reference is made to Fig. 5 showing the anaerobic digestion plant 110 in accordance with some aspect of the present invention, as a crosscut along an (imaginary) longitudinal

symmetry axis. The plant 110 thus comprises the reactor 100, the pre-treatment facility 401, the feed tank 301 advantageously equipped with a lid 311, and a number of feed supply appliances 302, 402 configured to convey feedstock in a direction of the reactor 100.

5 The feed tank 301 is configured to receive entirely unprocessed (“raw”) feedstock or pre-crushed feedstock. Pre-crushing, where applicable, is preferably implemented in a conventional crusher or a grinder prior to loading feedstock into the feed tank 301. It is desirable that size of discrete aggregates, such as feedstock clumps and/or solid residues / inorganic matter, entering the reactor 100 does not exceed a size of two clenched fists (150 – 200 mm). Whether organic waste to be processed by the plant 110 contains or can be expected to contain
10 larger aggregates and/or solid pieces (stones, gravel or cattle bones, for example), such waste should be pre-crushed in a manner described above.

On the other hand, whether feedstock to be processed is essentially homogenous and/or contains no outsized aggregates, the reactor 100 can be loaded with the impure substrate containing essential amounts of indigestible residue, such as sand, stone and a variety of
15 plastics contaminants, in view of the embodiments described hereinabove.

In order to handle impure feedstock prior it enters the reactor 100 a first feed supply appliance 302 for conveying said feedstock from the feed tank 301 to the pre-treatment facility 401, and a second feed supply appliance 402 for conveying pre-treated feedstock from the pre-treatment facility 401 to the reactor 100 are preferably configured as screw conveyors or as
20 piston pumps. Provision of both appliances 302, 402 as screw conveyors or piston pumps is preferred; alternatively, a combination of a screw conveyor (302 or 402) with a piston pump (402 or 302) can be realized.

In preferred embodiments, the pre-treatment facility 401 is configured to adjust the temperature of organic feedstock entering the reactor 100 to conform to the temperature maintained in the reaction chamber 101. From the facility 401, temperature-adjusted
25 feedstock is further conveyed into the reactor 100 by the feed supply appliance 402 and is received into the reactor through the influent port 18 provided at the entrance end 16.

In most instances, the pre-treatment facility 401 is a thermal pre-treatment facility configured to heat organic feedstock, as the temperature maintained inside the reaction chamber 101
30 (*inter alia*, primarily by the temperature regulating arrangement 40) is normally higher in comparison to that of unprocessed feedstock. Need in regulation of temperature within the reaction chamber 101 arises, in turn, from a necessity to maintain vital functions and activity of resident microorganisms. In some exceptional instances, the facility 401 can be configured to cool down input feedstock.

In some embodiments the plant 110 further comprises the heat-exchanger 50 for delivery of thermal energy from the at least one reactor 100 to the pre-treatment facility 401. The heat exchanger 50 is advantageously configured to mediate heat transfer between the temperature regulating arrangement 40 and/or the hygienization system 30, provided within the reactor
5 100, and the pre-treatment facility 401. Heat extracted from the facility 401 can be stored and/or transferred for further use.

It is clear to a person skilled in the art that with the advancement of technology the basic ideas of the present invention are intended to cover various modifications and equivalent arrangements included in the spirit and the scope thereof. The invention and its embodiments
10 are thus not limited to the examples described above; instead they may generally vary within the scope of the appended claims.

Claims

1. A reactor (100) for anaerobic digestion of biodegradable organic substrate, comprising a horizontally extended reaction chamber (101) with an influent port (18) at an entrance end (16) and at least two effluent ports at a discharge end (17) opposite to the entrance end (16), wherein said reaction chamber (101) comprises, within an interior (10) thereof, at least two longitudinally extending agitators (22) disposed side by side and configured to convey said organic substrate along the length of the reaction chamber (101) towards the discharge end such, that the digested organic substrate is discharged from the reaction chamber (101) through a primary effluent port (19), and the indigestible residue is discharged through an at least one auxiliary effluent port (20, 21), and wherein the reactor further comprises an at least one encased conduit (31) traversing through its' lateral walls and/or a base in a longitudinal direction and configured to thermally sanitize digested substrate discharged through said primary effluent port (19) and received into said conduit (31).
2. The reactor of claim 1, configured to convey, by means of a discharge appliance (202), a non-buoyant indigestible residue from the bottom of the reaction chamber (101), via a first auxiliary effluent port (20) disposed below the primary effluent port (19), outside the reactor (100).
3. The reactor (100) of any of the claims 1 or 2, configured to convey a buoyant indigestible residue residing at a surface of the organic substrate advancing along the length of the reaction chamber (101), via a second auxiliary effluent port (21) disposed above the primary effluent port (19), outside the reactor (100).
4. The reactor (100) of any preceding claim, in which lateral walls that define, in a longitudinal direction, the interior (10) of the reaction chamber (101) are sloped, thereby a slope element or elements (S) are formed along an entire length of the reaction chamber at intersections between the lateral walls and the bottom.
5. The reactor (100) of any preceding claim, in which each lateral wall is defined by a number of L-shaped profiles (11) with the slope element (S) integrated into each L-shaped profile.

6. The reactor (100) of any preceding claim, in which the L-shaped profiles (11) are positioned against each other and joined at the bottom by a base element or elements (12) such, that at least two adjoining subsections (10A, 10B) are formed within the interior (10) of the reaction chamber, each subsection is configured to receive the agitator (22).
7. The reactor of any of the claims 1-4, in which each lateral wall comprises a substantially flat panel or panels (11A) with the slope element (S) provided as a separate module (11B).
8. The reactor (100) of any preceding claim, in which the at least one conduit (31) is encased in a jacket (32) and is configured to traverse, in a longitudinal direction, through the slope elements (S) formed in the interior (10) of the reaction chamber (101) and/or through the base element or elements (12), whereby a hygienization system (30) is formed.
9. The reactor (100) of claim 8, in which the hygienization system (30) is configured to receive digested substrate discharged from the reaction chamber (101) through the primary effluent port (19), to mediate advancement of said digested substrate along the at least one conduit (31) from the discharge end (17) to the entrance end (16), thereupon microorganisms residing in said digested substrate are inhibited and/or inactivated, and to extract hygienized digested substrate through an least one aperture (33) disposed at the entrance end of the reaction chamber.
10. The reactor (100) of any one of claims 8 or 9, wherein the hygienization system (30) is configured to deliver heat to the conduit (31) via the encasing jacket (32).
11. The reactor (100) of any preceding claim, further comprising a plurality of internal ducts (40) configured to traverse, in a longitudinal direction, through lateral walls and/or the base element or elements (12) of the reaction chamber (101) and to convey temperature regulating fluid therealong.
12. The reactor (100) of any preceding claim, wherein each agitator (22) comprises a drive shaft (23) with a number of blades (24) mounted thereto.
13. The reactor (100) of any preceding claim, wherein at least two agitators (22) are configured to rotate in opposite directions.

14. The reactor (100) of any preceding claim, further comprising, within the reaction chamber (101), a number of separating devices (25) positioned adjacent to the discharge end (17) and configured as vertical oscillating rods.

5

15. An anaerobic digestion plant (110) comprising an at least one reactor (100) as defined in any one of the claims 1-14, and a pre-treatment facility (401) configured to adjust the temperature of organic substrate entering the reactor to conform to the temperature maintained in the reaction chamber (101).

10

16. The plant (110) of claim 15 further comprising a heat exchanger (50) for mediating heat transfer between the at least one reactor (100) and the pre-treatment facility (401).

15

17. Use of the reactor (100) as defined in claims 1-14 for anaerobic digestion of organic waste.

18. Use of the reactor (100) as defined in claims 1-14 for production of biogas.

Patenttivaatimukset

1. Reaktori (100) biohajoavan orgaanisen substraatin anaerobista mädättämistä varten, käsittäen vaakasuuntaisesti ulottuvan reaktiokammion (101), jossa on sisäänvirtausportti (18) tulopäässä (16) ja ainakin kaksi ulosvirtausporttia tulopäätä (16) vastapäätä olevassa lähtöpäässä (17), jolloin mainittu reaktiokammio (101) käsittää sisustassaan (10) ainakin kaksi pituussuuntaisesti ulottuvaa sekoitinta (22), jotka on sijoitettu vierekkäin ja jotka on konfiguroitu kuljettamaan mainittu orgaaninen substraatti reaktiokammion (101) pituutta pitkin lähtöpäätä kohti niin, että mädätetty orgaaninen substraatti poistuu reaktiokammioista (101) ensisijaisen ulosvirtausportin (19) kautta, ja ei-mädätettävissä oleva jäännös poistuu ainakin yhden apu-ulosvirtausportin (20, 21) kautta, ja jolloin reaktori käsittää lisäksi ainakin yhden koteloidun kanavan (31), joka kulkee sen sivuseinien ja/tai pohjan läpi pituussuunnassa ja joka on konfiguroitu lämmön avulla puhdistamaan mädätetty substraatti, joka poistuu mainitun ensisijaisen ulosvirtausportin (19) kautta ja joka vastaanotetaan mainittuun kanavaan (31).
2. Patenttivaatimuksen 1 mukainen reaktori, joka on konfiguroitu kuljettamaan poistolaitteen (202) avulla kellumaton ei-mädätettävissä oleva jäännös reaktiokammion (101) pohjalta ensimmäisen apu-ulosvirtausportin (20) kautta, joka sijaitsee ensisijaisen ulosvirtausportin (19) alapuolella, reaktorin (100) ulkopuolelle.
3. Patenttivaatimuksen 1 tai 2 mukainen reaktori (100), joka on konfiguroitu kuljettamaan kelluva ei-mädätettävissä oleva jäännös, joka on reaktiokammion (101) pituutta pitkin etenevän orgaanisen substraatin pinnalla, toisen apu-ulosvirtausportin (21) kautta, joka sijaitsee ensisijaisen ulosvirtausportin (19) yläpuolella, reaktorin (100) ulkopuolelle
4. Jonkin edeltävistä patenttivaatimuksista mukainen reaktori (100), jossa reaktiokammion (101) sisustan (10) pituussuunnassa rajaavat sivuseinät ovat kaltevia, jolloin on muodostettu kalteva elementti tai kaltevia elementtejä (S) reaktiokammion koko pituudelle sivuseinien ja pohjan risteämiskohtiin.
5. Jonkin edeltävistä patenttivaatimuksista mukainen reaktori (100), jossa kunkin sivuseinän muodostaa lukumäärä L:n muotoisia profiileja (11) niin, että kalteva elementti (S) on integroitu kuhunkin L:n muotoiseen profiliin.

6. Jonkin edeltävistä patenttivaatimuksista mukainen reaktori (100), jossa L:n muotoiset profiilit (11) on sijoitettu toisiaan vasten ja liitetty yhteen pohjalla pohjaelementillä tai -elementeillä (12) niin, että muodostuu ainakin kaksi vierekkäistä aliosiota (10A, 10B) reaktiokammion sisustaan (10), jolloin kukin aliosio on konfiguroitu vastaanottamaan sekoitin (22).
7. Jonkin patenttivaatimuksista 1 - 4 mukainen reaktori, jossa kukin sivuseinä käsittää olennaisesti litteän paneelin tai paneeleja (11A), jolloin kalteva elementti (S) on järjestetty erilliseksi moduuliksi (11B).
8. Jonkin edeltävistä patenttivaatimuksista mukainen reaktori (100), jossa ainakin yksi kanava (31) on suljettu vaipan (32) sisään ja konfiguroitu kulkemaan pituussuunnassa reaktiokammion (101) sisustaan (10) muodostettujen kaltevien elementtien (S) läpi ja/tai pohjaelementin tai -elementtien (12) läpi niin, että muodostuu hygienisointijärjestelmä (30).
9. Patenttivaatimuksen 8 mukainen reaktori (100), jossa hygienisointijärjestelmä (30) on konfiguroitu vastaanottamaan reaktiokammion (101) ensisijaisen ulosvirtausportin (19) kautta poistettu mädätetty substraatti mainitun mädätetyn substraatin etenemisen mainittua ainakin yhtä kanavaa (31) pitkin lähtöpäästä (17) tulopäähän (16) toteuttamiseksi, jolloin mainitussa mädätetyssä substraatissa olevat mikro-organismit inhiboidaan ja inaktivoidaan, ja hygienisoidun mädätetyn substraatin ottamiseksi ainakin yhdestä aukosta (33), joka sijaitsee reaktiokammion tulopäässä.
10. Jonkin patenttivaatimuksista 8 tai 9 mukainen reaktori (100), joka hygienisointijärjestelmä (30) on konfiguroitu toimittamaan lämpöä kanavaan (31) sen sisäänsä sulkevan vaipan (32) kautta.
11. Jonkin edeltävistä patenttivaatimuksista mukainen reaktori (100), joka lisäksi käsittää joukon sisäisiä putkia (40), jotka on konfiguroitu kulkemaan pituussuunnassa reaktiokammion (101) sivuseinien ja/tai pohjaelementin tai -elementtien (12) läpi ja kuljettamaan lämmönsäätelyfluidia.
12. Jonkin edeltävistä patenttivaatimuksista mukainen reaktori (100), jossa kukin sekoitin (22) käsittää käyttöakselin (23), johon on asennettu lukumäärä lapoja (24).

13. Jonkin edeltävistä patenttivaatimuksista mukainen reaktori (100), jossa on konfiguroitu ainakin kaksi sekoitinta (22) pyörimään vastakkaisiin suuntiin.
- 5 14. Jonkin edeltävistä patenttivaatimuksista mukainen reaktori (100), joka käsittää lisäksi reaktiokammiossa (101) lukumäärän erotuslaitteita (25), jotka on sijoitettu lähtöpään (17) viereen ja konfiguroitu pystysuuntaisiksi oskilloiviksi tangoiksi.
- 10 15. Anaerobinen mädätyslaitteisto (110), joka käsittää jonkin patenttivaatimuksista 1 - 14 mukaisen ainakin yhden reaktorin (100) ja esikäsittelytilan (401), joka on konfiguroitu säätämään reaktoriin tulevan orgaanisen substraatin lämpötila reaktiokammiossa (101) ylläpidetyn lämpötilan kanssa yhteensopivaksi.
- 15 16. Patenttivaatimuksen 15 mukainen laitteisto (110), joka käsittää lisäksi lämmönvaihtimen (50) lämmönsiirron toteuttamiseksi ainakin yhden reaktorin (100) ja esikäsittelytilan (401) välillä.
- 20 17. Patenttivaatimusten 1 - 14 mukaisen reaktorin (100) käyttö orgaanisen jätteen anaerobiseen mädättämiseen.
18. Patenttivaatimusten 1 - 14 mukaisen reaktorin (100) käyttö biokaasun tuottamiseen.

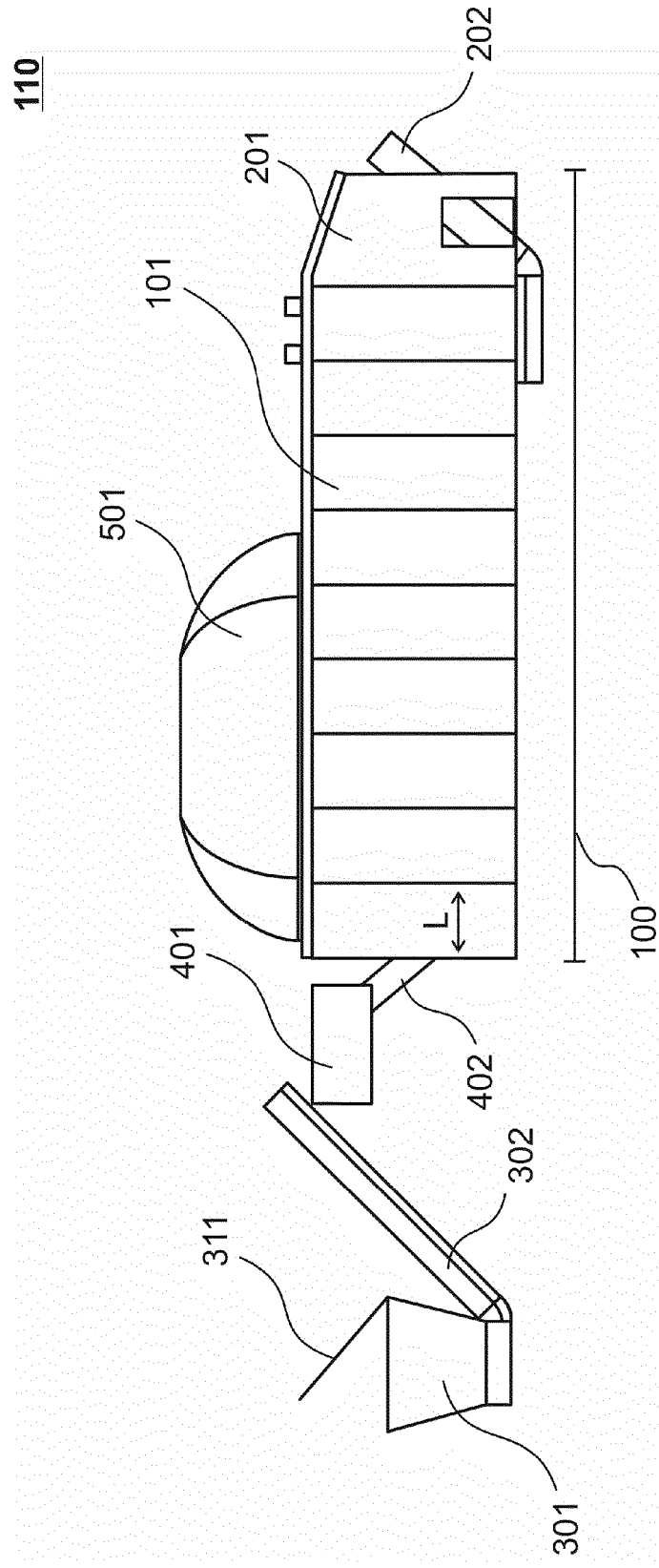


Figure 1

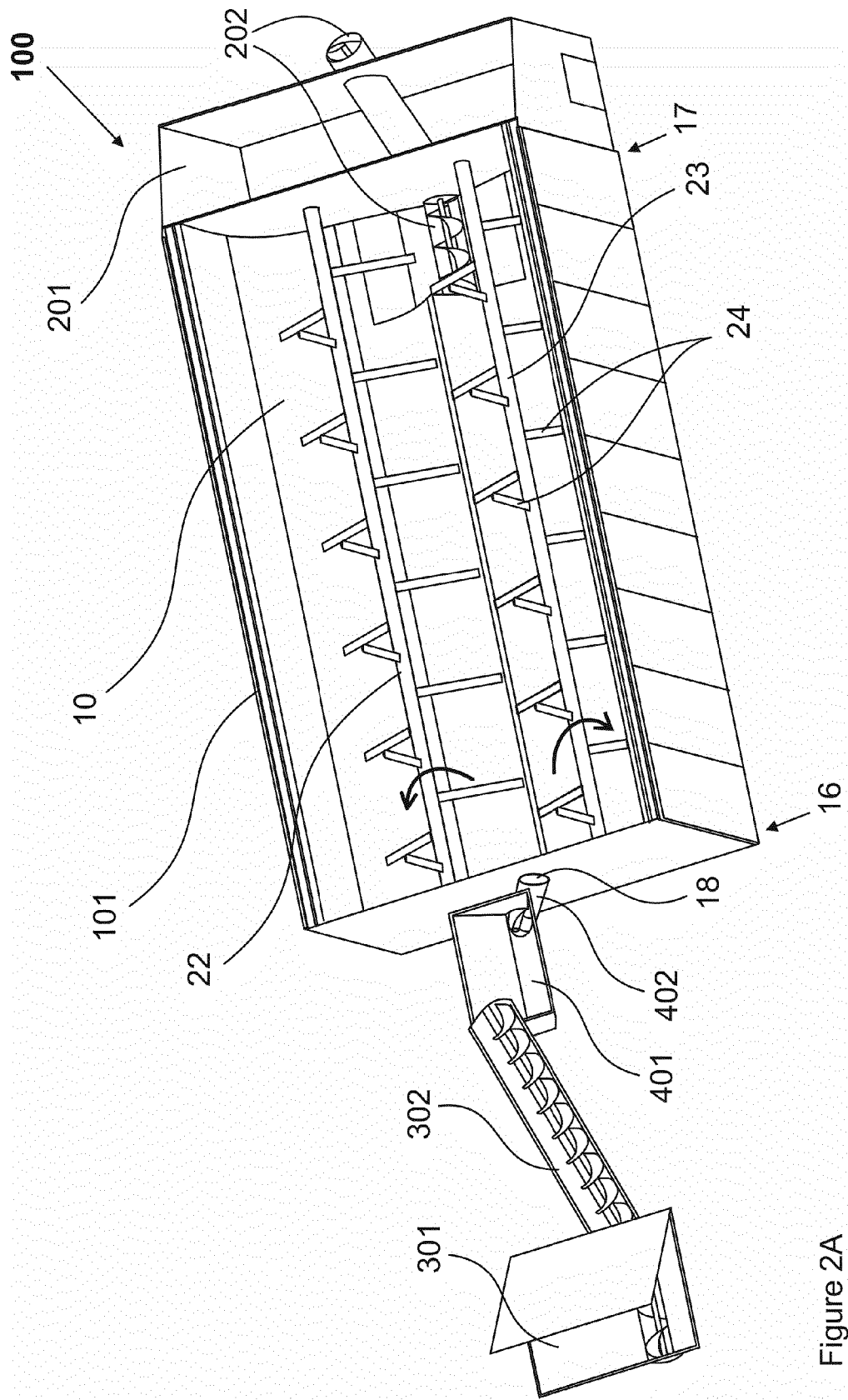


Figure 2A

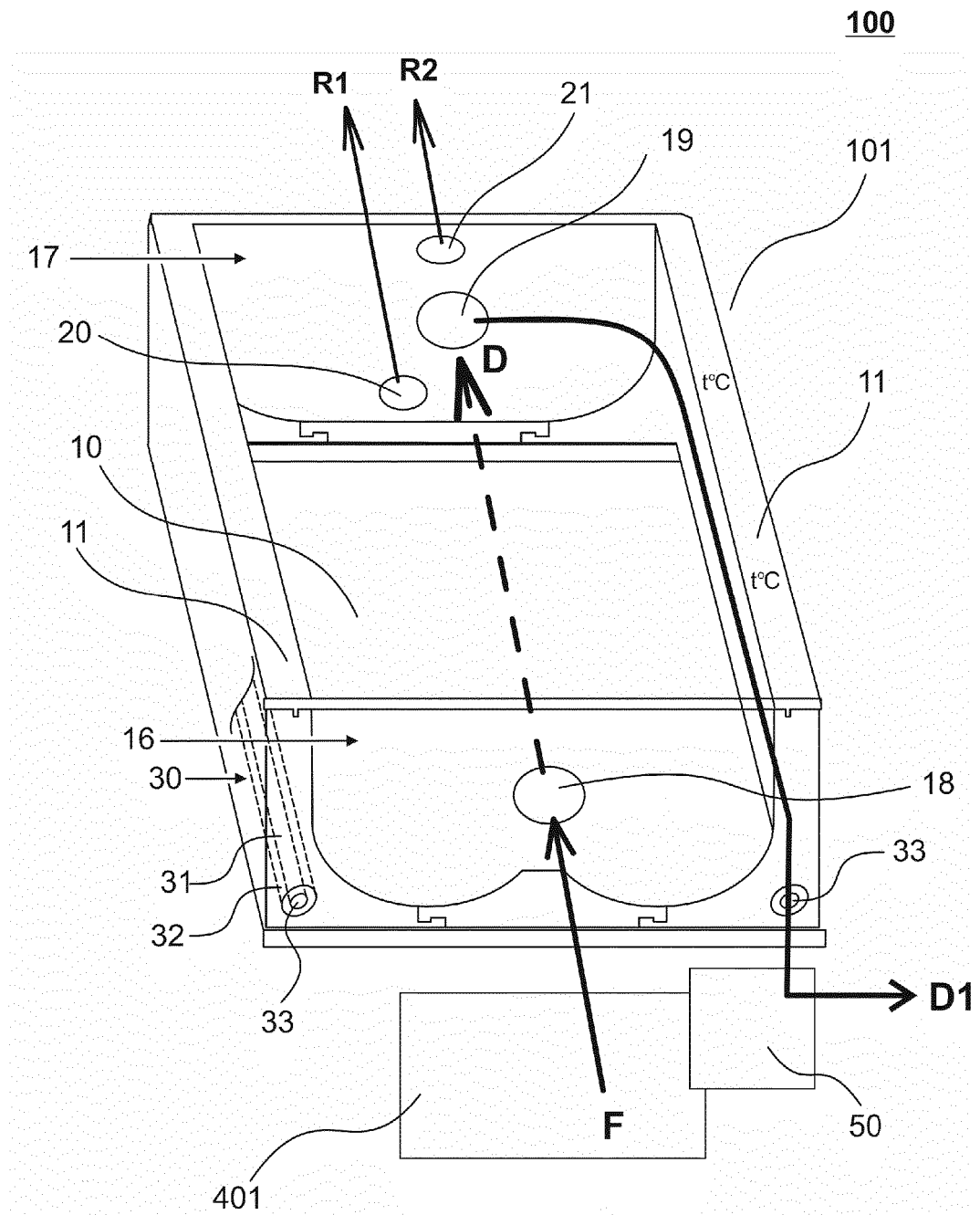


Figure 3

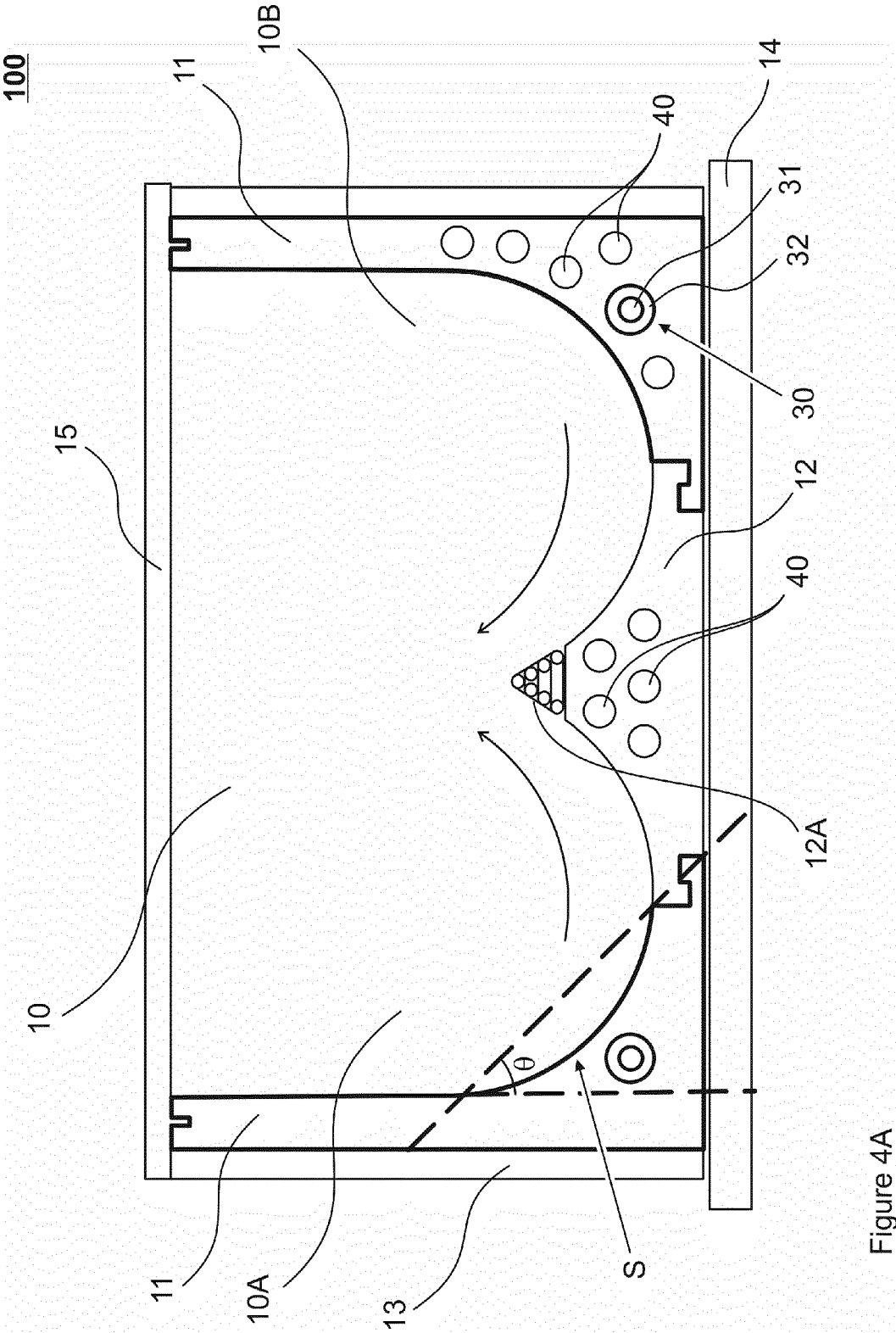


Figure 4A

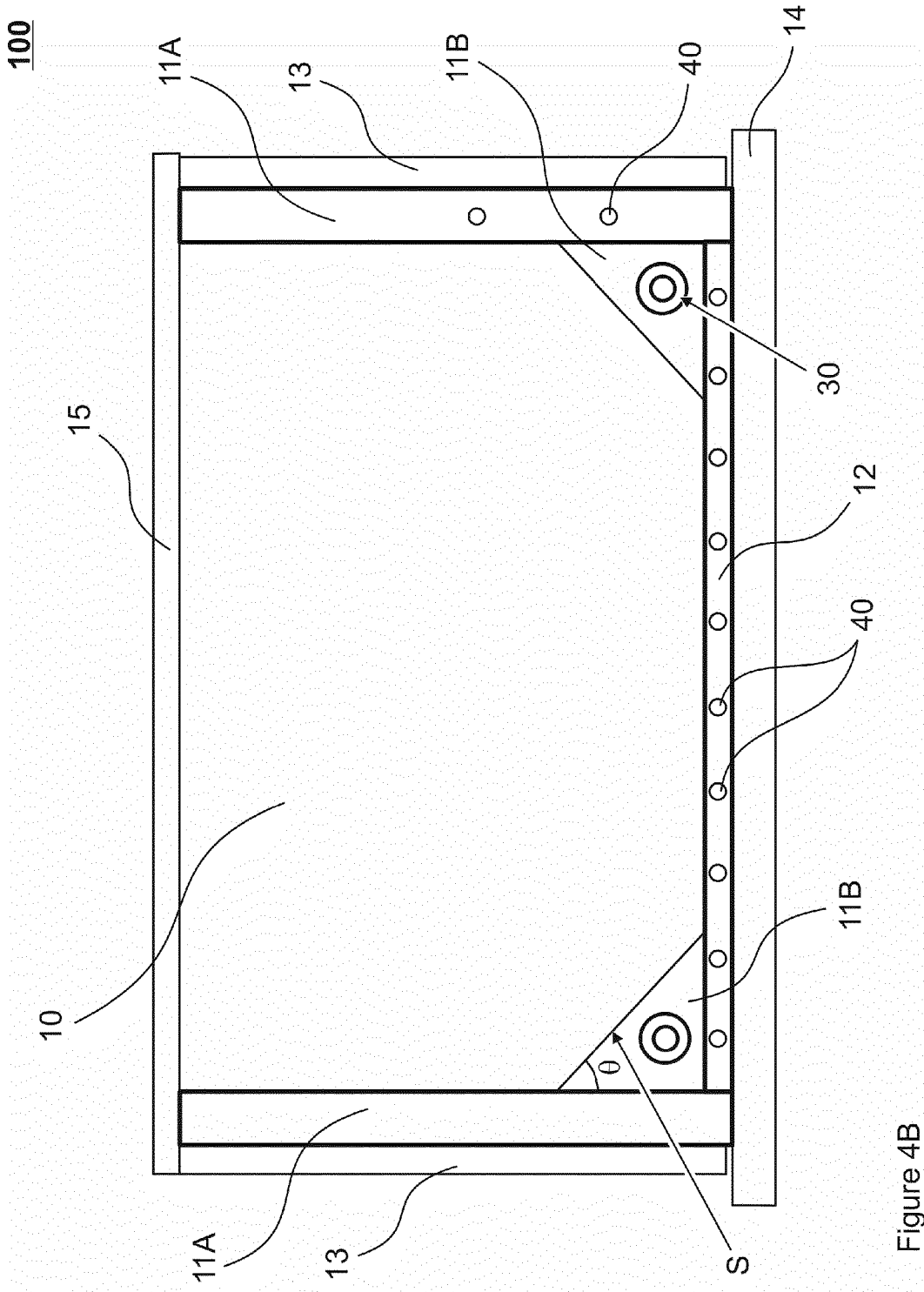


Figure 4B

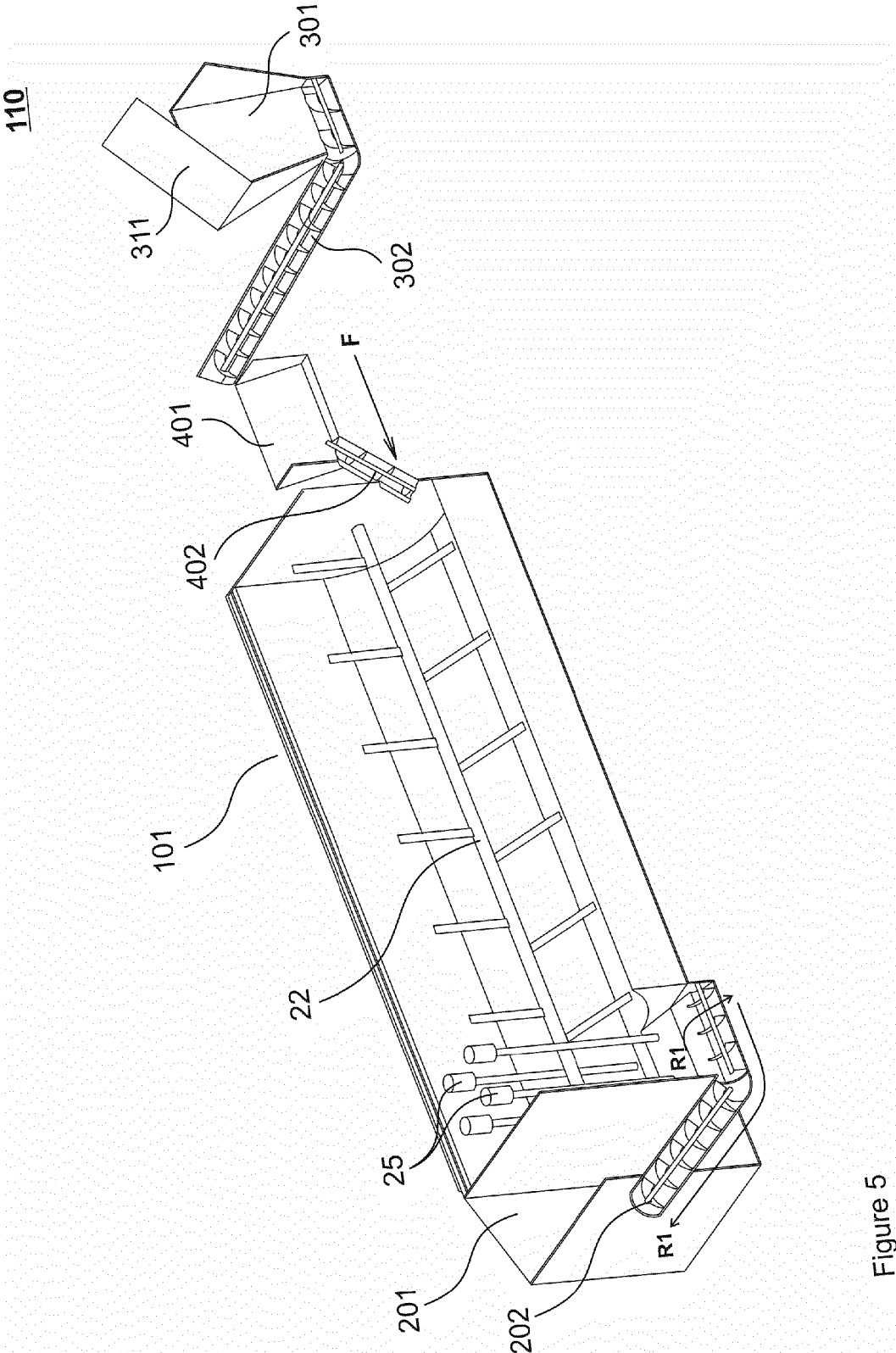


Figure 5